UNDERSTANDING THE REQUIREMENTS FOR DEVELOPMENT OF AGRICULTURAL PRODUCTION AND OF RURAL AREAS IN THE KUYAVIAN-POMERANIAN PROVINCE AS A RESULT OF SCIENTIFIC RESEARCH

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Contents

PREFACE

Progress in plant production and agricultural development depend on biological, habitat, environmental, economic and organizational conditions, as well as on the application of new production technologies which are both effective and environmentally safe. With that in mind, the unfavourable effect of one factor can be partially compensated by other natural or anthropogenic conditions.

Beneficial interactions between the natural environment and sustainable agriculture are objectives in rural areas in order to meet basic social, economic and environmental requirements. Evaluation of the status of sustainable agriculture must be dynamic and consider agricultural production and economic and social indices (economic activities of the agricultural population, sources and levels of income, education, demographic situation).

Plant productivity depends on many factors, such as cultivar-specific characteristics of the crop and the habitat conditions during its growth and development, which can affect ecological safety. Agricultural production is controlled by environmental and agrotechnical factors, which have a direct effect on crop productivity and quality. The success of plant production involves the implementation of technology, which must be effective and environmentally safe and facilitate the production of plants with the required qualitative and functional parameters.

The papers included in this monograph, offering a review of current research into sustainable development and plant production, have been put together for a conference on 'Conditions of development of plant production and rural areas in the Kuyavian--Pomeranian Province in research', held on the occasion of the 40th anniversary of the Faculty of Agriculture, the University of Technology and Life Sciences, on 19.09.2009 in Bydgoszcz, Poland.

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BIOLOGICAL REQUIREMENTS FOR DEVELOPMENT OF AGRICULTURAL PRODUCTION AND OF RURAL AREAS IN THE KUYAVIAN-POMERANIAN PROVINCE

INTENSIFICATION OF CEREAL APHID (*Sitobion avenae* F.) OCCURRENCE AGAINST THE ACTIVITY OF ITS NATURAL ENEMIES

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Cereals belong to the basic group of cultivated plants in Poland, in which winter wheat takes up over 30% of the general area of cereal cultivation (Jaczewska-Kalicka 2009). Implementation of modern, simplified cultivation, cultivation area increase, intensive protection against weeds and diseases, abundant fertilisation, elimination of balks, hedges and natural pastures, as well as deeply progressing climatic changes, all of these factors contribute to the increase in their threat by agrophages. Important wheat pests are, present in the whole country, cereal aphids. Among them, the species of very high economic significance due to feeding place (generative organs) is cereal aphid (*Sitobion avenae* F.).

Mass appearance of pests resulting form the strong floristic impoverishment of agroecosystems consequently leads to chemical fight with cultivated plants pests (Hurej and Twardowski 2009). At present, according to the European Union directive, many chemical substances of plant protection means are withdrawn due to a threat for human health and the environment. This inclines to look for new, alternative methods of plant protection, mostly with the utilisation of useful insects, natural allies in the fight with pests (Matyjaszczyk 2009). Main task and aim of modern plant protection systems is their agreement with the idea of sustainable agriculture, which should be economically profitable, environmentally friendly, and socially acceptable, as well as compliant with good plant protection practice (Pruszyński and Skrzypczak 2007). Expression of these endeavours is integrated protection consisting in the use of all available pest fight methods in such a way as to limit insecticide application to the minimum. It is also described as a programme for pests number directing in such a way as to keep the size of their populations on a level lower than the economic harmfulness threshold (Olszak et al. 2000), as they are a rich nourishment source for many useful insect species, particularly for the predatory ones: lady beetles, hoverflies, golden-eyed files, and parasitic *Hymenoptera* (*Hymenoptera parasitica*; Pruszyński 2007).

Agricultural fields, as ranges that undergo strong anthropopression, are agrocenoses poor in useful organisms compared with natural habitats, and therefore more and more attention is being paid to crop surroundings and agricultural landscape formation in such a way as to fully use the natural resistance of the environment. This means, among others, widely understood biodiversity protection. Ensuring an additional

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source of food to useful insects on cultivated plants plantations poor in this respect may increase their number and consequently lead to a reduction in phythophage numbers (Pruszyński 2007). Unfortunately, the presence and effectiveness of the actions of predators and parasitoids is often unnoticeable, whilst their role, even in the impoverished agrocenoses of great commercial production is never overrated. Utilisation of these organisms or making active action possible for them depends to a great extent on what our knowledge on them is (Olszak 2005). Therefore, the aim of the study was the recognition of the dynamics of the numbers of the most important natural enemies of cereal aphid (*S. avenae*) on winter wheat plantations and the assessment of the possibility of the utilisation of the natural resistance of the environment in the fight with these pests, while keeping great agrocenosis biodiversity in the conditions of agricultural crop mosaicism (balks and mid-field afforestation).

Materials and methods

Field trials were performed on individual farms on winter wheat plantations (area ca. 1 ha) in years 2005-2006 in two places (Stążki and Huba) in Kuyavian-Pomeranian Province. Environments from which the samples were taken were alike. Both plantations bordered on ruderal species, afforestation, and other cereal crops. Moreover, no chemical pest control was undertaken in the trail objects.

Entomological observations of aphids and their natural enemies were conducted once a week, from the moment of first offspring production through individuals migrating to agricultural fields, to the phase of full crop maturity. Each time, in the period of crop growing, catches with the use of an entomological scoop were done, including 25 captures, in four spots of the plantations, on the field diagonal. Number, qualitative composition, and the percentage participation of useful entomofauna were estimated. In order to determine the degree of the intensification of aphid occurrence (that is plant occupancy), systematically once a week 25 randomly chosen straws were collected from four plantation spots. Moreover, in the particular observation days, depending on the degree of plantation infection and cereal development phase, different plant parts with aphids were collected: at the beginning with lower leaves, then flag leaves, and in the final phase with spikes, in order to conduct parasitoids laboratory breeding. Plant fragment occupied by one aphid colony was taken as a single sample. Density, parasiting degree in aphid colonies, and hyperparasitism in *Hymenoptera* groups were calculated.

Distinguished sets-groups of parasitic *Hymenoptera* were processed qualitatively (marking the genus), and in order to show the quantitative relations, number and individual domination were determined for every taxon (percentage participation of taxon in the general number of a given group of parasitoids and hyperparasitoids). After Barczak (1993), the following domination classes were taken into account: dominants – species making over 20% of the collected material in a given habitat, subdominants – species including 10-20% of the total number of specimens from a given trial area, and recedents, namely species represented by less than 10% of all individuals in the group.

In order to obtain information on the diversification of the described entomofauna, for the genera, in *Hymenoptera* groups, and for useful insects families, the Shannon-Wiener biological diversity index (H') was calculated according to the formula:

$$H' = -\sum_{i=1}^{S} p_i \cdot \ln p_i$$

where:

p_i – the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: $\frac{n_i}{N}$,

n_i – the number of individuals in species i,

N – the total number of all individuals,

S – the number of species.

Higher values of this index indicate higher biotic diversification of the biocenosis (Paullin 2005).

Statistical analysis of the results was carried out using programs MS Excel 2000 and Statistica 8, since not all the comparison groups were characterised by normal distribution, nonparametric statistics were applied for comparisons. Between the factors, the Spearman ranks correlation coefficient was calculated, and the significance level and regression equations were given.

Results and discussion

In the years of the trials, the total of 8284 individuals of cereal aphid were collected, in 2005 – 3496, and in 2006 – 4788 representatives of the species. Both in 2005 and 2006, aphids appeared during their greatest harmfulness for cereals (Fig. 1), mostly during caryopses creation, so at the most critical and decisive time on yield height and quality (Leszczyński et al. 1990; Łęski 1991; Kąkol and Miętkiewski 2001).

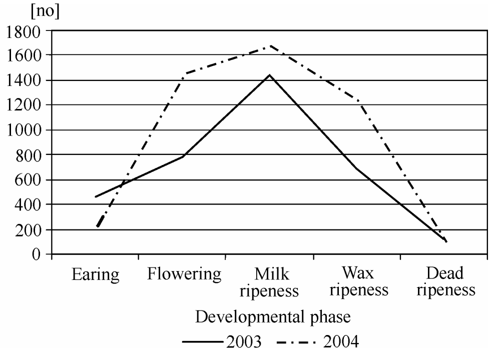

Fig. 1. Dynamics of the cereal aphid number in the years of the trials

Period during which aphids feeding may cause significant economic losses starts from flowering, that is during grain formation and filling, and ends with the ending of milk ripeness when spikes stop being proper food for aphids (Łęski 1991). Starting from the earing phase, the number of aphids began to increase, reaching the maximum in the phase of caryopses milk ripeness. In the initial period, aphis *S. avenae* occupied the youngest leaves, then flag leaves, and eventually moved to spikes. In the trial years, the most occupied spikes were observed in the marginal area of the plantation, neighbouring balks and afforestation. Cooker (1980) and Leszczyński et al. (1990) state that a higher number of aphids may be observed in the marginal area of the plantation. However, this dependency can be applied only to small fields; this tendency has not been noted on great area plantations. In 2005, the highest percentage of colonized plants, namely 88%, was noted in the flowering phase, whilst in the second year of the trial in the phase of milk ripeness, when aphid colonies were situated on all the analyzed plant parts. Mean winter wheat plants occupancy by aphid *S. avenae* in 2005 was 60.6%, and in 2006 was a little lower, namely on 56% percent of the analyzed plants the presence of phythophageous bugs was noted.

Mean density of aphids in colonies in the first year of the trial was ca. 15 aphids, and in 2006, in spite of the fact that a greater number of aphids was noted, was similar and amounted to 16 aphids on average per occupied plant fragment. In 2005, *S. avenae* created numerous colonies starting from the earing phase (17) up to the wax ripeness phase, where the average number in a colony was 15 aphids (Fig. 2). Similar results are given by Ciepiela (1991), although Ruszkowska (2002) claims that latter appearance of cereal aphids does not have a negative effect on the subsequent cereal development and does not require application of plant protection means, and the colonies that are being created are destroyed in a natural way. In 2006, the biggest number of aphids in the colonies was noted in the flowering phase (22) and in the phase of caryopses milk ripeness (22.8), that is in the period when aphids feeding may cause the greatest economic losses (Fig. 3). In the phase of wax ripeness, there were only 9 aphids in the colony, whilst towards the end of the growing period, the number of these insects decreased to 3 individuals per occupied plant fragment.

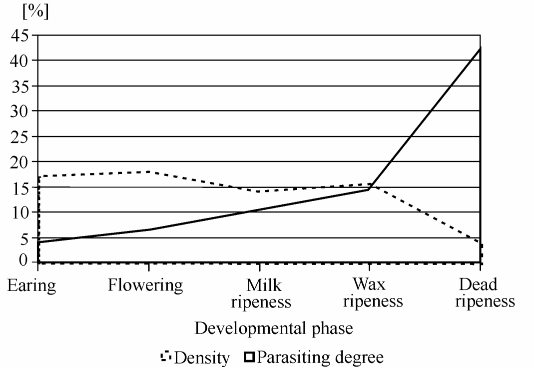

Fig. 2. Aphids density and the degree of colony parasiting in 2005

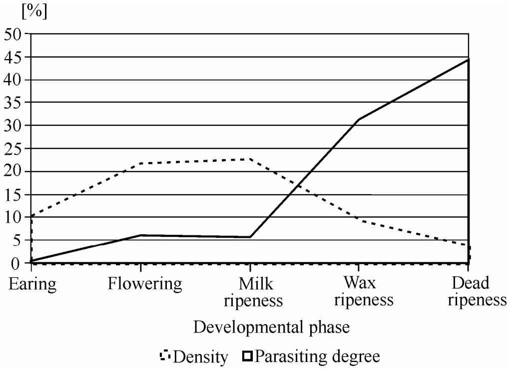

Fig. 3. Aphids density and the degree of colony parasiting in 2006

Negative correlation was found between aphids density in the colony and the degree of aphids parasiting by *Hymenoptera parasitica* (Fig. 4).

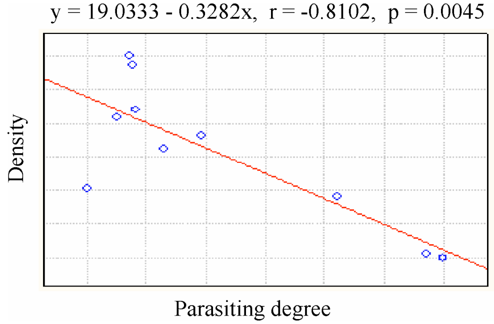

Fig. 4. Equation and regression line for aphids density and degree of colony parasiting

Parasiting degree in the years of the trials increased with the decrease in the number of cereal aphids on wheat plantations (Figs 2 and 3). In the period of rapid aphid number decrease, most frequently in the phase of grain wax ripeness, the highest number of aphid mummies was found. Similar results were obtained by Abo Kaf and Miczulski (1991), Chambers et al. (1986), Kąkol and Miętkiewski (2001), and Pankanin-Franczyk (1982). The highest percentage of attacked phytophages was noted in 2006, in the phase of dead ripeness, when over 44% of the individuals were infected by parasitoids. The situation was similar in 2005, when the parasiting degree towards the end of the growing period was 42.3%. Unfortunately, during the greatest number, hence the highest aphid harmfulness, *Hymenoptera* activity was small, in the years of the trials mean parasiting degree in caryopses flowering and milk ripeness phases was only 6.9%.

In order to estimate the relation between the intensification of aphid occurrence and the number of its natural enemies: *Hymenoptera* (parasitoids and hyperparasitoids), hoverflies, golden-eyed files, and lady beetles, the Spearman ranks correlation coefficient was calculated.

Significant correlations between the number of cereal aphids and the number of *Hymenoptera* and hoverflies have been demonstrated. Correlation coefficients were respectively $r = 0.7174$, $p = 0.0195$ for *Hymenoptera* and $r = 0.8037$, $p = 0.0051$ for hoverflies. Figures 5. and 6. present the described relations. No significant correlation was found in the case of lady beetles and golden-eyed files. However, an increase in the number of lady beetles in the period of cereal development until the mild ripeness phase in the first and until wax ripeness in the second year of the trials was observed. Number of golden-eyed flies, although small in both years of the trials, was higher during caryopses maturation than during wheat flowering. Together with the increasing number of aphids on all plantations, an increase in the number of parasitoids and predators was observed. It can be stated that the cooperation of all natural enemies of cereal aphid on winter wheat cultivation, with a moderate intensification of phytophages occurrence, may be of significant importance as one of the factors that decrease aphid harmfulness to the tolerance level (Ruszkowska 2001).

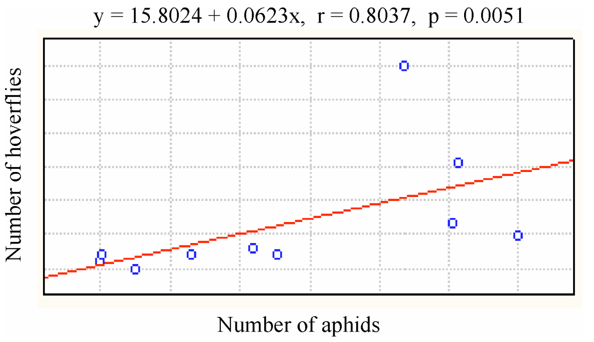

Fig. 5. Equation and regression line for aphids and hoverflies

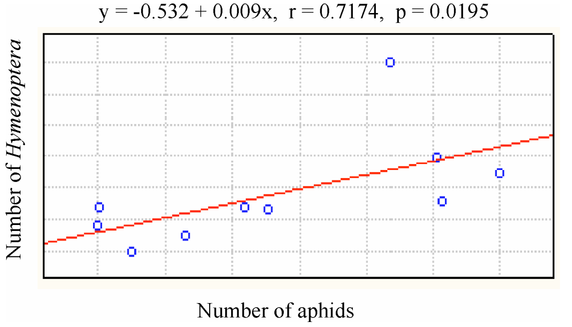

Fig. 6. Equation and regression line for aphids and *Hymenoptera*

Unfortunately, in all the positions, a significant parasitoids reduction by hyperparasitoids was found (Fig. 7). For both plantations, the degree of hyperparasitism for a given observation time and the total hyperparasitoids participation in *Hymenoptera* groups associated with aphid *S. avenae* in the years of the trials were calculated.

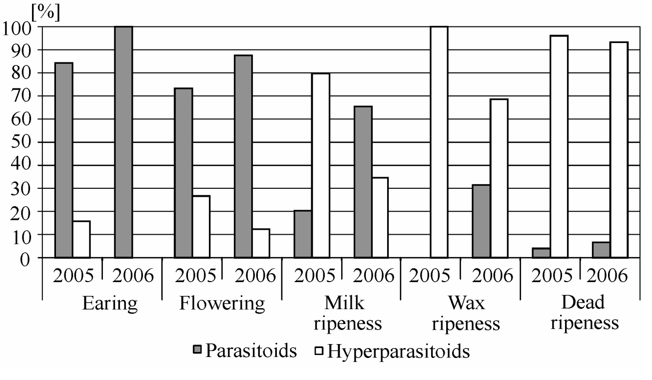

Fig. 7. Percentage participation of parasitoids and hyperparasitoids in *Hymenoptera* groups

Degree of hyperparasitism in the first year of the trials oscillated between 15.8 and 100%, whereas in 2006 between 12.3 a 93.3%; moreover, hyperparasitoids appeared with a significant delay in relation to parasitoids (Fig. 7). In the first year of the trials, aphid population on winter wheat was to a small extent reduced by primary parasitoids, as the mean degree of hyperparasitism was 72.7%. In 2006, the situation was somewhat different, hyperparasitism in *Hymenoptera parasitica* groups was lower (54.3%), which from the point of view of natural biological cereal protection is a beneficial phenomenon (natural resistance of the environment was higher and less restrained), and the aphid population on winter wheat was reduced to a higher degree by primary parasitoids than the latter by hyperparasitoids. Observed activity of parasitic *Hymenoptera* in relation to the aphid population in total for both trial years was 16.5%. Presence of hyperparasitoids weakens parasitoids activity and may significantly limit their role, as well as make possible introduction or colonisation difficult within the frame of biological aphids fight (Barczak 1994). Therefore, in spite of the fact that the effectiveness of parasitoids in cereal agrocenoses was not high, they constitute one of the elements of the natural resistance of the environment, which ought not to be disregarded. This is why aphicides should be used only when it is necessary (Carter 1984), since improperly used reduce the number of natural enemies, not so much by their direct killing but through their starvation, and thus influence the increase in the number of aphids (Barbagallo 1982; Kröber and Carl 1991).

Qualitative and quantitative structure of parasitic *Hymenoptera* in the years of the trails was diversified (Fig. 8). In total, in the years of the trials, 674 parasitic *Hymenoptera* were bred. Dominant in 2005 were genera: *Phaenoglyphis* (20.9%) and *Asaphes* (20.9%). In 2006, dominant were the representatives of genus *Aphidius* (29.0%) (primary parasitoids), whereas among hyperparasitoids the most frequently occurred genus *Dendrocerus carpenterii* (27.3%). In 2005, representatives of both the above named genera belonged to subdominants, in great numbers occurred also species belonging to genera *Praon* (10.1%) and *Alloxysta* (11.9%), whilst in 2006 this group was represented by genera *Praon* (16.7%) and *Pachyneuron* (12.1%). Recedents in both years of the trials were *Hymenoptera* from genus *Ephedrus*.

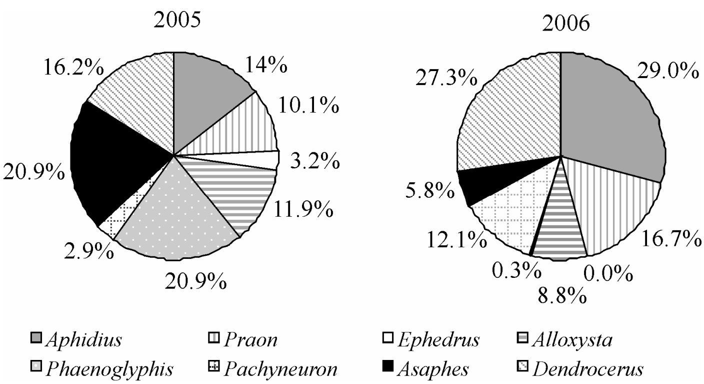

Fig. 8. Percentage participation of particular taxons in *Hymenoptera* groups

Relation between the chosen taxons of parasitic *Hymenoptera* and the number of aphids in both years of the trials was studies. Correlation between the number of aphids and individuals from genera *Aphidius*, *Praon* and *Alloxysta* was found. Occurrence of the representatives of these taxons was closely correlated with the number of aphids on winter wheat plantations in both studied objects.

For the entire useful fauna present in agricultural fields, including parasitoids and useful predators, crop surrounding is of great significance, nowadays described as the ecological infrastructure of agrocenoses. Diversity present in the surroundings of the fields is an irreplaceable nourishment source in the form of pollen or nectar for the adult forms of parasitic *Hymenoptera* and hoverflies, and also a shelter and hibernation place for many parasitoids and predator species (Łabanowska-Bury and Dąbrowski 2009). In order to obtain information of the diversification of the described entomofauna, the Shannon-Wiener biological diversity index (H') was calculated. Biodiversity in the agricultural fields and in their surroundings plays many biological roles, among others in the circulation and usage of nutritional components or in keeping balance among the insects that attack cultivated plants and their natural enemies. Species diversification of the agroecosystem depends on both the abundance of the present species and on their number (Feledyn-Szewczyk 2008). The lowest diversification within parasitic *Hymenoptera* in both years was observed in the wheat earing phase. Systematic increase in the value of the Shannon-Weiner index up to the milk ripeness phase was observed, in which diversification within the *Hymenoptera* order was the highest. During caryopses ripeness diversification decreased (Fig. 9).

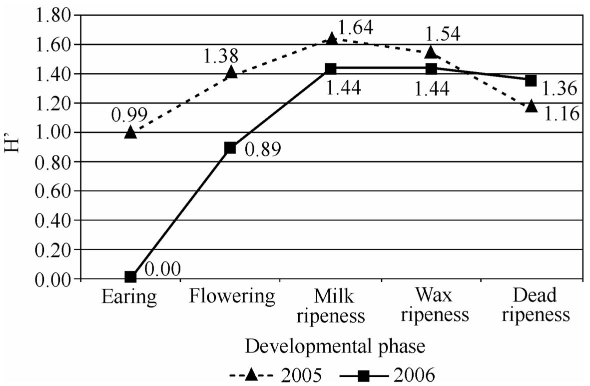

Fig. 9. Biodiversity index of parasitic *Hymenoptera* groups

When it comes to the diversification within the remaining groups of the natural enemies of cereal aphids, in the first year of the trials, from the phase of wheat earing, no biodiversity changes were observed up to cereal wax ripeness, when over double increase in the value of the Shannon-Wiener index occurred. In the following year, increase in biodiversity was observed from the milk ripeness phase (Fig. 10).

As can be seen, predatory and parasitic arthropods make up a constant and important element of biological fight in various agrocenoses, especially in the conditions of agricultural crop mosaicism. Studies on many species of plant pests show that the above mentioned group of organisms is a significant element of the so-called resistance of the environment. Therefore, undoubtedly without the participation of these two groups of natural enemies, pest fight would be extremely difficult, and sometimes even impossible. This is why, in the process of plant growing, such actions need to be taken that make it possible to increase their number in agrocenoses, and at the same time the effectiveness of their actions. Important elements of such proceedings are: the use of selective plant protection means; creation of the possibility of undisturbed development (refugia); increasing biodiversity of agricultural crops (Olszak 2005).

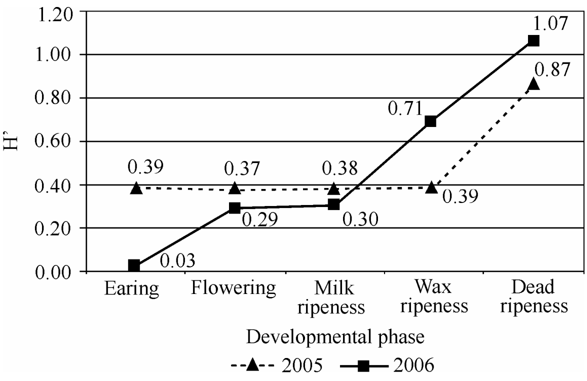

Fig. 10. Biodiversity index in the groups of natural enemies of aphid *S. avenae*

Through the formation of landscape and biological diversity, by leaving tree clusters, bushes and mid-field afforestation on farms, one creates perfect conditions for the development of useful organisms, which may migrate to adjacent fields and reduce the number of the pests that occur there. Through the formation and modification of the landscape that surrounds a farm and through the use of natural phenomena and ecological processes one may prevent mass multiplication of agrophages and positively influence the increase in natural enemies (Fiedler and Sosnowska 2008).

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ACTIVITY OF ENZYMES PARTICIPATING IN TRANSFORMATIONS OF LUVISOL NUTRIENTS DEPENDING ON DIVERSIFIED FERTILISATION

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Soil fertilisation is the main agrotechnical practise in the agriculture intensification process. If it is applied in different forms and doses, it can affect soil properties, especially its bioactivity, namely all the transformations of compounds which occur in soil together with its energy balance (Runowska-Hryńczuk 1992). Mineral and organic fertilisation stimulates the development of plants and microorganisms and affects the activity of soil enzymes (Kucharski 1997). The effect of fertilisation on soil enzymes depends on the kind of enzyme, soil type, fertiliser form, and its application time (Gianfreda and Bollag 1996).

The applicable literature provides different approaches towards the role of mineral fertilisation on the development of enzymatic activity of soil. Einland (1980) refers that fertilisation to the effect on high activity of dehydrogenases, while Kucharski (1997) shows that excessively high nitrogen fertilisation limits its activity considerably. Mineral fertilisation, especially the long-term and high-dose application, can inhibit the enzymatic reactions causing the inactivation of enzymatic proteins by high ion concentration (especially anion concentration) and thus low soil pH.

The organic substance of soil and the products of its biochemical transformations determine a favourable pattern of the entire soil properties complex, defining its fertility. The organic matter of soil is the source of food for microorganisms, thus determining the biomass level of microorganisms, constituting the main source of soil enzymes (Wiśniewski and Bielińska 1998).

Selenium is a trace element found in nature, indispensable for an adequate functioning of living organisms. Being part of glutathione peroxidase, selenium plays an essential role protecting cell membrane lipids from oxidation (Maas 1998). Soil plays an important role as the source of selenium for plants, including fodder crops, and as a result, for final links of the food chain: namely, for animals and humans. Some authors (Maas 1998; Nowak et al. 2004) point to a considerable effect of selenium on the activity of oxidoreductases such as: catalase, glutathione peroxidase and superoxide dismutase in animal organisms. However, there is little literature coverage on the share of selenium in biochemical processes which occur in soil and in plants.

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To compare the effect of different organic and mineral fertilisation variants on the content of macro- and micronutrients and on the enzymatic activity of different soil types, long-term experiments are often used, which seems justifiable since permanent biological changes which occur in it are most frequently seen only after many years of the effect of the agrotechnical practises applied.

Materials and methods

Soil material for research was sampled from many-year fertilisation experiment set up in 1948 at the Experimental Station of the Faculty of Agriculture of the University of Technology and Life Sciences in Mochełek, in the vicinity of Bydgoszcz. The fields of the Experimental Station are located in the area of the macroregion Pomeranian Lakeland and mesoregion Krajeńskie Lakeland; much of that area is raised 95 m above sea level, at a slight denivelation.

The station soils, according to ‘Poland’s soil classification’ (PN-R-04033 1989), represent typical Luvisol, which is classified as soil valuation class IVa, of the good rye soil.

The soil fertilisation involved the following fertilisers: ammonium nitrate, simple fine superphosphate or triple granulated superphosphate, high-percentage potassium salt, magnesium sulphate, carbonate agricultural lime. Manure (FYM) was applied once every five years, each time under root crop, liming was applied prior to beetroot growing. Straw at the dose of 5 $t \cdot ha^{-1}$ was used prior to winter plough under sugar beet (Table 1). Straw was added with nitrogen at the dose of 35 $kg \cdot ha^{-1}$. The following crops were grown: sugar beet, spring barley with undersown red clover, red clover (2 cuts), winter rape, and winter wheat.

Table 1. Fertilisation treatments at the Experimental Station in Mochełek

Treatment No	Fertilisation treatments in 2001	Fertilisation treatments in 2003
1	Control	Control
2	Straw 5 $t \cdot ha^{-1}$ + NPK	Ca
3	NPK + Ca	NPK + Ca
4	NPK	NPK
5	FYM (50 $t \cdot ha^{-1}$)	FYM (30 $t \cdot ha^{-1}$)
6	FYM + PK	FYM + PK
7	FYM + KN	FYM + KN
8	FYM + KN + Mg	FYM + KN + Ca
9	FYM + PN	FYM + PN
10	FYM + PN + Mg	FYM + PN + Ca
11	FYM + NPK	FYM + NPK
12	FYM + NPK + Ca + Mg	FYM + NPK + Ca + Mg

The research reported by Urbanowski et al. (1999) in that experimental treatment at Mochełek in 1969-1973 and 1989-1993 rotations demonstrated that with time diversified fertilisation had an essential effect on soil reaction, causing its acidity, except for liming treatments. The authors observed also a decrease in soil richness in some nutrients which had not been applied in some treatments for many years and organic substance in the mineral fertilisation treatments (Urbanowski et al. 1999). In 2002, after 53 years of the application of diversified organic-mineral fertilisation, the experiment was modified and in all the experimental treatments liming was applied – new mineral-organic fertilisation considering lime. Crop rotation was to be continued in the crop selection used so far. After red clover harvest in 2001, winter rape was sown. Due to bad wintering, winter rape growing was stopped in spring 2002 and oat was sown. In 2003, according to the crop rotation planned, winter wheat was grown.

The experimental part of research involved the use of soil material sampled before a change in fertilisation (2001) and a year after modification (2003). Soil for analysis was sampled from the soil surface (5-30 cm), four times throughout the vegetation period: in spring (May 17, 2001 and March 25, 2003), in spring or at the beginning of summer (July 09, 2001 and June 05, 2003), in summer (August 28, 2001 and August 1, 2003) and in autumn (September 21, 2001 and October 06, 2003).

The following were determined: soil reaction in KCl, content of organic carbon, content of total nitrogen with the distillation method using the Büchi type apparatus (Lityński and Jurkowska 1976). The content of available phosphorus ($P_{E\text{-}R}$) was determined with the Egner-Riehm method – DL (Lityński et al. 1976), sulphate sulphur (VI) – with the Bardsley-Lancaster method (1960). The content of total selenium in soil was defined with the Watkinson method (1966) with the use of spectrofluorimeter F-2000 by Hitachi. Besides, the activity of the following enzymes was assayed in soil: dehydrogenases (EC 1.1.1 – 1.1.8.) according to Thalmann (1968), urease (E.C. 3.5.1.5.) according to Kandeler and Gerbera (1988), rhodanase (EC 2.8.1.1.) following Tabatabai and Singh (1976), the activity of alkaline phosphatase (AlP) (EC 3.1.3.1.) and acid phosphatase (AcP) (EC 3.1.3.2) with the Tabatabai and Bremner method (1969), arylsulphatase (EC 1.3.6.1.) according to Tabatabai and Bremner (1970).

Results and discussion

The content of organic carbon (TOC) in the soil material analyzed ranged from 4.65 to 6.68 $g \cdot kg^{-1}$ in 2001 and from 4.74 to 6.86 $g \cdot kg^{-1}$ in 2003. An effect of the fertiliser combinations (1-12) applied for over 50 years on the content of both components of organic matter was found (Table 2). Significantly lowest TOC content was determined in the soil sampled from the control, whereas the highest content of organic carbon was determined in the soil sampled from the plots fertilised with complete organic-mineral fertilisation (treatment 12). The TOC content in the soil sampled from those plots was 30% higher as compared with the content determined in the soil sampled from the control. A similar effect of a simultaneous fertilisation with manure and mineral fertilisers on the content of organic carbon in soil was reported by Mercik et al. (1995). Similarly, Ellmer et al. (1999), in the soil sampled from a many-year pot experiment on typical Luvisol in Thyrow, observed the highest TOC content in the soil sampled from treatments fertilised simultaneously with manure with NPK and limed. The present results are confirmed by the reports by Panak et al. (1990) which show that manure enhances the general soil fertility, and it is especially active in the case of a combined application with mineral fertilisers.

The content of total nitrogen (TN) in the soil sampled from the experiment at Mochełek ranged from 0.390 to 0.640 $g \cdot kg^{-1}$ in the vegetation period of red clover and from 0.415 to 0.675 $g \cdot kg^{-1}$ during winter wheat cultivation (Table 2). The lowest TN content was determined in the soil sampled from fertilisation treatment FYM + PK. An 8% increase in the TN content in the soil sampled in 2001 and 10% – in 2003 due to soil fertilisation with manure was recorded, as compared with the amount determined in the soil sampled from the plots without fertilisation. It is not compliant with the results reported by Czekała et al. (1999) who found that 40-year Luvisol fertilisation with manure resulted in a 52.5% increase in total nitrogen content in soil, as compared with the control and a 71.8% increase in the amount reported for the mineral fertilisation treatment. In Luvisol sampled at Mochełek, the highest TN amount, similarly as in the case of TOC, was determined in the soil sampled from the full mineral-organic fertilisation (treatment 12). The content of total nitrogen in the soil sampled from that treatment was about 20% higher than in the soil sampled from the NPK treatment only.

Table 2. Content of total organic carbon (TOC), total nitrogen (TN), C : N ratio, and pH in the soil. For fertilisation treatments see Table 1

Treatment No	TOC [g·kg^{-1}]		TN [g·kg^{-1}]		C : N		pH	
	2001	2003	2001	2003	2001	2003	2001	2003
1	4.65	4.74	0.460	0.455	10	10	4.53	4.67
2	4.74	4.96	0.425	0.445	11	11	3.71	4.59
3	4.91	4.86	0.420	0.440	12	11	4.12	4.72
4	4.90	4.97	0.435	0.440	11	11	3.67	4.31
5	5.06	5.14	0.500	0.500	10	10	3.85	4.23
6	4.95	4.96	0.390	0.415	13	12	4.04	4.46
7	5.48	5.53	0.535	0.550	10	10	3.71	4.20
8	5.53	5.65	0.465	0.485	12	12	3.78	4.24
9	5.35	5.55	0.525	0.545	10	10	3.71	4.14
10	5.38	5.59	0.495	0.560	11	10	3.90	4.28
11	5.28	5.57	0.525	0.535	10	10	3.73	3.96
12	6.68	6.86	0.640	0.675	10	10	5.80	6.14
Mean	5.24	5.36	0.485	0.504	11	11		
$LSD_{0.05}$	0.077	0.281	0.067	0.310				

The differences in the value of ratio C : N average for the four research years were inconsiderable. The highest value of that feature in the vegetation period, of both clover and winter wheat, was recorded in the soil sampled from the plots fertilised with FYM + PK (Table 2). The value of that ratio demonstrates an advantage of mineralization processes over immobilization of nitrogen in soil.

Considering pH values in 1 mol·dm^{-3} KCl of soil sampled in respective research years, one can observe an increase in the reaction in soil samples after liming. It was found that, depending on the fertiliser combinations applied, the soil sample was undergoing changes (Table 2). The lowest value of the reaction in soil sampled from the red clover plantation (2001) was recorded in the soil sampled from the NPK fertilisation (treatment 4), slightly higher pH, namely by 0.03 units, was determined in straw (treatment 2), FYM + NK (treatment 7) and FYM + NP (treatment 9). Liming increased the soil pH. In the soil sampled in 2003 low soil pH in some treatments (4-11) qualified them as very acid soils, but there were found also treatments with pH > 4.6: treatments 1-3 and 12. The highest reaction, 6.14 units, was reported in soil sampled from the full mineral-organic fertilisation treatment. The soil from that treatment has been then classified as soils of slightly acid reaction.

The content of available phosphorus determined according to the Egner-Riehm method over the research years ranged from 52.7 to 180 mg P·kg^{-1} of soil. According to the criteria defined by PN-R-04023 (1996), the availability of soil in phosphorus available to plants was very high. Fotyma et al. (1996) noted that the optimal content of available phosphorus (determined with the Egner-Riehm method) should be 105-108 mg P·kg^{-1}. A significant effect of the soil sampling date on the content of P_{E-R} in Luvisol, both in 2001 and in 2003, was found (Table 3). Significantly highest content of that phosphorus fraction was recorded in the soil sampled at date IV (123 mg P·kg^{-1} in 2001 and 120 mg P·kg^{-1} in 2003), whereas the lowest content of P_{E-R} was reported in the soil sampled at the first date (early spring). A low content of available phosphorus at the first soil sampling date could have been due to high requirements of the plant at the initial development period when phosphorus determines the root system growth rate and thus defines the capacity of the plant for water and nutrients uptake from soil.

There was found a significant effect of varied mineral and organic fertilisation on the content of available phosphorus in the Luvisol researched. The highest content of that nutrient (180 mg P·kg^{-1} in 2001 and 174 mg P·kg^{-1} in 2003) was found in soil fertilised with FYM + NPK + Ca + Mg. The content is, on average, 69% higher, as compared with the content of P_{E-R} in the soil sampled from the control. Similarly the soil sampled from the treatments with mineral fertilisation only (Ca, NPK + Ca, NPK) showed significantly lower content of that phosphorus fraction. Natural fertilisers (manure and slurry) are an easily available source of phosphorus to plants since, depending on the degree of mineralization, 50-70 % of the entire content of phosphorus contained in those fertilisers occurs in mineral compounds, mainly as calcium phosphate (Potarzycki 2003). Sienkiewicz et al. (2004) found that mineral fertilisation does not meet the requirements of plants for C, N, and P fully. The highest effectiveness occurs in the case of combined manure and mineral fertilisation. Liming applied in experimental treatments (combination FYM + KN + Ca) resulted in a significant increase in the content of available phosphorus fraction in Luvisol both sampled in 2001 (128 mg P·kg^{-1}) and in 2003 (131 mg P·kg^{-1}).

Recognizing the content of sulphate sulphur(VI) in soil, both in the case of its excess and deficit, is becoming more and more important in contemporary rational fertilisation (McGrath et al. 2003; Kopeć and Gondek 2004). The content of that fraction of sulphur points to the supply of plants with the nutrient indispensable for their life and to ecological threat connected with changes in soil it causes (Motowicka-Terelak and Terelak 1998). The content of sulphate sulphur in the soil sampled from plots on which clover was grown ranged from 7.67 to 19.3 mg·kg^{-1} (Table 3). The concentration of SO_4^{2-} in Luvisol sampled from the experiment performed in 2003 fell within a narrower range of 10.1-16.5 mg·kg^{-1}. In most soils under agricultural use in Poland the content of sulphate sulphur does not exceed 25 mg·kg^{-1} of soil. Most soils, namely 70% of the arable land, show the content of that sulphur fraction in the range from 5.0 to 20.0 mg·kg^{-1} (Lipiński et al. 2003). The content of $S\text{-}SO_4^{2-}$ in the soil sampled from the experiment at Mochełek fell within the country's average sulphur content in arable soils. The amount of that sulphur fraction in the studied soil was on average 14.2 mg·kg^{-1}, which, according to the boundary contents of sulphate sulphur in the upper layer of light soils (0-20% of fraction <0.02 mm) classifies it as soils of natural content (Motowicka-Terelak and Terelak 1998). According to the five-degree scale of soil richness in sulphate sulphur(VI) developed by those authors, depending on how the plant to be grown in the future is classified in the group of plants in terms of sulphur requirements, the soil researched should be enriched with a dose of that element from 10 to 110 kg S·ha^{-1}.

Table 3. Content of available phosphorus and sulphate sulphur. Dates of sampling in 2001: I – May 17, II – July 09, III – August 28, IV – September 21; in 2003: I – March 25, II – June 05, III – August 01, IV – October 06. For fertilisation treatments see Table 1

Specification		Available phosphorus [mg·kg^{-1}]		SO_4^{2-} [mg·kg^{-1}]	
		2001	2003	2001	2003
Date of sampling (I factor)	I	91.3	93.9	11.3	12.9
	II	92.8	103	13.3	12.5
	II	102	116	15.9	17.7
	IV	123	120	12.5	11.3
Fertilisation treatments (II factor)	1	55.2	52.7	7.67	14.6
	2	65.2	72.4	8.09	10.8
	3	69.5	79.6	10.1	10.1
	4	75.2	85.9	9.11	13.6
	5	88.2	91.4	10.0	13.3
	6	95.7	103	10.8	12.5
	7	104	116	11.6	14.7
	8	128	131	15.9	13.5
	9	108	120	18.4	14.6
	10	121	131	19.1	15.1
	11	137	144	19.1	16.5
	12	180	174	19.3	14.1
Mean		102	108	13.3	13.6
$LSD_{0.05}$ for:					
I factor		3.349	2.258	1.30	0.565
II factor		3.365	2.149	1.17	1.542
interactions:					
I/II		5.419	3.259	2.33	3.085
II/I		6.223	3.641	2.09	2.343

An effect of the fertilisation applied on the sulphate sulphur concentration in the studied soil was found. In growing clover the lowest amount of that sulphur fraction, 7.67 mg·kg^{-1}, was determined in the soil material sampled from the control. The content of sulphate sulphur in the soil sampled from that treatment was 23% lower than in the soil sampled from the manure treatment (5) and 60% lower than in the soil sampled from complete mineral-organic fertilisation (treatment 12), which complies with the results reported by other authors who also reported a varied content of sulphate sulphur in soil depending on the fertilisation method (Czekała et al. 1999; Mercik et al. 1999).

Liming applied in the experiment in 2002 enhanced a release of sulphur by accelerating the decomposition of organic compounds and a release of adsorbed sulphates. Under such conditions, the availability of sulphur for plants, however, also helps its leaching (Kopeć and Gondek 2004). The changes have been clear in the soil material sampled from winter wheat. The lowest content of sulphate sulphur (10.1 mg·kg^{-1}) was determined in soil sampled from the plots earlier fertilised with NPK plus lime (treatment 3). The highest content of that sulphur fraction (16.5 mg·kg^{-1}) was determined in the soil sampled from the FYM + NPK fertilisation (treatment 11).

The content of total selenium in Luvisol sampled from the control in 2001 was 0.085 mg·kg^{-1}, and after the change in fertilisation in 2003 – 0.071 mg·kg^{-1} (Fig. 1). As reported by Kabata-Pendias and Pendias (1999), the average selenium content in the subsoil horizons of arable soils of the world was 0.33 mg·kg^{-1}, and Polish soils – 0.27 mg·kg^{-1}. In finish soils which also demonstrate deficit content of selenium, already the

0.2-0.3 mg·kg^{-1} level is considered low (Aro and Alfthang 1998). A comparison of the present results with literature reports suggests that the soil sampled from Mochełek was poor in that element. The application of varied fertilisation, especially fertilisation with manure, resulted in a significant increase in the content of total selenium in the Luvisol researched. In the soil sampled in 2001 from the FYM or FYM with full mineral fertilisation treatments, the content of total selenium increased, respectively, by 35% and 45%, as compared with the control soil. In the soil sampled in 2003, following the fertilisation modification, from the treatments fertilised with manure or manure with mineral fertilisation added (treatments 5-12), the content of total selenium was, on average, 0.162 mg·kg^{-1} and it was, on average, 56% higher than the control soil. The increase in the content of total selenium in soil must have been due to the application of manure in which, as reported by Maćkowiak (1994), the average content of selenium was 2.4 mg·kg^{-1} of d.m.

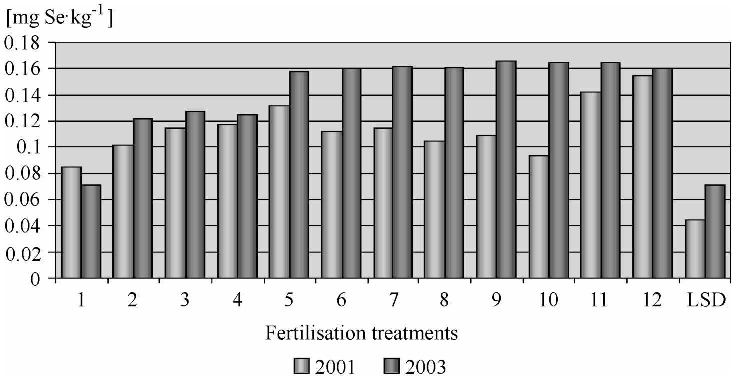

Fig. 1. Total selenium content in studied soil. For fertilisation treatments see Table 1

The diversified organic-mineral fertilisation, both prior to and after the experiment modification as well as the soil sampling dates in both research years had a significant effect on the changes in the activity of the studied soil enzymes (Table 4).

The highest activity of soil dehydrogenases in the vegetation season of red clover (0.033 mg TPF·g^{-1}·h^{-1}) was determined in the soil sampled from the complete organic-mineral fertilisation (treatment 12). The change in the fertilisation introduced in the experiment at Mochełek increased the activity of dehydrogenases in the soil sampled in 2003 by an average of 54% for all the fertilisation treatments (Table 4). Liming revealed successive effect of many-year FYM + NPK fertilisation with lime and magnesium added: the treatment was identified with the highest activity of dehydrogenases (0.224 mg TPF·g^{-1}·h^{-1}). Similar results were reported by Šimek et al. (1999) who recorded a considerable increase in the activity of dehydrogenases in soils fertilised with organic fertilisers together with mineral fertilisation with lime added, as compared with those which were not treated with lime. The lowest activity of dehydrogenases was determined in the soil sampled from the plots fertilised with mineral fertilisers only (treatments 3 and 4); they were, on average, 35% lower in 2001 and 48% in 2003 than in the control (Table 4). Myśków et al. (1996) also found the lowest activity of dehydrogenases and other fertility indices in soil fertilised with mineral fertilisers. The activity of dehydrogenases lower than in the soil sampled from the non-fertilised treatment suggests the existence of factors inhibiting the activity of enzymes in those soils. Results reported by many authors (Myśków et al. 1996; Barabasz et al. 1999) show that fertilisation affects the abundance of microorganisms and the selection of the entire cultures of microorganisms. Inadequate agrotechnical treatments and irrational mineral fertilisation can disturb the soil metabolism and contribute to the production of different compounds in the soil environment; e.g. nitrosamines, mycotoxines, nitrites, nitrates, which have an unfavourable effect on soil microorganisms (Gianfreda and Bollag 1996; Barabasz et al. 1999).

The activity of urease ranged from 0.204 to 0.305 mg $N\text{-}NH_4 \cdot kg^{-1} \cdot h^{-1}$. The soil sampled in 2001 showed a 25% higher activity of urease than the one determined in the soil sampled under winter wheat. The pattern of enzymatic processes in soil during the plant vegetation period varies a lot and depends e.g. on the seasonally changing temperature and moisture of the soil environment (Gianfreda and Bollag 1996). It is believed that enzymes are relatively active at the end of spring, in summer or in early autumn (Januszek 1993). In the present research the highest activity of urease occurred in the soil sampled in May for both research years. A higher activity of urease was noted for the soil sampled under clover as compared with its activity defined in the soil material sampled under winter wheat, which could have been, to some extent, due to a higher dose of nitrogen fertilisation applied under winter wheat, which complies with literature reports showing that the activity of urease can be inhibited by adding increased doses of fertilisers containing ammonium compounds to soil (Kieliszewska--Rokicka 2001). The activity of urease decreases since N mineral uptake by soil microorganisms inhibits the enzymatic protein synthesis (Burket and Dick 1998). A comparison of the activity of urease in the soil sampled from FYM + PK as well as FYM + NPK fertilisation treatments (except for the soil sampled in June 2001) showed a significant effect of nitrogen fertilisation applied in a form of ammonium nitrate on the enzymatic activity in the soil sampled under red clover, while the fertilisation did not have a significant effect on the activity of the studied enzyme in the soil sampled under winter wheat. A comparison of the activity of urease in the soil sampled from the plots fertilised with respective components of the fertilisers applied with its activity determined in the soil samples from control plots (e.g. for the P fertilisation, FYM + NK and FYM + NPK treatments) no clear-cut effect of fertilisers containing P, K, Mg, and Ca on the activity of the enzyme was found.

The activity of alkaline phosphatase was changing significantly throughout the vegetation period of the plants and ranged from 0.400 to 0.600 mM $pNP \cdot kg^{-1} \cdot h^{-1}$ in the soil sampled in 2001 and from 0.534 to 1.114 mM $pNP \cdot kg^{-1} \cdot h^{-1}$ in the soil sampled in 2003 (Table 4). The highest activity of the phosphomonoesterase was reported in the soil sampled at the first date, whereas the lowest – in the soil sampled at the fourth date. The intensity of exudation of phosphatases by plants and microorganisms is strictly related to the phosphorus requirements of plants. Besides, seasonal changes in the enzymatic activity of soil are a derivative of the hydrothermal conditions: temperature and rainfall pattern since those are the factors which have the highest effect on the life of microorganisms and related enzymatic activity of soil. Usually the activity of soil phosphatases is inversely proportional to the content of mineral phosphorus since an increased level of inorganic phosphorus in soil decreases the activity of phosphatases (Kieliszewska-Rokicka 2001). The activity of phosphatases then gets inhibited by mineral phosphate which acts as a competitive inhibitor.

Table 4. Enzymatic activity of the soil. Dates of sampling in 2001: I – May 17, II – July 09, III – August 28, IV – September 21; in 2003: I – March 25, II – June 05, III – August 1, IV – October 06. For fertilisation treatments see Table 1

Specification		Dehydrogenases [mg TPF·g^{-1}·h^{-1}]		Urease [mg N-NH_4·kg^{-1}·h^{-1}]		Arylsulphatase [µM pNP·g^{-1}·h^{-1}]		Rhodanase [µM SCN^-·g^{-1}·h^{-1}]		Phosphatases [mM pNP·g^{-1}·h^{-1}] Alkaline		Phosphatases [mM pNP·g^{-1}·h^{-1}] Acid		AlP/AcP	
		2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003
Date of sampling (I factor)	I	0.029	0.032	0.226	0.204	0.117	0.322	0.97	2.18	0.547	0.854	1.294	0.801	0.423	1.066
	II	0.034	0.053	0.338	0.254	0.135	0.336	0.61	1.37	0.509	0.705	0.685	1.026	0.743	0.687
	III	0.008	0.063	0.317	0.187	0.110	0.192	1.06	1.31	0.506	0.653	0.881	0.779	0.574	0.838
	IV	0.013	0.075	0.209	0.175	0.108	0.341	1.68	1.31	0.492	0.690	1.070	0.883	0.460	0.781
Fertilisation treatments (II factor)	1	0.031	0.056	0.212	0.211	0.117	0.291	0.59	1.45	0.400	0.534	0.858	0.737	0.466	0.725
	2	0.023	0.035	0.253	0.191	0.109	0.289	0.86	1.38	0.428	0.584	0.814	0.736	0.526	0.793
	3	0.023	0.029	0.295	0.205	0.109	0.297	1.00	1.41	0.456	0.601	0.777	0.746	0.587	0.806
	4	0.020	0.029	0.294	0.192	0.109	0.301	0.77	1.46	0.498	0.628	0.903	0.721	0.541	0.871
	5	0.029	0.036	0.300	0.181	0.119	0.292	0.91	1.49	0.489	0.632	0.884	0.826	0.563	0.765
	6	0.026	0.040	0.288	0.238	0.123	0.291	0.97	1.54	0.521	0.663	0.984	1.021	0.529	0.649
	7	0.028	0.030	0.291	0.210	0.114	0.296	1.21	1.63	0.540	0.687	1.183	0.884	0.456	0.777
	8	0.026	0.078	0.322	0.204	0.124	0.301	1.16	1.63	0.567	0.838	0.999	0.834	0.568	1.005
	9	0.026	0.034	0.291	0.181	0.124	0.299	1.22	1.51	0.552	0.753	0.960	0.823	0.542	0.915
	10	0.025	0.033	0.305	0.214	0.118	0.302	1.36	1.67	0.535	0.770	1.096	1.006	0.488	0.765
	11	0.026	0.043	0.252	0.212	0.116	0.305	1.35	1.65	0.577	0.901	1.137	1.070	0.507	0.842
	12	0.033	0.224	0.195	0.216	0.128	0.309	1.58	1.70	0.600	1.114	1.195	1.064	0.502	1.047
Mean		0.026	0.056	0.273	0.205	0.117	0.298	1.08	1.54	0.514	0.725	0.984	0.872	0.522	0.831
$LSD_{0.05}$ for:															
I factor		0.002	ns	0.002	0.009	0.005	0.021	0.017	0.052	0.002	0.008	0.011	0.009		
II factor		0.003	0.062	0.005	0.011	0.007	0.014	0.046	0.068	0.011	0.008	0.018	0.013		
interaction:															
I/II		0.006	ns	0.012	0.005	0.015	0.027	0.093	0.136	0.011	0.012	0.015	0.021		
II/I		0.005	ns	0.003	0.013	0.012	0.028	0.071	0.111	0.017	0.013	0.020	0.025		

ns – no significant difference

A significant effect of the fertilisation applied in the experiment on the activity of alkaline phosphatase in the Luvisol was found. The FYM + NPK + Ca + Mg fertilisation resulted in a significantly highest increase in the activity of alkaline phosphatase (0.600 mM pNP·kg^{-1}·h^{-1} in the soil sampled in 2001 and 1.11 mM pNP·kg^{-1}·h^{-1} in 2003) as compared with the control soil, while the application of manure only without mineral fertilisation resulted in a decrease in the activity of the phosphomonoesterase as compared with the FYM + NPK + Ca + Mg combination by an average of 35%. Similarly, the application of mineral fertilisation only decreased the activity of alkaline phosphatase. Parham et al. (2002), investigating the activity of soil phosphomonoesterases, observed a significantly higher activity in the soil fertilised with FYM as compared with the activity of those enzymes in the soil exposed to mineral fertilisation. FYM demonstrated a significant effect on the activity of microorganisms and the biogeochemical phosphorus cycle. The activity of alkaline phosphatase was lower (0.489 mM pNP·kg^{-1}·h^{-1} in 2001, 0.628 mM pNP·kg^{-1}·h^{-1} in 2003) in the soil sampled from the NPK fertilisation (treatment 4) than the activity of that enzyme in soil fertilised with manure (treatment 5; 0.498 mM pNP·kg^{-1}·h^{-1} in 2001 as well as 0.632 mM pNP·kg^{-1}·h^{-1} in 2003). The activity of alkaline phosphatase was 29% higher in the soil sampled in 2003 as compared with the activity of that enzyme in soil in 2001 in which red clover was grown, which must be related to the soil reaction which was higher in the soil sampled under winter wheat. Wittmann et al. (2004) claim that the higher activity of acid must be due to phosphomonoesterases being enzymes most sensitive to changes in the soil reaction; the optimum pH of soil for the activity of alkaline phosphatase ranges from 9.0 to 11.0, and for acid phosphatase from 4.0 to 6.5.

The activity of acid phosphatase ranged from 0.777 to 1.195 mM pNP·kg^{-1}·h^{-1} in the soil sampled under clover and from 0.721 to 1.064 mM pNP·kg^{-1}·h^{-1} in the soil sampled under winter wheat. The activity of the enzyme in the soil samples under clover was on average 11% higher than the one reported in the soil material under winter wheat. The highest activity of that enzyme was determined in the soil sampled from the following fertilisation treatments: FYM + PN + Ca, FYM + NPK, FYM + NPK + Ca + Mg for both research years and from the FYM + KN fertilisation in 2001 (Table 4). The growing acid phosphatase activity trend observed could have been due to the manure applied, affecting the biological activity of soil, but also due to the supply of the major components stimulating the enzymatic activity of soil. Nitrogen fertilisation, in general, stimulates the activity of acid soil phosphatase (Colvan et al. 2001), which coincides with the results of the present research in which the activity of that enzyme was significantly higher in the soil from the treatment fertilised with nitrogen: (FYM + NPK), as compared with its activity reported in the soil fertilised with FYM + PK in both research years, which coincides with the reports by Kucharski (1997) who showed that nitrogen fertilisation at the doses increasing up to 120 kg N·ha^{-1} regularly increased the activity of acid phosphatase. Study on Luvisol at Mochełek did not identify any unambiguous effect of soil liming on the activity of acid phosphatase by a comparison of its activity in the soil samples from the following treatments: (NPK + Ca) and (NPK), (FYM + KN) and (FYM + KN + Ca) as well as (FYM + PN) and (FYM + PN + Ca). It was demonstrated that the secretion of protein of acid phosphatase of plants is stimulated by cations Ca^{2+} and Mg^{2+}. Some research, however, showed that sometimes soil liming decreases its phosphatase activity (Gianfreda and Bollag 1996). Frequently, the greater the amount of lime added to soil, the higher the decrease in its activity (Trasar-Cepeda and Carballas 1991). The effect of lime on the phosphatase activity of soil is thus very complex. On the one hand, it is connected with changes in the soil reaction the direction of development of respective groups of soil microorganisms depends on and, on the other hand, liming increases the content of inorganic phosphorus which can inhibit that activity. As reported in literature (Kucharski 1997; Colvan et al. 2001), FYM usually had a stimulating effect on the activity of acid phosphatase, which must have been due to an increased biological activity of soil and the stabilization of extracellular enzymes by binding them with humus substance. As reported by Kucharski (1997), the phosphatase activity was higher in the soils fertilised only with FYM, as compared with their activity in soils fertilised with complete organic-mineral fertilisation. In the present research, however, in the samples of soils fertilised with FYM only the activity of acid phosphatase was significantly lower (by 26% in 2001 and 22% in 2003) than in the samples fertilised simultaneously with FYM and mineral fertilisers (FYM + NPK + Ca + Mg).

Based on the present results of the activity of alkaline phosphatase and acid phosphatase, there were calculated the values of the AlP : AcP ratio referred to as an enzymatic index of the pH level. Values of the AlP : AcP ratio during the present research ranged from 0.456 to 1.047, irrespective of the fertilisation treatment (Table 4). The pH value range adequate for the growth and development of plants can be referred to as the value at which an adequate ratio of AlP : AcP activity occurs (Dick et al. 2000). According to those authors, if the value of the AlP : AcP ratio is lower than 0.5, which shows an acid reaction of soil, then liming is recommended. The present results of the value of the AlP : AcP ratio show that the soil sampled in 2001 showed lower values of the AlP : AcP ratio as compared with the values of that ratio reported based on the present analysis in 2003.

The activity of arylsulphatase in soil sampled from the plots in which red clover was grown ranged from 0.109 to 0.128 μM pNP$\cdot g^{-1}\cdot h^{-1}$, while from winter wheat ranged from 0.289 to 309 μM pNP$\cdot g^{-1}\cdot h^{-1}$ (Table 4). The activity of the enzyme in the Luvisol samples in 2001 was lower by an average of about 60% than that recorded in the soil material sampled from winter wheat in 2003. According to Klose and Tabatabai (1999), about 45% of the total activity of arylsulphatase in soil is of extracellular origin, while 55% of the activity of that enzyme is connected with the biomass of microorganisms in soil. As shown earlier in the soil sampled at Mochełek, a significant increase in the activity of soil dehydrogenases, being an indicator of the abundance of the population of microorganisms, was found (Table 4). Therefore one can assume that it had an effect on increasing the activity of arylsulphatase in soil following liming and the change in fertilisation. That change resulted in an increase in the activity and persistence of extracellular enzymes in soil (Ganeshamurthy and Nielsen 1990).

The activity of the enzyme was changing throughout the plant vegetation period. The highest activity of arylsulphatase during red clover cultivation (0.135 μM pNP$\cdot g^{-1}\cdot h^{-1}$) was recorded in the soil sampled at the second date when it was 20% higher as compared with its lowest activity defined in the soil sampled at the fourth date (Table 4). During the vegetation period of wheat the lowest activity 0.192 μM pNP$\cdot g^{-1}\cdot h^{-1}$ was determined in the soil sampled prior to its harvest (01.09.) and the highest (0.341 μM pNP$\cdot g^{-1}\cdot h^{-1}$) in the material sampled before cultivating measures under successive crop (06.10.). According to Neal (1982), growing crops as well as the size of rhizosphere affect the activity of arylsulphatase. A varied mineral-organic fertilisation significantly determined the activity of arylsulphatase in the Luvisol during the cultivation of clover (Table 4).

The lowest activity of that enzyme (0.109 μM pNP·g^{-1}·h^{-1}) was determined in the soil sampled from the following treatments: straw fertilisation + NPK (2) and NPK + Ca (3) as well as NPK (4). The activity of arylsulphatase in the soil sampled from those fertilisation treatments was lower than the activity determined in the soil sampled from the control (1), which points to the inhibiting effect of mineral fertilisers on the activity of arylsulphatase. A negative effect of ions on the enzymatic activity of soil was observed by many researchers (Ganeshamurthy and Nielsen 1990, Germida et al. 1992). The activity of rhodanase in soil from Mochełek in both research years ranged from 0.59 to 1.70 μM SCN^-·g^{-1}·h^{-1} (Table 4). The activity was slightly higher than that reported by Tabatabai and Singh (1976) in the non-fertilised soils: 0.130-0.880 μM SCN^-·g^{-1}·h^{-1} or the one defined in soils sampled from Saskatchewan by Germida et al. (1992) – 0.038-0.875 μM SCN^-·g^{-1}·h^{-1}. The analysis of variance of the results reported in the experiment with over 50-year application of various fertilisation combinations showed that the activity of that enzyme depended significantly on the fertilisation applied (Table 4). The highest activity was reported in the soil sampled from the plots fertilised with manure with NPK with lime and magnesium added. It was also shown that the activity of rhodanase in the soil sampled from FYM and mineral fertilisation (treatments 7-12) was higher than the calculated average activity for respective research years (in 2001 the average was 1.08 μM SCN^-·g^{-1}·h^{-1}, and in 2003 – 1.54 μM SCN^-·g^{-1}·h^{-1}). The activity of the enzyme in the soil sampled under red clover was on average about 30% lower than the winter wheat average. The increase in the activity of rhodanase must have been due to an increase in the population of microorganisms after liming in the soil researched since mostly chemolithotrophic and heterotrophic bacteria and fungi participate in elemental sulphur oxidation in soil (Deng and Dick 1990; Czaban and Kobus 2000). The activity of rhodanase was changing during the red clover vegetation period; the highest activity of the enzyme, 1.68 μM SCN^-·g^{-1}·h^{-1}, was determined in the soil sampled at the last date. The dynamics of the activity of rhodanase in the vegetation period of wheat was different (Table 4). Its highest activity of 2.18 μM SCN^-·g^{-1}·h^{-1} was determined in the soil sampled at the beginning of the vegetation period. With plant development, it was decreasing and its lowest activity, 1.31 μM SCN^-·g^{-1}·h^{-1}, was determined in the soil sampled at the end of the vegetation period of wheat. Similarly Szajdak (2004) recorded the highest activity of that enzyme in the soil sampled at the beginning of March, once the plants started vegetation.

The analysis of correlation* showed significant and positive coefficients of correlation between the activity of urease and the content of TOC ($r = 0.551$; $p = 0.05$) and TN ($r = 0.623$) only in the soil sampled in May 2003. The activity of dehydrogenases also depended on the content of carbon and nitrogen in 2001 for the contents of TOC $r = 0.34$ and TN $r = 0.29$; in 2003 coefficients of correlation were higher and amounted to, $r = 0.77$ and $r = 0.68$, respectively. The activity of rhodanase is often correlated with the content of organic carbon in soil (Singh and Tabatabai 1978). In the present research a positive correlation between the activity of rhodanase and the content of organic carbon and total nitrogen in the soil sampled was recorded in 2001 ($r = 0.41$, $r = 0.43$). Similarly in that year there was reported a relationship between the activity of arylsulphatase and the content of TOC $r = 0.24$ and TN $r = 0.20$. There was

* The full data of the analysis ofcorrelation is not shown; only the significant coefficients are provided in the text.

also reported a significant positive correlation between the content of carbon of organic compounds in soil, and the activity of alkaline phosphatase (r = 0.678) in the soil sampled in August and (r = 0.613) in the soil sampled in October.

Conclusions

A varied mineral-organic fertilisation significantly determined the content of macroelements in the Luvisol. A regular application of FYM combined with mineral fertilisation increased the content of carbon of organic compounds and total nitrogen.

The soil researched represented the first class of richness in available phosphorus, whereas the content of sulphate sulphur(VI) classifies it as soil of natural content and, depending on the crop, it should be enriched in that component.

The content of total selenium in the Luvisol, from control treatments, was on average 0.078 $mg \cdot kg^{-1}$. A comparison of the results with applicable literature reports suggests that the soil researched was rich in that element. The application of FYM, especially in the soil sampled in 2003, after the modification in fertilisation, resulted in an over 2-fold increase in the content of that element in soil.

The activity of dehydrogenases, urease, alkaline and acid phosphatases, arylsulphatase, rhodanase in the soil analyzed showed a high variation depending on the combination of a varied mineral-organic fertilisation applied for 50 years and the development stage of the plants grown.

The decrease in the enzymatic activity of Luvisol observed at Mochełek sampled in the first research year was due to inadequate fertilisation which did not satisfy the nutrition requirements of plants fully and contributed to soil acidification.

Soil liming significantly modified its enzymatic activity, however, it did not show a clear-cut direction of that effect. The increase in the soil reaction increased the microbiological activity measured by the activity of dehydrogenases, arylsulphatase, rhodanase and alkaline phosphatase, whereas a decreased activity of urease and acid phosphatase after the change in fertilisation was due to the fertilisation in a form of ammonium nitrate. The enzymatic activity of soil lower than in the soil sampled from the control suggests that in those soils there exist factors inhibiting the activity of enzymes and that unbalanced mineral fertilisers can inhibit enzymatic reactions. The present results confirm the hypothesis that FYM is a fertiliser especially active when applied jointly with mineral fertilisers.

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EFFECT OF SPRINKLING IRRIGATION AND VARIED NITROGEN FERTILISATION OF MILLET ON OCCURRENCE OF INSECTS

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Area of millet crops in the world over 2001-2004 was 35.8 million ha, which accounted for 5.3% area of cereals and 2.5% area of arable lands (Żarski 2006). At the same time in Poland, the area of millet and buckwheat crops amounted to only 53 thousand ha (0.6% area of cereals and 0.4% area of arable lands). Millet is distinguished from other cereals by economical water relations. Good water supply during stem elongation and panicle emergence determines appropriate yielding (Songin 2003; Rolbiecki et al. 2008). Millet is used as a component of protein feeds for poultry and mostly for production of millet groats.

In Poland there is not much information regarding the fauna of insects on millet plants. There is more of it, however, in the countries where this plant is intensively cultivated. Major pests feeding on plants of the subfamily *Panicoideae* include: *Heteroptera* (*Blissus leucopterus leucopterus* Say – *Lygaeidae*), which does serious damage in the southern states of the USA (Kennedy 2002); *Aphididae* of the genera: *Rhopalosiphum*, *Schizaphis*, *Sitobion* in India (Ahmad and Rajendra 1997); genus *Schizaphis* in Pakistan (Akhtar and Hashmi 1994); *Cicadellidae*, *Delphacidae*, *Miridae*, *Pyralidae* and *Chrysomelidae* in Japan (Chiba et al. 1999); *Melanophis sacchari* (Zehntner) (*Homoptera*: *Aphididae*) – an important pest of these plants practically all over the world (Singh et al. 2004).

The aim of this research was to estimate the effect of sprinkled irrigation and differentiated nitrogen fertilisation on the insect occurrence on millet cv. 'Jagna' cultivated on soil of the weak rye complex, in a region with very low precipitation during the growing period.

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Materials and methods

A strict field experiment was carried out over 2005-2006 at Kruszyn Krajeński near Bydgoszcz on the soil classified as quality class V (the weak rye complex). The experiment was established as a two-factorial, in the dependent split-plot design in three replications.

The first-order factor was sprinkling irrigation applied in two variants: K – without sprinkling irrigation (the control), W – sprinkling irrigation based on readings of tensiometres (a decrease of water potential in soil below -0,03 MPa was not allowed). The second-order factor was varied nitrogen fertilisation: N_0 = 0 kg N·ha^{-1}, N_1 = 40 kg N·ha^{-1}, N_2 = 80 kg N·ha^{-1}, N_3 = 120 kg N·ha^{-1}. Phosphorus and potassium fertilisation, applied on the basis of soil fertility, was uniform on all plots.

The subject of this study were insects which were caught with an entomological net three times in successive growing seasons, in July and August. In each of four replications of the treatment with an area of 9.6 m^2 (12 plants) five sweeps were made with an entomological sweep net. The results presented were expressed in individuals per plot. Noxious and beneficial fauna of insects was determined by means of the keys by Cmoluchowa (1978), Korcz (1994), Nowacka (1996), Zawirska (1994). Statistical evaluation were made using an analysis of variance and Tukey's tests.

Due to their small number, insects of the orders: *Coleoptera*, *Diptera*, *Hymenoptera*, *Lepidoptera*, *Neuroptera*, *Orthoptera* were not discussed in details in this study.

The mean air temperature over the growing period (May-August) in the years 2005-2006 was 16.4°C (Fig. 1). The first year of research was characterized by low temperature during millet growing season (15.7°C), whereas the other was warmer (17.1°C). The average total rainfall from May to August in the years 2005-2006 amounted to 195 mm. Seasonal doses of sprinkling irrigation depended on the amount and frequency of precipitation, with an average of 125 mm. Greater amounts of water (155 mm) were sprinkled in the first year of study, which was characterized by less precipitation and smaller (95 mm) in the more humid year 2006. A single dose was usually 20 mm, smaller doses were applied in the cases when tensiometers indicated the necessity of sprinkling irrigation before approaching natural rainfalls.

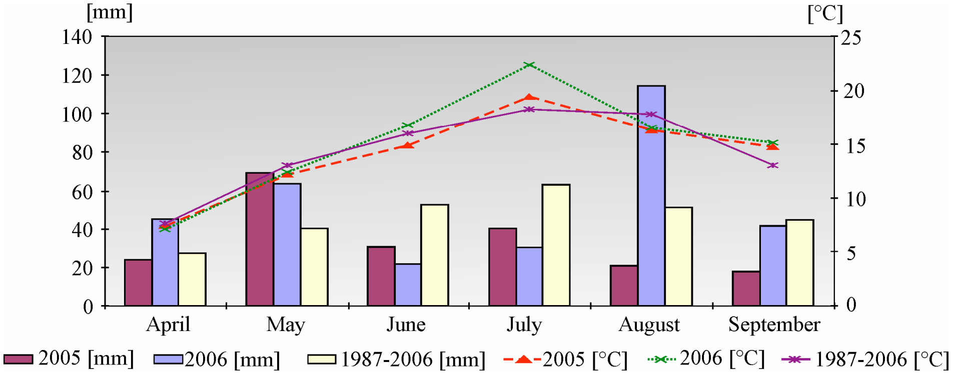
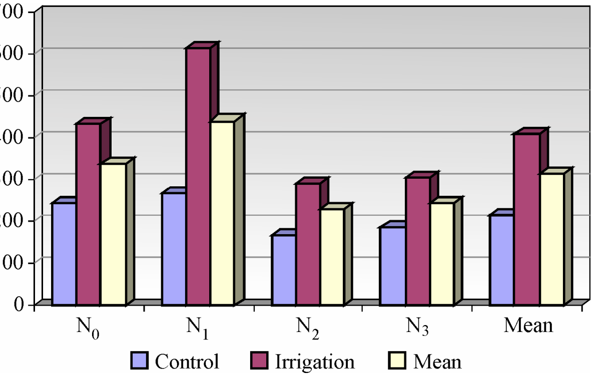


Fig. 1. Precipitation [mm] and temperature [^{o}C] at Kruszyn Krajeński in 2005 and 2006

Results and discussion

Millet plants of cv. 'Jagna' were inhabited by numerous insects during the growing season (Fig. 2). On average, more than 313 individuals were collected from each of the experimental treatments. The statistic analysis of the results obtained indicated that they prefer irrigated plants (409.96 individuals per plot), as compared with those not irrigated (216.65 individuals per plot). Nitrogen fertilisation is also a factor which differentiates their count. Definitely the most of them occurred on plants with a lower level of nitrogen fertilisation (N_1 = 439.78 individuals per plot). Plant fertilisation with higher rates (N_2 = 229.39 and N_3 = 245.14 individuals per plot, respectively) made definitely the least favourable conditions for their living.



$LSD_{0.05}$ I 15.58 II 29.88 II in I 42.25 I in II 30.02

Fig. 2. Effect of irrigation (I) and nitrogen fertilisation (II) on insects occurrence on millet cv. 'Jagna' plants [individuals per plot]

Insects that inhabit millet plants in the greatest number included *Thysanoptera* (Table 1). On average, more than 200 individuals per plot were caught, which accounted for 64.7% of the insect fauna. Their count was affected both by irrigation and varied nitrogen fertilisation. Significantly fewer of these insects were caught on plots without irrigation applied. The analysis of the effect of fertilisation on plant inhabiting by *Thysanoptera* indicated that definitely the least of them occurred in the combination where higher fertilisation levels were applied (N_2 and N_3). The fauna of *Thysanoptera* comprised both the phytophagic *Thripidae* and *Phlaeothripidae* and the beneficial *Aelothripidae*. *Phlaeothripidae* predominated on millet plants (74.87%). Their number were affected both by applying sprinkling irrigation and diversified nitrogen fertilisation. Significantly fewer individuals of those insects were caught on plots without irrigation. The analysis of the effect of fertilisation on the density of *Phlaeothripideae* indicated that considerably the fewest of them occurred in the combination where a high fertilisation level was applied (N_2 and N_3). Among the *Thysanoptera* fauna, beneficial *Aelothripidae*, were also distinguished; their proportion amounted to 2%. A greater number of the insects occurred on non-irrigated plants, as compared with those irrigated, whereas diversified nitrogen fertilisation did not have an effect on their count.

Table 1. Effect of irrigation and nitrogen fertilisation on *Thysanoptera* occurrence on millet cv. 'Jagna' plants [individuals per plot]; K – without sprinkling irrigation (the control), W – sprinkling irrigation, N_0 – 0 kg N·ha^{-1}, N_1 – 40 kg N·ha^{-1}, N_2 – 80 kg N·ha^{-1}, N_3 – 120 kg N·ha^{-1}

Irrigation (I)	Fertilisation (II)				
	N_0	N_1	N_2	N_3	Mean
Thripidae					
K	10.39	15.72	24.33	18.39	17.21
W	8.89	17.28	12.05	19.00	14.31
Mean	9.64	16.50	18.19	18.69	15.76
$LSD_{0.05}$	I 1.46	II 2.06	II in I 2.91	I in II 1.96	
Phlaeothripidae					
K	100.95	113.83	35.83	50.00	75.15
W	254.17	413.28	128.94	117.05	228.36
Mean	177.56	263.56	82.39	83.53	151.76
$LSD_{0.05}$	I 25.71	II 20.95	II in I 29.63	I in II 23.11	
Aelothripidae					
K	5.22	5.89	4.05	5.33	5.13
W	2.95	2.61	2.61	3.67	2.96
Mean	4.09	4.25	3.33	4.50	4.04
$LSD_{0.05}$	I 1.66	II 1.17	II in I 1.65	I in II 1.40	
Larvae *Thysanoptera*					
K	25.03	20.94	21.55	26.72	23.56
W	40.17	55.72	23.83	35.28	38.75
Mean	32.59	38.33	22.69	31.00	31.15
$LSD_{0.05}$	I 6.88	II 4.06	II in I 5.74	I in II 5.47	
Thysanoptera					
K	141.55	156.39	85.78	100.44	121.04
W	306.17	488.89	167.44	175.00	284.37
Mean	223.86	322.64	126.61	137.72	202.71
$LSD_{0.05}$	I 34.11	II 23.74	II in I 33.57	I in II 28.51	

The vast majority of *Thysanoptera* are phytophages of agricultural crops. As a result of their feeding, silver and white spots appear on shoots, which leads to wilting and withering of plants. Moreover, sucking juices from still soft grains results in a reduction of their mass. The feeding fauna of *Thysanoptera* can also cause white ear of grasses (Miętkiewski et al. 1984; Kukowski 1986; Jaworska et al. 1998). They constitute an important part of noxious fauna of many monocotyledonous plants. The count of those insects is to vast degree dependent on the weather conditions (Władyko and Żurańska 1991). The fauna of *Thysanoptera* on monocotyledonous plants is represented by species of the families: *Thripidae* and *Phlaeothripidae,* which are plant pests of great economic importance (Zawirska 1994; Lamparski and Szczepanek 2008).

The insects of *Homoptera* occurred on millet plants in large intensity (Table 2). On average, more than 70 individuals per plot are caught, which accounted for 22.5% of the whole tested fauna of insects. The use of irrigation did not have an effect on their count.

Table 2. Effect of irrigation and nitrogen fertilisation on *Homoptera* occurrence on millet cv. 'Jagna' plants [individuals per plot]. For explanations, see Table 1

Irrigation (I)	Fertilisation (II)				
	N_0	N_1	N_2	N_3	Mean
			Psammotettix alienus Dahlbom		
K	14.22	18.44	15.77	14.17	15.65
W	9.28	12.56	7.28	9.89	9.75
Mean	11.75	15.50	11.53	12.03	12.70
$LSD_{0.05}$	I 2.44	II 2.94	II in I 4.15	I in II 2.86	
			Macrosteles laevis Ribaut		
K	9.67	13.95	7.06	11.72	10.60
W	14.78	14.00	16.28	11.22	14.07
Mean	12.22	13.97	11.67	11.47	12.33
$LSD_{0.05}$	I 4.30	II 2.06	II in I 2.92	I in II 3.38	
			Empoasca pteridis Dahlbom		
K	8.61	9.83	5.78	8.45	8.17
W	8.61	8.33	5.56	8.89	7.85
Mean	8.61	9.08	5.67	8.67	8.01
$LSD_{0.05}$	I 2.64	II 2.49	II in I 3.52	I in II 2.59	
			Larvae *Cicadellidae*		
K	11.50	15.83	9.61	5.95	10.72
W	4.89	6.61	4.50	4.89	5.22
Mean	8.19	11.22	7.06	5.42	7.97
$LSD_{0.05}$	I 2.10	II 2.98	II in I 4.18	I in II 2.81	
			Cicadellidae		
K	44.00	58.28	38.22	40.39	45.22
W	38.83	42.39	34.95	36.67	38.21
Mean	41.42	50.33	36.59	38.53	41.72
$LSD_{0.05}$	I 9.63	II 7.18	II in I 10.15	I in II 8.27	
			Sitobion avenae (F.) H.R.L.		
K	10.94	5.28	5.94	4.61	6.69
W	7.72	7.94	12.22	13.00	10.22
Mean	9.33	6.61	9.08	8.81	8.46
$LSD_{0.05}$	I 1.58	II 2.70	II in I 3.83	I in II 2.52	
			Rhopalosiphum padi L.		
K	4.33	4.67	8.06	6.83	5.97
W	2.11	1.28	5.50	4.50	3.35
Mean	3.22	2.97	6.78	5.67	4.66
$LSD_{0.05}$	I 5.09 I	I 2.20	II in I 3.11	I in II 3.84	
			Metopolophium dirhodum Walk.		
K	0.56	1.22	0.39	1.22	0.85
W	1.39	1.83	2.00	2.78	2.00
Mean	0.97	1.53	1.19	2.00	1.42
$LSD_{0.05}$	I 1.45	II 0.67	II in I 0.94	I in II 1.12	
			Aphididae		
K	15.83	11.33	14.39	12.67	13.56
W	11.22	11.05	19.72	20.28	15.57
Mean	13.53	11.19	17.06	16.47	14.56
$LSD_{0.05}$	I 2.57	II 3.80	II in I 5.37	I in II 3.59	

			Calligypona pellucida (F.)		
K	11.22	9.67	7.33	8.61	9.21
W	9.89	10.78	6.00	10.00	9.17
Mean	10.56	10.22	6.67	9.31	9.19
$LSD_{0.05}$	I 1.84	II 1.85	II in I 2.61	I in II 1.89	
			Larvae *Delphacidae*		
K	0.00	6.85	1.02	1.17	2.26
W	8.12	4.89	4.22	6.88	6.03
Mean	4.06	5.87	2.62	4.03	4.15
$LSD_{0.05}$	I 1.25	II 1.85	II in I 1.61	I in II 1.14	
			Delphacidae		
K	11.22	16.83	8.50	10.17	11.68
W	18.39	16.10	10.56	18.17	15.93
Mean	14.80	16.72	9.53	14.17	13.81
$LSD_{0.05}$	I 1.77	II 2.47	II in I 3.49	I in II 2.35	
			Psyllodea		
K	0.11	0.00	0.44	0.22	0.20
W	0.44	0.67	0.39	0.50	0.50
Mean	0.28	0.33	0.42	0.36	0.35
$LSD_{0.05}$	I 0.37	II 0.28	II in I 0.39	I in II 0.32	
			Homoptera		
K	71.17	86.45	61.56	63.44	70.65
W	68.89	70.72	65.61	75.72	70.24
Mean	70.03	78.59	63.59	69.58	70.45
$LSD_{0.05}$	I 11.57	II 10.82	II in I 15.30	I in II 11.35	

The analysis of the effect of varied nitrogen fertilisation on the density of those insects indicated that definitely fewest of them occurred in the combination where a higher fertilisation level was applied (respectively, N_2 = 63.59 and N_3 = 69.58 individuals per plot). The fauna of *Homoptera* consisted of insects of the families *Cicadellidae* (59.22% proportion), *Aphidiae* (20.67% proportion) and *Delphacidae* (19.60% proportion). The count of *Cicadellidae* was affected only by varied nitrogen fertilisation. Significantly the most of those insects were found on plants fertilized with the lower rate (N_1 = 50.33 individuals per plot). The insects which were caught most often of *Cicadellidae* were *Psammotettix alienus* Dahlbom, *Macrosteles laevis* Ribaut and *Empoasca pteridis* Dalbom. Irrigation of millet plants had no effect on the 3 above mentioned species of insects (except for *P. alienus*, which occurred in a greater number on non-irrigated plants). Fewer Aphididae, as compared with the family Cicadellidae, fed on millet plants (14.56 individuals per plot). Only varied nitrogen fertilisation had an effect on their count. The fewest of those insects were found on plants fertilized with lower rates of nitrogen. The most frequently caught of *Aphididae* were the following insects: *Sitobion avenae* (F.) H.R.L., *Rhopalosiphum padi* L., and *Metopolophium dirhodum* Walk. Irrigation of millet plants had no effect on the 3 above mentioned species of insects (except for *S. avenae*, which occurred in a greater number on irrigated plants). A comparable count of *Delphacidae* in relation to the family *Cicadellidae*, was observed (13.81 individuals per plot). Their number was determined both by irrigation and varied nitrogen fertilisation. The fewest insects were found on plants fertilized with the lower nitrogen rate (N_1 = 9.53 individuals per plot). They preferred irrigated plants.

Homoptera are rated among the major pests of monocotyledonous plants. Their larvae and adult insects prick leaves and suck out juices. Yellowish or reddish spots appear in these places, and leaves curl (Müller 1976; Prestidge 1989; Miczulski 1994; Nowacka 1996). The major representatives of this order are *Cicadellidae*, which belong to stenothermic species, hence their greater numbers and related harmfulness is more noticeable in dry years with high temperatures (Nowacka 1996). Leszczyński et al. (1987) and Żurańska et al. (1994) report that cereals and seed grasses are most frequently inhabited by *S. avenae*, which until the stage of inflorescence emergence inhabits mostly flag leaves, and the maximum of its infestation falls on the milk-ripe stage. *R. padi*, inhabiting mostly bottom leaves, flag leaf, and stems, occurs in fewer numbers and the maximal count of the species occurs in the period of inflorescence emergence and flowering. Żurańska et al. (1994) confirms that the weather conditions had the greatest effect on the occurrence of these pets, particularly at the beginning of the growing season.

Also *Heteroptera* occurred on plants of millet in a considerable number (Table 3). On average, more than 32 individuals were caught per plot, which accounted for 10.34% of the whole fauna of insects tested. Their count was determined by the application of irrigation and varying nitrogen fertilisation. The analysis of density of these insects on millet indicated that they definitely preferred irrigated and unfertilized plants. The fauna of *Heteroptera* consisted of insects of the families *Miridae* (75.33%), *Rhopalidae* (1.05%), *Pentatomidae* (1.02%) and *Coreidae* (0.19%) as well as the beneficial: *Anthocoridae* (18,03%) and *Nabidae* (4,17%). The number of *Miridae* was determined only by applying irrigation in millet growing. Significantly the most of those insects were found on irrigated plants (34 individuals per plot). The insects of *Miridae* which were caught the most often were *Lygus rugulipennis* Popp. and *Trigonotylus coelestialium* Kirk. A considerable number of *Anthocoridae* was observed. Their occurrence was affected by a large number of small insects they feed on, as well as by irrigation of millet plants and varied nitrogen fertilisation. The most of those beneficial *Heteroptera* were observed when the plants were only irrigated and nitrogen fertilisation was not applied.

Heteroptera insects are common throughout Poland (Korcz 1994). Both their larvae and adult insects damage many species of agricultural crops (Miczulski 1994; Lamparski et al. 2007; 2008). In places of pricks tissue dies out and plants are deformed, shrivelled and bent (Korcz 1989; 1994; Soika and Łabanowski 1990). According to Korcz (1994), feeding of these insects from the inflorescence emergence stage may lead to withering of fescue leaves. *L. rugulipennis* (*Miridae*) is an important polyphagous species, which winters on perennial legumes, in July 2-generation imago flies on plants of the gourd family, and particularly willingly on cucumber plants (Robak and Wiech 1998). Lamparski et al. (2008) mention this species as definitely the most numerous on marrow plants. Sucking out of different plant parts by plant bugs, particularly of flowers and leaves, results in their withering and falling of infested plant organs (Bilewicz-Pawińska 1965; Ciepielewska and Kordan 1990; Korcz 1994; Zawirska 1994; Paradowska and Korcz 2000). Hannunen and Ekbom (2001) report that the pest begins feeding in the period of monocotyledonous plant inflorescence emergence.

Table 3. Effect of irrigation and nitrogen fertilisation on *Heteroptera* occurrence on millet cv. 'Jagna' plants [individuals per plot]. For explanations, see Table 1

Irrigation (I)	Fertilisation (II)				
	N_0	N_1	N_2	N_3	Mean
			Lygus rugulipennis Popp.		
K	7.28	5.78	3.50	5.61	5.54
W	23.33	23.33	27.33	29.72	25.93
Mean	15.31	14.56	15.42	17.67	15.74
$LSD_{0.05}$	I 2.28	II 3.04	II in I 4.30	I in II 2.92	
			Trigonotylus coelestialium Kirk.		
K	9.50	7.83	7.78	6.00	7.78
W	6.78	5.28	6.05	6.22	6.08
Mean	8.14	6.56	6.92	6.11	6.93
$LSD_{0.05}$	I 1.78	II 1.46	II in I 2.07	I in II 1.61	
			Miridae		
K	17.44	14.56	13.44	13.72	14.79
W	31.44	31.56	35.50	37.50	34.00
Mean	24.44	23.06	24.47	25.61	24.40
$LSD_{0.05}$	I 0.95	II 3.30	II in I 4.71	I in II 3.01	
			Pentatomidae		
K	1.39	0.11	0.00	0.00	0.38
W	0.44	0.06	0.55	0.11	0.29
Mean	0.92	0.09	0.28	0.06	0.33
$LSD_{0.05}$	I 0.10	II 0.33	II in I 0.47	I in II 0.30	
			Coreidae		
K	0.11	0.00	0.00	0.11	0.06
W	0.00	0.00	0.17	0.11	0.07
Mean	0.06	0.00	0.08	0.11	0.06
$LSD_{0.05}$	I 0.12	II 0.14	II in I 0.19	I in II 0.13	
			Rhopalidae		
K	0.17	0.45	0.22	0.39	0.31
W	0.83	0.67	0.00	0.00	0.38
Mean	0.50	0.56	0.11	0.19	0.34
$LSD_{0.05}$	I 0.26	II 0.42	II in I 0.59	I in II 0.39	
			Anthocoridae		
K	7.95	3.83	2.94	3.78	4.63
W	8.28	9.11	5.44	5.39	7.06
Mean	8.11	6.47	4.19	4.58	5.84
$LSD_{0.05}$	I 1.23	II 1.60	II in I 2.27	I in II 1.54	
			Nabidae		
K	2.16	1.05	1.33	0.22	1.19
W	1.61	1.39	1.89	1.11	1.50
Mean	1.89	1.22	1.61	0.67	1.35
$LSD_{0.05}$	I 0.50	II 0.48	II in I 0.68	I in II 0.50	
			Heteroptera		
K	29.33	20.00	18.00	18.33	21.42
W	42.89	42.78	43.56	44.22	43.36
Mean	36.11	31.39	30.78	31.28	32.39
$LSD_{0.05}$	I 1.11	II 4.17	II in I 5.90	I in II 3.76	

Heteroptera also include numerous predatory insects, such as: Nabidae and *Anthocoridae*, which are important representatives of beneficial fauna of insects occurring on many agricultural crops (Zawirska 1994; Pankanik-Franczyk and Bilewicz-Pawińska 2000; Lamparski et al. 2008).

Conclusions

1. Irrigation of millet cv. 'Jagna' plants causes an increased occurrence of the fauna of *Heteroptera* and *Thysanoptera*. It does not have an effect on the count of insects of the order *Homoptera*.
2. Insects of the order *Thysanoptera* inhabit millet plants in the greatest number and *Phlaeothripidae* are phytophagic dominants. They prefer irrigated plants with a low level of nitrogen fertilisation.
3. The fauna of *Homoptera*, including *Cicadellidae*, more readily inhabit plants with a low level of nitrogen fertilisation and millet plant irrigation does not differentiate their count. *Psammotettix alienus* Dahlbom, *Macrosteles laevis* and *Empoasca pteridis* are the insects belonging to the family *Cicadellidae* that occur in the largest numbers on millet plants.
4. Beneficial insects such as *Anthocoridae*, *Aelothripidae* and *Nabidae* account for several per cent of the whole fauna of insects inhabiting millet.

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MOLECULAR IDENTIFICATION OF *Fusarium sambucinum* IN DRY ROTTEN POTATO TUBERS AND ITS POTENTIAL ABILITY TO PRODUCE TRICHOTHECENES

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The genus *Fusarium* was described by Link in 1809 (Kwaśna et al. 1991). Since then many times and with a varied effect attempts have been made to classify it. The difficulties have originated from a similarity of morphological characters of respective species and, at the same time, the same species derived from different regions and growing in different conditions could have differed morphologically (Leslie et al. 2001; Moss and Thrane 2004).

In traditional methods the identification of *Fusarium* genus fungi is mainly based on morphological characters, mostly the microscopic ones. The presence of macro- and microconidia, their size, shape, way of formation, kind of conidiogenic cells and the presence, size and shape of chlamydospores are studied. Also macroscopic characteristics such as the colony growth rate in specific conditions, their colour and look are helpful (Kwaśna et al. 1991). The taxonomy of *Fusarium* genus fungi was published for the first time at the beginning of the 20th century. In 1935, Wollenweber and Reinking described 65 *Fusarium* species, which served as a springboard for a further development of taxonomic systems in which fungi of this genus have been classified in 9 to 90 species (Wollenweber and Reinking 1935). The diversity of the taxonomies created and using different taxonomic keys result in much confusion. Fungi of a given species can be classified as different species and the other way around.

Misunderstandings concern also the nomenclature. The name of a given species can have a few synonyms, e.g. *F. sambucinum* Fuckel being referred to as: *F. sulphureum* Schlecht, *F. trichothecioides* Wollenw., *F. tuberivorum* Wilcox et Link, *F. bactridioides* Wollenw., *F. roseum* Link emend. Snyd. et Hans '*Sambucinum*', or *F. roseum* Link emend. Snyd. et Hans. var. *sambucinum* (Fuckel) Snyd. et Hans. (Kwaśna et al. 1991).

A high diversity of *Fusarium* genus fungi and the confusion caused by the keys used to identify them can result in identification errors when traditional methods are applied. The development of molecular biology techniques has offered possibilities of an adequate fungal species determination, based on the methods where the credibility of results is not doubtful. The classification involves investigating the DNA sequence with the polymerase chain reaction (PCR) as well as investigating proteins and extracts of enzymes using electrophoresis (O'Donnell et al. 1998).

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Fusarium spp. causing dry rot in potato tubers

The species isolated from dry rotting potato tubers cover mostly: *F. sambucinum* (*F. sulphureum*), *F. solani* (*F. coeruleum*), *F. oxysporum*, *F. avenaceum*, *F. culmorum*, *F. equiseti*. In different parts of the world the number of isolates identified of respective species and their pathogenicity towards potato varies and thus it is difficult to provide the final identification which one is the main cause of the disease. At the same time one shall note that tuber rot caused only by a single pathogen occurs very rarely; tubers get rotten as a result of mixed infections (Boyd and Ticle 1972; Latus-Ziętkiewicz 1993).

In Poland, *F. sambucinum* (*F. sulphureum*) is considered to be the main cause of this disease, followed by *F. solani* (*F. coeruleum*; Wojciechowska-Kot et al. 1983; Kapsa 1993; Kurzawińska 1995). Potato tuber infection with *Fusarium* genus fungi is a secondary phenomenon. The primary factor is the damage of the peel in a form of open wounds, bumps, scratches, microscopic fractures of the peel or is an effect of infection of tubers with other fungi and fungus-like organisms (*Phoma exigua*, *Alternaria* spp., *Colletotrichum coccodes*, *Phytophthora infestans*), *Actinomycetales* (*Streptomyces* spp.) or bacteria. Soil is the main source of infection. During disease development inside the rotting tuber tissues there emerge cavities the walls of which are covered with mycelium. Tubers lose water, shrink and dry. At the final stage of dry rot, the so-called 'mummy' is created. *Fusarium* genus fungi cause losses mainly during storage and the extent of losses in some conditions can reach even up to a few dozen percent (Sadowski 2006).

The harmfulness of *Fusarium* genus fungi involves not only a decrease in yield and the quality deterioration but also the production of mycotoxins, toxic for humans, animals and plants.

Toxigenicity of *Fusarium* genus fungi

Mycotoxins are secondary metabolites produced by many filamentous fungi which show the toxic effect towards living organisms. Today, about 400 compounds referred to as mycotoxins are known (Bennett and Klich 2003). The most important ones include: aflatoxins, fumonisins, ochratoxin, trichothecenes, and zearalenone. They are produced mainly by fungi representing three genera: *Aspergillus*, *Penicillium*, and *Fusarium*. The first two are responsible for changes which occur in foods over drying and storage, whereas *Fusarium* spp. can produce toxins both during plant vegetation and after the plant harvest (Sweeney and Dobson 1999).

Fusarium genus fungi produce mycotoxins often referred to as fusariotoxins. They constitute a numerous group of compounds varied in chemical structure and of a wide effect spectrum, represented by trichothecenes, fumonisins, zearalenone and its derivatives, moniliformin. The most important group of fusariotoxins, of about 170 compounds, is made up by trichothecenes (Krska et al. 2001). Due to their chemical structure, they have been divided into four groups: A, B, C, and D. The most numerous one, including the most toxic metabolites, is A group, which, in turn, includes i.a. toxin T-2, toxin HT-2, diacetoxyscirpenol (DAS), monoacetoxyscirpenol (MAS), and neosolaniol (NEO). The trichothecenes can be produced by *Fusarium sambucinum*, *F. culmorum*, *F. avenaceum*, *F. poae*, *F. sporotrichioides* and *F. solani*. Group B includes e.g. deoxynivalenol (DON), 3-acetyldeoxynivalenol (3AcDON), 15-acetyldeoxynivalenol (15AcDON) and nivalenol (NIV), and they can be mostly produced by *F. graminearum*, *F. culmorum*, *F. cerealis* and, according to some researchers, by *F. sambucinum* and *F. solani*. So far *Fusarium* spp. have not been observed to produce mycotoxins representing groups C and D.

Mycotoxins can enter the human or animal body through the alimentary canal, inhalation or through the skin. Lower doses accumulate in tissues and initially they do not show their effect. However, one shall stress that in the case of strongly toxic mycotoxins, already little amounts can cause disturbances in the process of metabolism of proteins, carbohydrates or fats. An essential character which distinguishes trichothecenes from other mycotoxins is the fact that they do not require activation; they are poisons as such. Besides, the way of penetrating into the body, sex or animal species neither limit nor change their toxicity (Grzybowski and Baranowski 2003).

Contaminated feed consumed by animals can cause poisoning referred to as fusariotoxicoses. The most frequent symptoms are vomiting, loss of appetite, skin inflammation, blood effusion and haemorrhages, bone marrow damage and anaemia. Potato infected by *F. sambucinum* poses a potential threat to the health status of animals fed with it (Desjardins and Plattner 1989). It is well known that lower quality potatoes, also with rot symptoms, are fed to farm animals, especially pigs, especially sensitive to the effect of trichothecenes. Their unfavourable effect on growth and development of piglets as well as a negative effect on the immunological system and vascular systems was observed. In the tissues of animals fed with contaminated feed an accumulation of toxins which can then reach the consumer in a form of contaminated meat is observed (Rotter et al. 1992; Rafai et al. 1995).

Materials and methods

The research carried out at the Department of Phytopathology of the University of Technology and Life Sciences in Bydgoszcz using the PCR method involved verifying the potential capacity for producing trichothecenes in *F. sambucinum*, one of the main causes of dry rot in potato tubers.

DNA isolation

The first stage of research involved obtaining single-spore cultures. The fungal isolates were transferred onto Petri dishes with the selective nutrient agar (SNA) medium and placed in the thermostat at 20°C. After 10 days of incubation, from the sporulating mycelium smear was made on the dishes with 2% aqueous agar, and after 17-20 hours, with the help of a microscope, using the preparation needle, single sprouting spores were cut out, which were then transferred onto slants with solidified potato-dextrose agar (PDA) medium and placed at 20°C.

The next preparation stage involved multiplication of the material for DNA isolation. To do so, the single-spore cultures produced were transferred onto Petri dishes with solidified PDA medium and incubated for 4-5 days at 20°C. From the marginal part of the grown mycelium four discs of 5 mm in diameter were sampled and transferred to 250 ml Erlenmayer flask with 60 ml potato-dextrose (PD) liquid medium. Flasks prepared in such a way were shaken (150 rotations$\cdot$min^{-1}) for 5-6 days at the room temperature using the rotary shaker. Total DNA was extracted using modified protocol of Doyle and Doyle (1990). DNA concentration was measured with spectrophotometer, diluted to final concentration of 100 ng$\cdot\mu$l^{-1} and kept in the freezer (-30°C).

Confirming the species identification of the *F. sambucinum* isolates researched and defining their potential mycotoxicity involved the use of polymerase chain reaction (PCR). To do so, using the *Taq* PCR Core Kit provided by Qiagen, (US), a mixture was prepared composed of (amounts per reaction): 3.9 µl H_2O miliQ, 2.5 µl solution Q, 1.25 µl buffer 10x, 0.5 µl $MgCl_2$, 0.25 µl dNTP, 0.75 µl Primer I, 0.75 µl Primer II, 0.1 µl Polymerase Taq, 2.5 µl DNA. The research involved the use of pairs of specific SCAR primers (Table 1); identification of *F. sambucinum* was performed according Mishra et al. (2003), potential capacity for the production of trichothecenes according to Edwards et al. (2001), and chemotype DON and/or NIV according to Chandler et al. (2003).

Table 1. Primers used in PCR assays

Test	Primer	Sequence (5' – 3')
F. sambucinum	FSF1	5'-ACATACCTTTATGTTGCCTCG-3'
	FSR1	GGAGTGTCAGACGACAGCT
*Tri*5	HA*Tri*/F	CAGATGGAGAACTGGATGGT
	HA*Tri*/R	GCACAAGTGCCACGTGAC
*Tri*13DON	*Tri*13F	5'-CATCATGAGACTACTTGTAGTTTGG-3'
	*Tri*13DONR	5'-GCTAGATCGATTGTTGCATTGAG-3'
*Tri*13NIV	*Tri*13NIVF	5'-CCAAATCCGAAAACCGCA-3'
	*Tri*13R	5'-TTGAAAGCTCCAATGTCGTG-3'

PCR (30 cycles) was performed using Biometra Uno II thermocycler according to the parameters of the thermal profile described by Lenc et al. (2008). The products were separated on 1.4% agarose gel in the TBE buffer in the 110V electric field. The images were recorded with the electronic gel documentation system provided by Vilber Lourmat and BioCapt software.

Results and discussion

Molecular identification of *F. sambucinum* isolates

The research was carried out using 16 single-spore isolates obtained from dry rotting potato tubers. The origin of the fungi is given in Table 2.

The PCR assay demonstrated the presence of the expected amplicon 315 bp in length in 11 out of 16 isolates researched, what classified them as *F. sambucinum* (Fig. 1). The reaction performed again for isolates marked as 28, 29, 31, 32, and 33, giving a negative or doubtful result, confirmed a lack of the expected species-specific product.

Defining the potential capacity for producing trichothecenes in *F. sambucinum*

The research of the potential capacity for producing trichothecenes in 11 formerly positively verified isolates showed the presence of *Tri*5 gene, and thus there was confirmed their potential capacity for the synthesis of mycotoxins of the trichothecenes group (Fig. 2).

Table 2. *F. sambucinum* isolates used for molecular testing of the species classification and potential capacity for producing trichothecenes

No.	Isolate symbol	Cultivar	Location	Province	Growing system
28	F_{SA}-06-08	Zeus	Osiny	Lublin	organic
29	F_{SA}-06-09	Orlik	Osiny	Lublin	organic
30	F_{SA}-06-13	Bartek	Osiny	Lublin	organic
31	F_{SA}-06-20	Korona	Osiny	Lublin	integrated
32	F_{SA}-06-28	Vineta	Zawidz Mały	Masovian	conventional
33	F_{SA}-06-38	Asterix	Mochełek	Kuyavian-Pomeranian	conventional
34	F_{SA}-06-03	Gracja	Osiny	Lublin	organic
35	F_{SA}-06-17	Orlik	Osiny	Lublin	integrated
36	F_{SA}-06-23	Syrena	Osiny	Lublin	integrated
37	F_{SA}-06-02	Drop	Osiny	Lublin	organic
38	F_{SA}-06-25	Bila	Mochełek	Kuyavian-Pomeranian	conventional
39	F_{SA}-06-30	Bryza	Pruszcz Pomorski	Kuyavian-Pomeranian	conventional
40	F_{SA}-06-26	Irga	Iława	Warmian-Masurian	conventional
41	F_{SA}-06-31	Asterix	Radostowo	Pomeranian	conventional
42	F_{SA}-06-27	Bila	Wałdowo	Kuyavian-Pomeranian	conventional
43	F_{SA}-06-37	Gracja	Kruszyn Krajeński	Kuyavian-Pomeranian	conventional

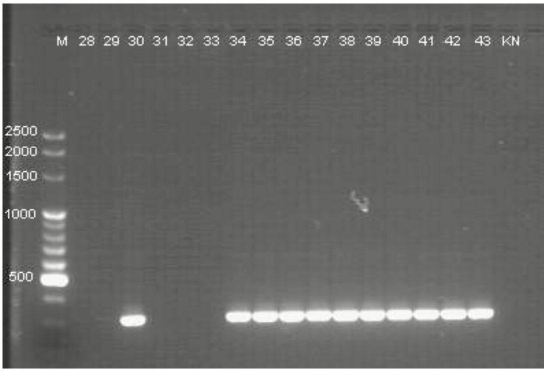

Fig. 1. Confirmation of the species classification of *F. sambucinum* using PCR

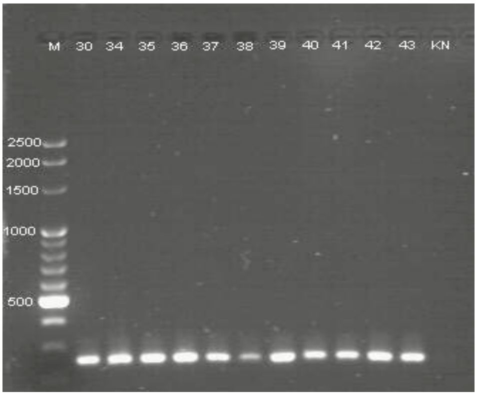

Fig. 2. Molecular analysis of potential capacity for producing trichothecenes by *F. sambucinum*

Further molecular analyses concerning the type of the trichothecenes produced did not show the capacity of this species to produce deoxynivalenol and nivalenol (Figs. 3 and 4).

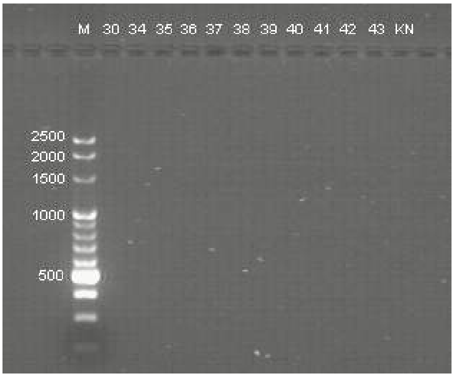

Fig. 3. Molecular analysis of potential capacity for producing DON by *F. sambucinum*

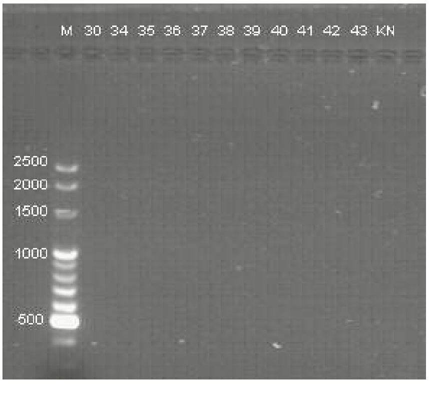

Fig. 4. Molecular analysis of potential capacity for producing NIV by *F. sambucinum*

Analysis of the content of trichothecenes in tubers infected by *Fusarium* spp.

Molecular study of the potential capacity for producing trichothecenes in *F. sambucinum* was supported by the analysis of the content of mycotoxins in artificially inoculated potato tubers with isolates of the fungal species investigated.

The inoculation was performed following the method described by Latus--Ziętkiewicz (1993). The analysis of the content of mycotoxins of the trichothecenes group was performed at the Laboratory of Physiology and Toxicology of the Kazimierz Wielki University in Bydgoszcz using the HPLC-MS/MS method.

No tuber was identified for trichothecenes group B (DON, NIV), however, there were recorded a high concentration of monoacetoxyscirpenol (MAS) and the presence of diacetoxyscirpenol (DAS), trichothecenes representing group A, which confirms the earlier research which involved PCR reactions concerning the potential capacity for producing trichothecenes in *F. sambucinum*. Interestingly, the concentration of mycotoxins does not depend on the size of the rotten potato tuber tissue.

The results of research into the production of mycotoxins by *Fusarium* genus fungi are ambiguous and trigger some doubts. El-Banna et al. (1984) report on *F. solani* var. *coeruleum* and *F. sambucinum* species can produce trichothecenes both of group A (HT-2) and group B (DON, ADON, NIV). Their production, according to the authors, depended on the length and conditions in which potatoes were stored. Desjardins and Plattner (1989) claim that *F. sambucinum* can produce trichothecenes of group A, mainly DAS, at lower amounts MAS, T-2 toxin, neosolaniol. Jeleń et al. (1995) in all the *F. sambucinum* isolates derived from potato identified trichothecenes of group A (DAS, 15-MAS, 4-MAS), however, their content varied depending on the isolate. The authors stress that in *F. sambucinum* isolates derived from other plants no such toxins were identified. Earlier Ripperger et al. (1975) and Steyn et al. (1978) reported on *F. solani* and *F. sambucinum* producing only trichothecenes type A (DAS) and no toxins type B.

In the present research, as part of the present paper, it was demonstrated that all the isolates determined with the mycological keys available and the microscope, represented *F. sambucinum* species. A further study of these isolates, determined only with the traditional methods, could produce incorrect results and conclusions.

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USE OF MOLECULAR TECHNIQUES IN MYCOLOGICAL RESEARCH

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One of the important aspects of phytopathology is working out the methods of the detection and identification of pathogenic factors, which make it possible to limit pathogen expansion (Łojkowska 2001). Classic methods of pathogen identification and characterisation based on the assessment of morphological, physiological, biochemical, and serological traits are often difficult, time-consuming, and ineffective. One may observe constant increase in the interest in modern diagnostic methods based on the application of molecular techniques, whose basis constitutes the analysis of DNA structure (in the case of some techniques – also RNA) as simpler, repeatable, certain, and possible to perform even in the case of small amounts of mycelia (Nicholson et al. 1998; Łojkowska, 2001; Golińska et al. 2002).

Many tools used in diagnostics and studies on the taxonomy of fungi are based on molecular methods, including also fast identification of isolates and mating types, searching for genes of virulence and coding the ability of some fungi to produce secondary metabolites (mycotoxins) that may constitute a serious threat not only for plants, but also for people and animals. They are also commonly used in the studies on inter- and intra-specific genetic variability. In addition, they were applied to the distinction of closely related species, which showed great morphological similarity, and also of pathotypes within a species (Edel 1998; Atkins and Clark 2004; Singh et al. 2006).

Molecular diagnostics of the causal agents of plant diseases is most often based on Polymerase Chain Reaction (PCR), which opened a new chapter in the molecular studies on fungi, including plant pathogens (Atkins and Clark 2004; Irzykowska 2006). Classic PCR reaction consists in specific amplification of a chosen DNA region with the help of short single-stranded oligonucleotydes (primers). Amplification of a DNA fragment occurs *in vitro* and is conditioned by the proper composition of reaction mixture containing: template DNA (double strand DNA or cDNA formed on the base of RNA), enzyme catalyzing the reaction (thermostable polymerase *Taq*), primers, free nucleotide mixture (dNTPs), reaction buffer, magnesium ions, water, and sometimes also other compounds that increase the sensitivity and specifity of the reaction (Czembor 1995; Łojkowska 2001). Numerous methods that use PCR (among others RAPD, AFLP, SCAR), as well as combining this method with restrictive endonucleases application made it possible to study genetic variability within species, sub-species, and even particular races of pathogens (Łojkowska 2001; Virdi and Sachdeva 2005).

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Among many methods applying PCR technique, the leading place in the studies on DNA polymorphism, including pathogens characteristics, is occupied by the analysis of random amplified polymorphic DNA (RAPD; Paran and Michelmore 1993; Bridge and Arora 1998; Łojkowska 2001). This method belongs to the group of MAAP (Multiple Arbitrary Amplicon Profiling) techniques, which make it possible to amplify randomly DNA areas included between complementary primers with both strands of template DNA, whose ends are oriented towards each other (Czembor 1995; Bednarek and Chwedorzewska 2001). RAPD method was developed in order to analyze DNA polymorphism and genetic maps construction (Williams et al. 1990). It is used in research on the diversification within closely related groups of organisms and is particularly useful in the case of fungi that reproduce vegetatively (McDonald 1997; Mehta 2001a). RAPD is a frequently used technique due to simple methodology, rapidity of experiment performance, and almost unlimited potential for generating DNA markers. It does not require any knowledge on the DNA sequence of the studied pathogen because, in the reaction, one randomly chosen primer of the length of circa 10 nucleotides is applied. In template DNA, usually more than one region complementary to the primer's sequence occurs, as a result of which many PCR products of various lengths are amplified. RAPD fragments are usually dominant markers, and the variability detected with their use in the studied population is displayed by the presence or lack of amplification products of a given size. RAPD products in the amount of several to several dozen of DNA fragments are separated in agarose gel. Image detection takes place with the use of fluorescent markers. In effect, a band scheme characteristic for a given genome is obtained (Williams et al. 1990; Williams et al. 1993; Edel 1998; Golińska et al. 2002; Wolko et al. 2004). For statistical results processing, different methods are applied, for example Unweighted Pair Group Method with Arithmetic Mean (UPGMA; Peltonen et al. 1996; Sun et al. 2003; Weber et al. 2005; Irzykowska 2007) or AMOVA (Analysis of Molecular Variance) (Miedaner et al. 2001; Rau et al. 2003), and relationship between the studied isolates are presented in the form of dendrogram, an example of which is shown in Fig. 1, which depicts the degree of intra-specific variability of isolates *Drechslera teres* from years 2006-2007 in research by the Department of Phytopathology from the University of Technology and Life Sciences in Bydgoszcz.

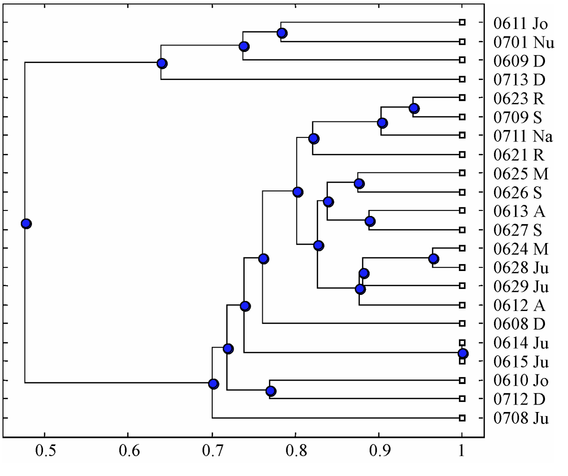

Fig. 1. Dendrogram depicting similarity between 22 isolates of *D. teres*

RAPD technique has many advantages:

- makes it possible to obtain a high level of polymorphism,
- does not require previous information on the sequence of the DNA that undergoes amplification,
- analysis methodology is relatively simple and fast,
- for producing a reaction, a small amount of DNA is sufficient – even nanogram DNA concentration is sufficient for obtaining a PCR product,
- does not require marking with radioactive isotopes,
- the same primers may be used for the analysis of genome structures of many diverse organisms,
- assuming that the access to a thermocycler is not a problem, the method is also relatively cheap,
- may give information making designing primers for the Sequence Characterized Amplified Region (SCAR) method possible (Bridge and Arora 1998; Fordyce and Meldrum 2001; Golińska et al. 2002).

On the other hand, it also has certain limitations, some of which are:

- difficulties in obtaining repeatable results in different laboratories, which is conditioned by factors such as quality and concentration of template DNA and primer oligonucleotides, and also the kind of DNA polymerase and thermocycler used,
- necessity for precise normalisation of the concentration of all components of the reaction mixture due to much higher than conventional PCR analyses sensitivity in relation to reaction conditions and the thermocycler used,
- problems with the interpretation of the obtained RAPD profiles,
- high sensitivity to DNA contamination,
- sensitivity to changes in experiment conditions,
- probability of unspecific binding of DNA with primers with template DNA, which is caused by a low melting temperature of short oligonucleotydes (MacPherson et al. 1993; Edel 1998; Golińska et al. 2002; Vagvölgyi et al. 2004; Irzykowska 2006).

In the studies on fungi pathogenic for plants, RAPD is one of the most frequently used methods (Czembor 1995; McDonald 1997). Particularly many studies have been conducted on those species belonging to kingdoms *Fungi* and *Chromista* that pose the greatest threat for crops, among others genera *Phytophthora*, *Fusarium*, *Pythium*, *Peronospora*, and *Verticillium* (Łojkowska 2001). RAPD technique in the case of pathogenic fungi is used mostly for their identification, detecting genetic variability, establishing similarity, and defining markers related to a particular trait (pathotype, mating type; Amoah et al. 1995; Czembor 1995; Parry and Nicholson 1996; Golińska et al. 2002). Moreover, they are used in the studies on the genetic structure of fungi population (Peever and Milgroom 1994), as well as for the explanation of the molecular bases for the diversified pathogenic abilities of pathogens (Chen et al. 1993; Fischer et al. 1996). These markers were also used for defining the so-called mating populations of genus *Fusarium* from section *Liseola* (Amoah et al. 1995). What is more, they allow defining the possible relations and phylogenetic distances between the studied strains (Łojkowska 2001). However, in relation to pathogenic fungi, the usefulness of the RAPD method for the determination of phylogenetic relationships is limited due to high sensibility of the technique and its sensitivity to changes in experiment conditions (Golińska et al. 2002).

RAPD technique is also applied for designating DNA fragments characteristic for a given species and designing primers specific for this species, basing on the sequence of chosen RAPD products (Łojkowska 2001). Moreover, it is a good tool for designing genetic maps, and it is also an effective method of molecular markers identification (Bridge and Arora 1998; Edel 1998). As stated by Irzykowska (2006), RAPD analysis makes up an effective way of detecting atypical isolates within a given species.

PCR technique is particularly often applied in the studies on the intra-specific variability of pathogenic fungi. Its high degree was found, among others, in the case of *Mycosphaerella graminicola*, causal agent of *Septoria* leaf blotch of wheat (Razavi and Hughes 2004) and *Fusarium oxysporum* f. sp. *ciceri*, pathogen that infects Italian pea (Singh et al. 2006). This technique is also used for studying the populations of many other pathogens of genus *Fusarium*, such as *F. culmorum* (Gargouri et al. 2003), *F. poae* (Kerenyi et al. 1997), *F. avenaceum* (Yli-Mattila et al. 1996; Golińska et al. 2004), *F. graminearum* (Dusabenyagasani et al. 1999; Carter et al. 2000), and *F. oxysporum* (Gordon and Martyn 1997). Schilling et al. (1994, 1996), by amplifying DNA of *Fusarium avenaceum*, *F. culmorum*, *F. graminearum,* and *F. crookwellense* with 120 RAPD primers, as a result of a reaction with one of them, obtained a band scheme specific for isolates of *F. culmorum* and *F. graminearum*, differing those species from one another. Authors, using RAPD markers as well, detected the highest genetic variability within *F. graminearum* isolates. Achenbach et al. (1997) found a low variability level of the isolates of *Fusarium solani* f. sp. *phaseoli,* which infects soybean and causes SDS (Sudden Death Syndrome).

RAPD technique has also been used for the analysis of many other fungi species: *Rhynchosporium secalis* (McDermott et al. 1989; Goodwin et al. 1993), *Sclerotinia sclerotiorum* (Sun et al. 2005), *Drechslera teres* (Krämer and Kopahnke 1997; Frazzon et al. 2002), *Phomopsis* spp. (Król 2002), *Bipolaris sorokiniana* (Fordyce and Meldrum 2001, Baturo et al. 2004), *Stemphylium solani* (Mehta 2001b), and also *Gaeumannomyces graminis* var. *tritici* (Weber et al. 2005) and *Alternaria alternata* (Morris et al. 2000). Variability analysis of *Rhizoctonia cerealis* made it possible to find correlation between RAPD markers and the degree of pathogenicity of the isolates that infect wheat (Irzykowska et al. 2005).

RAPD method has also been applied for the analysis of the relation degree of fungi from genus *Helminthosporium* and its later division into three separate genera: *Bipolaris*, *Drechslera*, and *Exserohilum* (Bakonyi et al. 1995). This technique has also been used for the analysis of the variability of four cereal pathogen species: *Bipolaris sorokiniana*, *B. oryzae*, *B. maydis*, and *Exserohilum turcicum* (Weikert-Oliveira et al. 2002).

RAPD test has been successfully applied for the discrimination of pathogenic and non-pathogenic *Leptosphaeria maculans* isolates (Plummer et al. 1994), and also for the discrimination of *Peronospora parasitica* pathotypes (Tham et al. 1994) and *Cochliobolus carbonum* races (Jones and Dunkle 1993). Czembor and Arseniuk (1996) used RAPD technique in studies aimed at the identification and evaluation of genetic variation between the isolates of three fungi species: *Septoria tritici*, *Stagonospora nodorum,* and *S. avenae* f. sp. *triticea*, which widely infect cereals. McDermot et al. (1994) analysed the genetic structure of *Erysiphe graminis* f. sp. *hordei.*

In the studies conducted at the Department of Phytopathology at the University of Technology and Life Sciences in Bydgoszcz, RAPD technique was applied for the determination of the influence of chosen factors (isolation year, cultivar and organ of the plant from which the isolates came, crop region, crop system – organic, integrated, conventional, and monoculture) on the intra-specific variability of the chosen species of pathogenic fungi – *F. avenaceum*, *F. culmorum*, *D. teres*, and *B. sorokiniana*. No clear relation between the variability level of the fungus and the above stated factors was found (Baturo 2005; Łukanowski 2005). In the case of *F. culmorum*, the majority of isolates that came from the south-east regions of Poland characterised by more dry climate was genetically different from those obtained form the regions with high relative air humidity. This may probably be related to a different selective pressure put in a given region on the pathogen (Irzykowska and Baturo 2008).

A way of increasing the usefulness of unspecific markers of the RAPD type may be their conversion into specific SCAR markers, as a result of sequencing of a chosen RAPD fragment (Paran and Michelmore 1993). Testing a significant number of RAPD markers makes it possible to choose from the generated band scheme only the fragments that are informative for the performed analysis. Result of sequencing of selected band is a basis for designing specific primers that in PCR reaction amplify exclusively that fragment, that is single genetically defined *locus*. Here, a pair of two different primers flanks the sequence, which is searched for in the genome of the studied organisms (Czembor 1995; Hintz et al. 2001). In molecular analysis, with the use of SCAR markers, usually one polymorphic DNA fragment is obtained (Irzykowska 2006).

SCAR method is a fast and relatively inexpensive technique used, among others, for the comparative analysis of the studied organisms. Obtained results make it possible to state whether the sequence that undergoes analysis occurs in all the studied organisms or only in selected ones, and also if amplification products show polymorphism. Specific primers used in SCAR analysis are usually longer (17-24 nucleotides) than the non-specific ones, which are used in the RAPD assay. As a result, the temperatures of their attachment in PCR reaction are higher, due to which the method is more repeatable and less sensitive to the influence of experimental conditions (Golińska et al. 2002). Use of species-specific primers makes it possible to identify the pathogen, often even before the appearance of disease symptoms, directly in the extract from the infected tissues, without the necessity of its isolation (Chen et al. 1993; Parry and Nicholson 1996; Irzykowska 2006). Thanks to SCAR primers, which allow selective copying of sequences that appear only in specific groups of isolates, it is possible to determine or verify the systematic position of the studied fungi.

Analysis of the sequence of copied fragments is significant for defining phylogenetic connections and consequently fungi systematics (Golińska et al. 2002). SCAR markers are useful for the detection of genetic variability and distinction of very closely related organisms, particularly within genotypes localised on the same field, plant, leaf, or colony. Moreover, they make it possible to follow the gene flow and geographic divisions between populations (Czembor 1995).

Another important aim of conducting SCAR analysis is studying the presence of particular genes in given strain populations, which allows the identification of the genetic markers of pathogenicity and toxigenicity (Golińska et al. 2002). An example of this is biosynthesis of trichothecenes catalysed, among others, by trichodiene synthase, an enzyme coded by *Tri*5 gene (Proctor et al. 1995). This gene occurs in all *Fusarium* species that form this group of mycotoxins. Identification of the presence of gene cluster *Tri* in the genome makes it possible to determine potential ability of the fungi of the *Fusarium* genus to produce trichothecenes and to distinguish from them isolates potentially capable of the synthesis of their specific type (chemotypes DON and NIV) (Doohan et al. 1999; Edwards et al. 2001; Chandler et al. 2003; Nicholson et al. 2003; Jennings et al. 2004).

In the studies on the chemotypes of fungi from the *Fusarium* genus, a very important role is played by genes *Tri*7 and *Tri*13. Their functionality enables the conversion of deoxynivalenol (DON) into nivalenol (NIV) or nivalenol into its derivative 4-acetylo-NIV (Lee et al. 2001). As shown by studies, isolates of *F. culmorum,* capable to produce only deoxynivalenol, do not contain *Tri*7 and *Tri*13, or these genes occur in non-functioning forms (Chandler et al. 2003). Gene *Tri*3 that codes acyltransferase is responsible for the production of the acetylated derivatives of deoxynivalenol (McCormick et al. 1996; Jennings et al. 2004). Thanks to the familiarity of the structure of particular genes that take part in trichothecenes biosynthesis, SCAR primers were applied for the identification of the potential capability of fungi of the *Fusarium* genus to produce trichothecenes from groups A and B (Nicholson et al. 2004)

Our Department's studies concerning the potential ability of 80 *F. culmorum* isolates originating from various regions of Poland to produce mycotoxins showed that 77 of them (96.2%) represented chemotype DON, and only 3 chemotype NIV. Within its frame, all isolates showed potential ability to produce only one derivative of this toxin – 3-acetylDON (Łukanowski 2005). This corresponds with the results obtained by Jennings et al. (2004), who found 59% of the isolates of chemotype DON originating from different locations of wheat production in Great Britain. Use of primer pairs *Tri*7 and *Tri*13 allowed determining the diversification of the studied *F. culmorum* population in regard to the chemotypes described above. Presence of the above chemotypes was also confirmed in Germany, the Netherlands, Italy, Norway, and France (Tanaka et al. 1986; Gang et al. 1998; Langseth et al. 1999; Muthomi et al. 2000; Bakan et al. 2001).

In other studies on this topic, conducted in our Department, potential ability of *Fusarium sambucinum* to produce trichothecenes from group A was also confirmed (Lenc 2008; Lenc et al. 2008).

SCAR method is commonly used for the identification of various *Fusarium* species and strains. Specific SCAR primers were used for such species as *F. avenaceum*, *F. poae*, *F. graminearum* (Parry et al. 1995; Schilling et al. 1996; Nicholson et al. 1998; Doohan et al. 1998), *F. moniliforme* and *F. subglutinans* (Möller et al. 1999), *F. sambucinum* (Yoder and Christianson 1998), *F. sporotrichioides* (Kulik et al. 2004; Wilson et al. 2004), *F. graminearum* (Ouellet and Seifert 1993), *F. langsethiae* (Wilson et al. 2004; Lukanowski et al. 2008), or *F. culumorum* (Schilling et al. 1996, Jaroszuk-Ściseł et al. 2008).

SCAR technique is also used for the identification of *Tapesia yallundae* and *T. acuformis* (Nicholson et al. 1997), pathotypes PG1 and PG2 *Verticillium albo-atrum*, (Radisek et al. 2004), studies on the migration and recombination of *Magnaporthe grisea* (Soubabere et al. 2001), and also for the analysis of genetic structure of *Erysiphe graminis* f. sp. *hordei* population (McDermott et al. 1994), or for the distinction of two forms of *D. teres* (*teres* and *maculata*) (Leisova et al. 2005), which was also the subject of studies at the Department of Phytopathology, where the analyses of 41 isolates of *D. teres* obtained in years 2005-2007 showed that all belonged to form *teres*. Moreover, in the present study, the technique was also used for the determination of the belonging of isolates *Rhizoctonia cerealis* to anastomosis groups and for the identification of endophytic fungi in grass seeds, as well as for the correctness confirmation of the identification of species *F. sambucinum*. In this case, SCAR technique proved to be particularly useful because it was shown that 30% of the isolates of the above species were wrongly identified. Further PCR assays showed that they belonged to *F. culmorum* (Lenc 2008; Lenc et al. 2008).

Even a few years ago, the method was considered to be infallible (Schilling et al. 1996; Radisek et al. 2004). However, as the authors' experience with the use of PCR technique show that SCAR markers do not always guarantee obtaining correct results. This has been proven by the studies on the systematic position of 70 isolates of *F. culmorum* identified with standard method with the use of microscope and mycological keys, obtained from potato and various species of cereals, conducted with two pairs of primers of the SCAR type (Schilling et al. 1996; Nicholson et al. 1998) commonly applied for the identification of this species. As a result of a reaction with the first pair of $OPT18F_{470}/OPT18R_{470}$, no product was obtained in the case of several isolates. In order to verify the correctness of such obtained results, another test was carried out with the use of a second pair, Fc01F/Fc01R, and the expected amplification product was obtained. In the case of one isolate, which in reaction with the first primer pair gave a positive result, the expected product was not obtained. This means that, in the genome of the analysed isolates, probably changes took place in the fragments to which primers are attached. This points out to the existence of a certain risk of obtaining falsely negative results. Thus, a negative result of a PCR test should be treated with a dose of carefulness, and in case of doubts, if there is a possibility to do so, it ought to be verified using other primer pairs or, for example, the analysis of Internal Transcribed Spacer (ITS) regions. In practice, this means that in the case of some isolates, the use of one of the primer pairs of the SCAR type does not always allow confirming (determining) systematic position and may lead to faulty conclusions.

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ACTIVITY OF PLANT EXTRACTS IN CONTROLLING THE POPULATION OF COLORADO POTATO BEETLE (*Leptinotarsa decemlineata* Say)

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Beetles and larvae of Colorado potato beetle are the most dangerous agrophages of potato plantations. Every year their count considerably exceeds the threshold of economic harmfulness. In the event of mass occurrence and the lack of protection, the losses may reach even 80% of tuber yield. The damage in over 70% is the work of feeding larvae. Therefore, there is a need for constant crop protection based mostly on the use of chemical agents. However, the long-term application of insecticides, particularly those of the same chemical group, may result in pests becoming resistant which, consequently, causes a decrease in the control effect. Colorado potato beetle has five main, genetically determined mechanisms of resistance: increased metabolism of a biologically active substance, reducing the permeation of a biologically active substance through body covers, decrease in nervous system sensitivity in the area of insecticide action, changes in behaviour (behavioural resistance), and increasing excretion (Malinowski 1991). Within the framework of preventing Colorado potato beetle becoming resistant, Insecticide Resistance Action Committee (IRAC) worked out a strategy aiming at prolonging the pest sensitivity to chemical compounds by avoiding the constant selection pressure with the same factor. Thus protection of potato fields involves constant introduction of new insecticides and parallel activities limiting the possibility of generating resistance. At the same time, safe preparations are introduced in order to protect the natural environment and human health (Pruszyński 1999).

One of the trends realizing these assumptions is based on the application of biologically active substances of plant origin as bioinsecticides or compounds affecting insect behaviour. In the course of evolution, plants defending themlseves from insects have generated diverse defensive mechanisms such as hard covering tissues, hairs on the surface or substances with allelopathic, bacteriocidal or insecticidal effects. These compounds are mostly minor (secondary) plant metabolites – alkaloids, glycosides, phenols, terpenes, saponins, cucurbitacins etc. Quantitative and qualitative composition of those compounds is varied and depends on the plant development stage and on the environmental and climatic conditions (Łakota et al. 1993). Their big advantage is selective activity. They do not kill pests but considerably limit their potential.

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Chemical compounds occurring in plants may cause intensive feeding (attractants and stimulants) and may also have an inhibitory effect on taste receptors, acting as antifeedants, or on smell receptors, having a repellent effect (Benz et al. 1989; Adel et al. 2000; Harmatha 2000). Antifeedants are compounds which act by means of causing changes in insect physiology, i.e. disorders in activities related to choosing the host plant, feeding and laying eggs (Harborne 1997). According to Bernays and Chapman (2000) and Messchendorp et al. (2000), the effect of nutritional deterrents on insects is the outcome of nervous impulses from chemoreceptors (deterrent cells) sensitive to secondary plant metabolites and inhibiting the activity of neurons sensitive to fagostimulants.

Pest feeding is closely related to the species adaptation for taking up the particular food from the given environment. Introducting changes in chemical signals (allomones or kairomones) by means of covering plants with different extracts results in disorders in insects and mites behaviour (Dąbrowski 1974). Plants which were sprayed with water or alcohol plant extracts become less attractive for pests. Due to this, females do not lay eggs on them and larvae or imagines are reluctant to feed on them, which results in the growth stunting of the pest population or reduction in plant damages.

Many plants containing considerablde amounts of active substances grow in tropical and subtropical countries, where they are exposed to pest activities all year round. Also extracts obtained from numerous plants growing in the Central-European climate exhibit an active effect against harmful insects. Herbs are a group of plants whose composition is relatively well known. Compounds contained in them can be a source of natural crop protection preparations, which could constitute the base for production of synthetic compounds. Chances of finding in plants substances that are active against insects are high, since only a few plant substances have been examined so far. Wide research is conducted on the effect of plant products and biologically active chemical compounds isolated from plants on insect development and behaviour. The results of this research can be of special importance in organic agriculture, where preparations obtained by industrial chemical synthesis are not applied. Currently, there is no preparation in Poland, admited for organic agriculture purposes, which controls Colorado potato beetle. Registration of the only biological preparation, based on crystals of the bacteria *Bacillus thuringiensis* ssp. *tenebrionis,* with the trade name Novodor, expired a few years ago. The lack of possiblity of protection of ecological potato crops results in a decrease in its cropping area. In other European countries, the active substance applied for protection in organic agriculture is azadirachtin, showing a very strong antifeedant activity against insects, first isolated in 1968 from the seeds of the neem tree (*Azadirachta indica* A. Juss), of the family *Meliaceae* (Butterworth and Morgan 1968). It is applied under the name "neem" for protection purposes as an insecticide, repellent and antifeedant. It has the ability to control development and reproduction ability. About 400 species of insects and mites are sensitive to its activity (Szczepanik et al. 2000; 2003; Weathersbee and Tan 2002; Pavela and Holy 2003; Surviliene and Raudonis 2003; Kowalska and Hummel 2007). It would be advisable that it could be included in pesticides allowed in Poland as well.

In view of a growing interest in new proecological methods of pest control in the world and in Poland, research is conducted in order to find an alternative to the chemical method for limiting the harmful insect population. In a trial conducted in the Department of Applied Entomology of University of Technology and Life Science in Bydgoszcz for many years, extracts and dry plants have been tested for their effect against Colorado potato beetle, large cabbage white butterfly and pests of stored products. Some results of the research were published before (Lamparski and Wawrzyniak 2004; Wawrzyniak and Lamparski 2007; 2008). In this study, the results have been presented concerning plant extracts which limit feeding and development of Colorado potato beetle the most effectively.

Materials and methods

The study was carried out in the laboratory conditions in the Department of Applied Entomology. Tested extracts were made of plants collected from the sites typical of them (meadows, forests, idle lands) which were dried and ground in the laboratory, and only some of dry plants were purchased in herbalist's shops (Table 1). Water extracts were prepared by pouring cool water over dried plants for 24 h in suitable ratios (1 : 10 and 1 : 5). After filtering through filter paper, an extract was obtained referred to as 10% and 5%.

Table 1. Specification of plants applied in the study

Family	Species	
	Latin name	Common name
Lamiaceae	*Mentha piperita* L.	peppermint
	Ocimum basilicum L.	basil
	Majorana hortensis L.	common origanum
	Melissa officinalis L.	lemon balm
	Rosmarinus officinalis L.	rosemary
	Origanum vulgare L.	oregano
	Salvia officinalis L.	common sage
Labiatae	*Thymus vulgaris* L.	common thyme
Caryophyllacea	*Saponaria officinalis* L.	common soapwort
Asteraceae	*Artemisia dracunculus* L.	tarragon
Geraniaceae	*Geranium sanquineum* L.	cranesbill geranium
	Pelargonium x *hortorum*	common geranium
	Erodium cicutarium L.	redstem filaree
	Geranium pusillum L.	small geranium
	Geranium pratense L.	meadow cranesbill
	Geranium robertianum L.	herb Robert

In the laboratory, the effect of plant extracts on feeding and development of Colorado potato beetle was assessed according to the method given by Wyrostkiewicz (1992). In order to estimate the effect of the tested extracts on insect feeding, weighed-out potato leaves were immersed in them for about 3 seconds, which after drying were placed in Petri dishes. One pair of beetles or 10 previously weighed out larvae of the L_3 stage were put on leaves in each dish. The experiment was conducted for 48 hours, and at the same time, food (prepared in the way described above) was exchanged and supplemented. Test and control (not treated dry leaves) treatments were carried out in 5 replications. After 48 hours the other leaves and insects were weighed again. The following were estimated on the basis of the data obtained:

- mass of food eaten by larvae and beetles (the calculations considered mass loses due to evaporation at a temperature of 20^{o}C and humidity of 80%),
- changes in the body weight of larvae,

– efficiency of food utilization by larvae (calculated from the relation of weight of food eaten to weight growth of larvae),
– absolute index of deterrentness (AID), according to the equation (Kiełczewski et al. 1979):

$$AID = [(K - T) : (K + T)] \times 100$$

where:
K – mass of food eaten in the control,
T – mass of food eaten with an addition of extract.

In the event of the total lack of feeding, AID approaches 100, whereas the value 35 indicates feeding reduction by about 50%, as compared with the control.

Analysing the effect of extracts on potato beetle development, the following have been observed:
– female fertility – breeding of beetle pairs was carried out fed with potato leaves treated with the tested plant extracts, and a number of eggs laid per female,
– development of larvae from eggs treated with the tested extracts – eggs laid on potato leaves in the field by wintering females were brought to the laboratory and covered with the tested extract by means of a brush and left on Petri dishes. The test was conducted in four replications; for comparison, a control treatment was established with untreated eggs. Hatching larvae was counted in each treatment, assuming that the eggs from which larvae did not hatch died as a result of the effect of the extract,
– effectiveness of metamorphosis – larvae of the L4 stage after 48 hours of feeding on leaves treated with the extracts were placed in containers with sand where pupation occurred. Beetles hatching in the given experimental treatments were counted and weighed.

The results obtained were worked out statistically using the analysis of variance with a single classification, in a totally randome design. The significance of differences between the means for particular levels of the factor was estimated by means of Tukey's test at $p = 0.05$.

Results and discussion

The tests performed enabled the selection of plants from which water extracts were obtained that actively limited the feeding and development of Colorado potato beetle.

Of 5% plant extracts analyzed, the extracts obtained from peppermint, lemon balm and rosemary had the strongest effect on limiting the mass of food eaten by larvae and beetles of Colorado potato beetle (Table 2). In the experimental treatments where they were added to food, also a very low larvae body mass growth was noted. Among 10% extracts, that from common geranium was characterized by a considerable effect on limiting the mass of food eaten by beetles and larvae of the pest. In the treatment where this extract was applied, also a very low growth of larvae body mass was observed.

The absolute deterrentness index calculated for beetles of the winter generation indicated that of the tested 5% extracts, the extracts obtained from peppermint, common thyme, and basil showed the significantly strongest antifeedant effect (AID above 40;

Figs. 1, 2). A considerably higher index was found in the case of 10% extracts. For plants of the family Geraniaceae it was from 76 (cranesbill geranium) to 64.8 (redstem filaree). When analysing the index value in relation to larvae of Colorado potato beetle, it was found that 5% extract of peppermint has the significantly strongest inhibitory effect on their feeding (AID = 77.7). The other tested 5% and 10% plant extracts showed a considerably weaker deterrent activity.

Table 2. Effect of plant water extracts on feeding of imagines and larvae of Colorado potato beetle

Plant species	Mass of food eaten by 1 pair of imagines [mg]	Mass of food eaten by larvae [mg]	Larvae body mass growth [mg]	Food consumption for growth of 1 mg larva body mass [mg]
		5% extract		
Mentha piperita	103.0	19.0	9.0	2.1
Thymus vulgaris	324.0	475.0	150.0	3.2
Ocimum basilicum	344.0	647.0	280.0	2.3
Majorana hortensis	341.0	464.0	183.0	2.5
Melissa officinalis	223.0	39.0	12.0	3.3
Saponaria officinalis	403.0	443.0	149.0	3.0
Rosmarinus officinalis	212.0	35.0	15.0	2.3
Artemisia dracunculus	275.0	32.0	13.0	2.5
Control	451.0	136.0	46.0	3.0
Mean	297.0	254.0	95.0	2.7
$LSD_{0.05}$	121.0	92.0	74.0	0.8
		10% extract		
Geranium sanquineum	64.0	51.0	40.0	1.3
Pelargonium x *hortorum*	85.0	43.0	23.0	1.9
Erodium cicutarium	103.0	83.0	41.0	2.0
Geranium pusillum	132.0	71.0	39.0	1.8
Geranium pratense	143.0	60.0	38.0	1.6
Geranium robertianum	154.0	66.0	38.0	1.7
Mentha piperita	333.0	74.0	31.0	2.4
Origanum vulgare	348.0	90.0	36.0	2.5
Salvia officinalis	381.0	79.0	27.0	2.9
Control	492.0	150.0	46.0	3.0
Mean	224.0	77.0	36.0	2.1
$LSD_{0.05}$	113.0	28.0	11.0	0.7

The response of Colorado potato beetle was likely to be affected by considerable amounts of substances of secondary metabolism occurring in the tested extracts, called allelocompounds (other names are ksenobiotics, allelochemicals, phytoncides, blastokolins) which are the main chemical substances inhibiting feeding and development of insects. Those compounds differ in the chemical structure and occur both on the plant surface and in their tissues. The majority of them are located in vacuoles and cell walls of peripheral tissues. Some metabolites have a deterrent effect already during plant choosing by insects, preventing their inhabiting, feeding, laying eggs or hiding on them. After inhabiting plants by insects, the way of influence of secondary metabolites depends on their concentration. In low concentrations, they can function as feeding stimulants, whereas in higher concentrations, they negatively affect development or even cause insect mortality (Harborne 1997; Malinowski 2008).

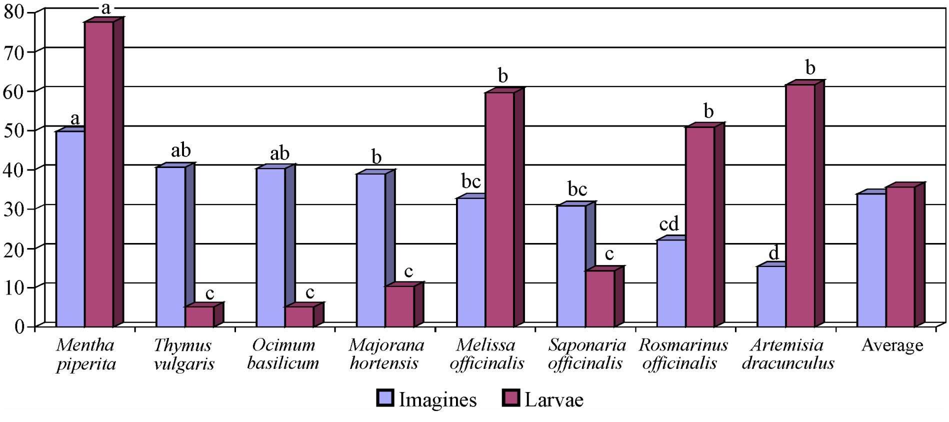

Fig. 1. Absolute deterrentness index for imagines and larvae of Colorado potato beetle (plant extracts 5%). The same letters indicate values that are not significantly different for imagines or larvae

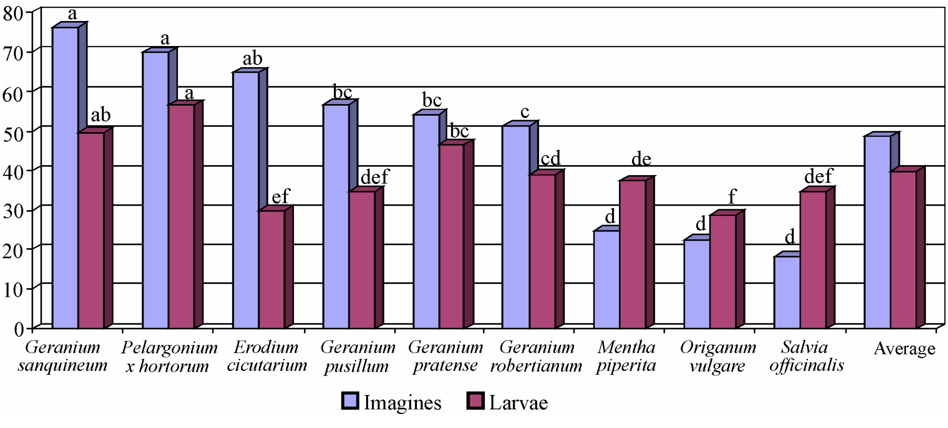

Fig. 2. Absolute deterrentness index for imagines and larvae of Colorado potato beetle (plant extracts 10%). The same letters indicate values that are not significantly different for imagines or larvae

Feeding is most often limited by terpene compounds, particularly those low-molecular (mono-, sesqui- and diterpenes). Disorders in food assimilation, in turn, are caused by high-molecular phenolic compounds occurring in a considerable concentration. Polymerized phenolic compounds can cause inactivation of proteases of insect saliva, decrease food assimilability owing to inhibiting digestive enzymes activity, reduce intestine wall permeablility for digested nutrients and irritate walls of the alimentary tract. Moreover, a synergistic effect of plant phenolic compounds is manifested by immobilizing of main detoxification mechanisms of herbivorous insects. Compounds having such an effect include hydrolysing tannins as well as oligo- and polymers of flavonols (Leszczyński 1987). In most tested plants those substances occur in varying concentrations. Hedin (1983) and Harborne (1997) report that the inhibition of taking-up food by a pest is also affected by flavonoids. According to Leszczyński (1987), however, that is not single substances or their particular groups but a mixture of all those chemical compounds that has an effect on feeding insects.

Also an extract of common soapwort, strongly limiting beetle feeding, contains numerous triterpene saponins. Saponins have proved to be toxic for such pests as European corn borer (Nozzolillo et al. 1997), cotton leaveworm (Adel et al. 2000), and Colorado potato beetle (Waligóra and Krzymańska 1994). They also cause disorders in development and fertility of store pests such as grain weevil (Wawrzyniak et al. 2003).

Extracts obtained from mint, thyme, basil and common origanum, showing a very active antifeedant effect, contain considerable amounts of volatile oils. Leaves of pepper mint contain additionally menthol, menthone, tannins, and flavonoids and their glycoside combinations that show a strong physiological effect on the animal organism (Ożarowski and Jaroniewski 1987). Limiting effect of the thyme extract is likely to be related to the content of numerous phenolic derivatives. The main role of those substances is to inhibit enzymatic activity, particularly that of oxidoreductases and hydrolases. A high content of phenolic compounds is usually accompanied by an increased content of peroxidase and phenolic oxidases which cause the accumulation of large amounts of polyphenols and quinones, showing strong antibiotic properties relative to insects. Large contents of quinones and their considerable biological activity favour the process of oxidation of many chemical compounds, including amino acids and vitamins, which considerably lower the nutritional value of host plants. Many examples exist of negative correlations between the content of total phenols or particular phenolic compounds in plant tissues and the count of leaf-eating insects of many orders (Ciepiela and Chrzanowski 2000) and pathogens (Soliman and Badea 2002) occuring on them.

Most extracts showed a stronger effect against beetles than larvae (Figs. 1, 2). This is probably related to a chemosensory reaction at migrating and sedentary stages and determines different behaviours of insects in relation to negative plant stimuli. Migrating forms (beetles) are neurophysiologically adapted for leaving potato shrubs and looking for food in another place. Negative stimuli affecting the insect nervous system let it “choose the host plant”, and to be precise, “avoid non-host plants” and force it to move. Those stages can be relatively easily influenced by means of factors preventing them from feeding (Harmatha and Nawrot 1985). In contrast, insects at not migrating stages (larvae), due to their separate physiological adaptations, respond differently to plant stimuli. Larvae are behaviorally much stronger linked to the particular host plant and hence all the negative stimuli triggering either rest or slowed movement. Larvae do not leave easily plants with infavourable properties or they leave them considerably later than migrating forms (Blaney and Simmonds 1986).

On the basis of the data obtained it has been stated that feeding females on food with extracts from common origanum, common sage and peppermint affects the inhibition of oviposition. Reduction of laying eggs by pests can have important effects in protecting plants against their mass occurrences. All the tested extracts also significantly reduce the number of hatched larvae of Colorado potato beetle. Extract from sage limited both the hatch of larvae and the proces of pupation the most effectively of all the extracts (Table 3). This was likely to be mostly affected by the essential oil of characteristic smell, containing up to 50% of the strongly toxic thujone

(Kohlmünzer 1985). Attempts have been made to apply preparations obtained from common sage for the control of carrot rust fly, diamondback moth, large cabbage white and cabbage moth (Ignatowicz and Wesołowska 1994).

However, no negative effect of the tested extracts on the proces of Colorado potato beetle pupation has been observed (Table 3). In all the experimental treatments (except for the extract from sage) the number of imagines leaving and their mass do not differ significantly from those observed in the control treatment.

Table 3. Effect of water extracts on development of Colorado potato beetle

Plant species	Number of eggs laid by 1 pair [pieces]	Hatching of larvae [%]	Pupation	
			Beetles [%]	Beetle mass [mg]
5% extract				
Mentha piperita	42.2	41.8	64.0	90.0
Thymus vulgaris	44.8	26.1	90.0	95.9
Ocimum basilicum	55.8	21.7	87.5	83.7
Majorana hortensis	8.3	0.0	86.7	99.3
Melissa officinalis	14.7	29.5	67.2	80.0
Saponaria officinalis	60.5	26.3	40.0	81.4
Rosmarinus officinalis	16.2	25.8	74.7	90.0
Artemisia dracunculus	13.5	34.9	70.8	80.0
Control	477.0	84.1	100.0	102.0
Mean	81.4	32.2	75.7	89.1
$LSD_{0.05}$	122.8	14.6	28.4	12.4
10% extract				
Geranium sanquineum	122.0	65.7	88.2	102.0
Pelargonium x *hortorum*	70.0	31.9	47.1	89.0
Erodium cicutarium	300.0	51.7	94.1	97.0
Geranium pusillum	277.0	65.2	94.1	103.0
Geranium pratense	31.0	50.0	94.1	100.0
Geranium robertianum	313.0	85.6	88.2	103.0
Mentha piperita	29.5	36.1	49.9	97.1
Origanum vulgare	31.5	69.3	58.4	76.8
Salvia officinalis	7.3	37.8	22.3	73.3
Control	477.0	84.1	100.0	102.0
Mean	165.8	57.7	73.6	94.3
$LSD_{0.05}$	133.6	15.9	27.5	13.7

The effect of the extract on pest feeding and development can be determined by synergistic interaction of biologically active substances contained in it. Of the plant pharmacological components examined so far, from which the analysed extracts were obtained, especially numerous terpenoids, flavonoids, tannins and phenolic compounds, playing important defensive and regulatory roles, can take an active part, being effective inhibitors of insect feeding, growth and development (Harborne 1997; Landolt et al. 1999). A lactonic group occurs in the structure of many natural antifeedants, which is thought to have a high deterrent activity (Szczepanik et al. 2003).

At the current stage of the research, it may be suggested that antifeedants do not constitute the effective weapon which could be used for the full control of harmful insect populations. In some situations, however, they can serve as auxiliary measures.

Seeking effective plant compounds, the researchers hope to discover a substance with a wide spectrum of activity. However, it is unlikely that there are natural substances which are universal antifeedants. Even the famous neem tree, from which azadirachtin and other related substances are obtained, currently being the most effective antifidants known, is also food for various insects such as beetles, butterflies, heteroptera, aphids and mites (Warthen 1979). Those compounds require the same thorough study as chemical insecticides. More detailed research should be conducted on plant chemistry and insect behaviour.

Due to the complex character of compounds present in plants, no final conclusions can be drawn before the isolation and identification of the active substances, allowing their synthesizing in the future. Nevertheless, the negative result of tests with application of extracts is not necessarily the evidence that the given plant does not have compounds affecting the phytophage. Water or ethanol may have not extracted the active compound. Its concentration in the extract may have been too low to indicate significant differences in comparison with the control. Plant extracts, depending on whether the dried or fresh raw material was applied and how long it was extracted, have often varying amounts of active substances expressed in dry matter. Also conditions in which the plant had grown may have determined its biochemical composition. Calculation of dry weight of active substances in extracts involves great difficulty, thus during the discussion at the seminar "Natural substances of plant origin from the perspective of application in plant protection" (Pszczyna, 29-30.06.1995) it was stated that the determination of gravimetric ratios of plant material in particular extracts can be considered sufficient.

Acquiring nutritional deterrents from natural sources, such as plants, is difficult and economically unprofitable. Possibilities for the practical application of those natural compounds for insect control are limited due to their low contents in plants and expensive extraction and purification (Ley and Toogood 1990; Lavrencet 2000). Their synthetic structural analogues have much better chance to be applied. However, they can be substrates or model compounds for the chemical synthesis of those compounds. Owing to their specific activity, antifeedants can be applied as alternative pesticides used in integrated programs of pest control. Thus, the application of plant extracts on a large scale will be possible only when many problems, both of biological and technological character, have been solved.

Conclusions

Looking for new ways of the control of Colorado potato beetle alternative to the chemical method, several dozen water, alcohol and acetone plant extracts were tested in the laboratory of the Department of Applied Entomology UTP in Bydgoszcz. From among them extracts were selected which effectively limit feeding and development of this pest. The highest antifeedant activity of the analysed water extracts is shown by 10% extracts from the plants of Geraniaceae family (especially the extract from common geranium) and 5% extracts from peppermint, common thyme, and basil. However, feeding females on food containing extracts from common origanum, common sage, and peppermint results in inhibiting oviposition. All the tested extracts also significantly reduce the number of hatching larvae of Colorado potato beetle. Extract from common sage also limits the process of potato beetle pupation the most effectively.

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SOSNOWSKI'S HOGWEED (*Heracleum sosnowskyi* Manden.) – ALIEN INVASIVE SPECIES

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Sosnowski's hogweed (*Heracleum sosnowskyi* Manden), which originates from wild Caucasian flora, was introduced in Poland in the 1970s to many experimental farms as a potential fodder plant. The cause of the fascination with this plant was a very high yield and fast green mass growth (Lutyńska 1980; Pasieka 1984).

Not enough attention was then paid to its negative traits, related to the presence of coumarin photosenibilitic compounds, which sensitize the skin of people and animals, especially on hot, sunny days, causing burns and wounds difficult to heal (Krzemkowski 1995; Zobel et al. 2000; Nielsen et al. 2005). Moreover, difficulties in making and feeding with ensilage occurred (Bochniarz et al. 1987). Therefore, fast resignation from the cultivation of such a troublesome plant took place. However, hogweed forced its way from experimental fields to the natural environment and settled in many regions of the country, changing the nature of the hitherto existing plant communities and becoming a bothersome weed. It forms dense clusters on the shoulders of local roads and by busy communication routes, by the shores of water basins, on pastures, meadows, in gardens, around buildings, and also on waste lands. In addition, it enters the composition of natural forest communities (Korniak and Środa 1996). It threatens especially preserved natural plant communities of national parks (Wróbel 2001). In extreme cases, Sosnowski's hogweed creates almost congeneric aggregations (Korniak and Środa 1996; Stupnicka-Rodzynkiewicz and Klima 1996). Therefore, it became classified as a so-called alien invasive species that threatens biological diversity. Many countries introduced proper regulations and created special strategies of action in the fight with invasive species. They include creating methods of prevention, early detection, and elimination of alien invasive species (Lipa 2005; Nielsen et al. 2005). In the world, these plants are dealt with by two international organisations: Global Invasive Species Programme and Invasive Species Specialist Group. Of a particularly important role are invasive species in The Convention on Biological Diversity and the Bern Convention on the Conservation of European Wildlife and Natural Habitats (Wrzesińska 2006).

Fast spreading of hogweed is promoted by high diachenia production, which in the nearest surroundings are disseminated by wind, along the roads they travel attached to the wheels of vehicles and agricultural machines, and they are also carried by animals and in rivers with the current. In the initial period, hogweed grows individually in

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a given area. Later, it migrates in all directions, thus forming groups of plants. Furthermore, carrying hogweed to house gardens as an impressive decorative plant attributed to its further expansion. Getting rid of fast-growing sprouts and throwing them together with fruits on dumping grounds, waste lands, and into river-beds contributed to the expansion of this species in many places (Skawiński 2000).

Condition for succeeding in the fight with *H. sosnowskyi* is the connection of agrotechnical, mechanical, and biological methods in order to minimalise the threats for ecosystems. Connection of these methods and their introduction into modern protection is an important element of an integrated system of controlling weed development. Chemical method of fight is difficult and does not give the desired effect. Alternative method of the destruction of Sosnowski's hogweed may be the biological method, supplemented with mechanical methods. Among many species that occupy this weed, attention should be paid to: *Cavariella theobaldi* Gill-Bragg, *Dysaphis laubertii* Börn., *Paramyzus heraclei* Bürner, *Phytomyza spondylii* R.-D., *Philophylla heraclei* L., *Depressaria pastinacella* Dup, *Orthops campestris* L., and *O. kalmi* L. (Wrzesińska 2004; 2005a; 2005b; Wrzesińska and Bennewicz 2005; Wrzesińska and Wawrzyniak 2005).

Wrzesińska and Błażejewska (2000) observed numerous arthropods on Sosnowski's hogweed, for which this weed was an attractive food source, in spite of the presence in its tissues of furocoumarins that are a biochemical mechanism of defence against pests. This mechanism is broken down by specialized phythophages by metabolic detoxication and furocoumarin excretion (Nitao 1990; Berenbaum 1994; Green et al. 2001). *Papilio polyxenes*, which feed only on umbellifers, developed an effective detoxication system based on cytochrome oxidase P-450, a result of which is furan ring opening (Cohen et al. 1992). For the total detoxication of an oral dose in the amount of 5 $\mu g \cdot g^{-1}$, the insect needs 2 hours (Harborne 1997). Detoxication processes in *D. pastinacella*, which also feed on Sosnowski's hogweed, are regulated by a proper enzyme, whose highest level was fund in the last (sixth) growth stadium of caterpillars (Lee and Berenbaum 1990; Zangerl 2002). These processes were studied in the USA, where *D. pastinacella* do significant damage to *Pastinaca sativa* crops. Insects that are able to cope with the presence of furocoumarins in food bear specific metabolic costs. Unadapted insects undergo poisoning by furocoumarins (Berenbaum 1983).

The aim of the study was the estimation of the size of Sosnowski's hogweed population in the analysed stations, tracing its biology, and recognizing the species composition of insects and acarids that occupy this weed.

Materials and methods

Studies were conducted in years 2002 and 2004 in Kuyavian-Pomeranian Province in the following locations: Minikowo, Mochełek, and Topolno. Moreover, in 2002 two observations were carried out in Lesser Poland Province – in Kacwin, and also in Slovakia in Spišská Stará Ves. In the first three locations, hogweed biology was observed.

Hogweed development and samples for entomological analyses were taken every 7-10 days, from the beginning of vegetation to plant drying.

Following methods of collecting insects occupying hogweed were applied:
- scooping,
- shaking from inflorescences to bags from mill gauze – in this case, the scooping method due to the size of inflorescences was useless, and therefore big bags made from mill gauze were put on umbels and shaken, whilst scaring away bees and other pollinating insects beforehand – the collected material was analyzed in a laboratory,
- collecting insects and acarids with tweezers or a brush from cut leaves and inflorescences – making it possible to estimate the species composition of small, gentle arthropods – this was a complementary method, applied randomly.

In laboratories, the collected faunistical material was segregated and characterised in regard to quantity and quality, and species or genera were marked using keys to insect marking. Furthermore, breeding of some insects was carried out, from the egg or larva to imagines.

Qualitative characteristic of the collected arthropods was carried out using the Marczewski-Steinhaus coefficient (1959):

$$MS = \frac{w}{a + b - w} \cdot 100\%$$

where:

MS – similarity coefficient,
w – number of species common to the compared communities,
a – number of species of community A,
b – number of species of community B.

Results and discussion

Characteristics of chosen habitats of Sosnowski's hogweed

Stations of *H. sosnowskyi* in Kuyavian-Pomeranian Province were situated in the surroundings of Bydgoszcz.

The most numerous population of hogweed was observed in Minikowo at the Agricultural Experimental Station. In mid-1970s, hogweed for fodder was cultivated there. Due to difficulties in storing silage and its reluctant consumption by animals, cultivation of this plant was withdrawn. Plantation was not liquidated precisely and the plants spread in an uncontrolled way to the neighbouring meadows, on the shoulders of roads, and on waste lands. At present, hogweed is growing on a segment of ca. 2 km on both sides of a field road, up to a compact deciduous stand. Northern border of hogweed occurrence is posed by agricultural fields. Southern border of a compact plant group is a railway. This weed spread also to the other side of the tracks, towards the Bydgoszcz Canal. There, it grows in several smaller, dense groups. In 2002, two blooming specimens were also noted, as well as a few sterile ones on the railway embankment, and in 2004 six blooming ones and a dozen or so of the so-called vegetative forms. At the station in Minikowo the plants were not counted, as it was impossible due to the great area occupied by them. Figure 1 shows hogweed population that forms a monoculture.

On the territory occupied by hogweed, the Agricultural Experimental Station did not perform any chemical interventions, and mechanical interventions consisted in cutting the plants that grew right by the road, in order not to allow its overgrowth.

Fig. 1. Station in Minikowo

Second analysed hogweed station was a population situated in the area of the Experimental Station of the Faculty of Agriculture of the University of Technology and Life Sciences in Bydgoszcz (Fig. 2). Hogweed was sown there in the 1980s on a small plot – collection of plants. After plot liquidation, hogweed still grows on a farm. At present, it can be seen along the fence and the road and on the *Galega orientalis* plantation. This weed was fought mechanically by cutting the inflorescences and chemically before the rise of *Galega* with Roundup herbicide. Sosnowski's hogweed population at that station oscillated between 135 and 201 plants.

Fig. 2. Station in Mochełek

Station of *H. sosnowskyi* in Topolno (Fig. 3.) is situated in the area of the Lower Vistula Valley Landscape Park. Hogweed was sown there in a house garden of an individual farmer. Within several years, it escaped beyond the area of the garden in an uncontrolled way and grows at present in dense groups on both sides of the road that leads to Bydgoszcz-Fordon. Area occupied by this plant is estimated to be ca. 1200 m^2.

Fig. 3. Station in Topolno

The remaining analysed stations were situated in Lesser Poland Province and in a border town in Slovakia. In Kacwin and Spišská Stará Ves (Slovakia), observations were conducted twice, on the turn of June 2002 during hogweed blooming.

In the village of Kacwin, situated in Polish Spisz, hogweed grew in ditches along the road to Niedzica, at the foot of a mountain, in crop cultivation on the fields of individual farmers and in the area of some gardens. In this location, the total of over 1000 plants was found, from which over a half was made up by blooming plants (Fig. 4).

Fig. 4. Station in Kacwin

Next station was situated in the village of Spišská Stará Ves. In this location, on the former State Agricultural Farm, similar studies were conducted as in Minikowo on the usefulness of Sosnowski's hogweed as a fodder plant. Analysed hogweed population grew in the valley of the Rzeka stream, which flows into Dunajec (Fig. 5). In the place where *Heracleum* occurs, it was impossible to count the plants due to their occurrence in a large dense group in the area of 80 x 220 m. Besides this group, numerous smaller clusters and single specimens were noted.

Fig. 5. Station in Spišská Stará Ves

Vegetation course of Sosnowski's hogweed at the analysed research stations

Hogweed is a biennial or perennial plant, which bears fruits once and dies afterwards. In the first year of vegetation, it produces rosette, and in the second year, generative shoots grow. Therefore, observations were carried out on plants during the first or second year of vegetation.

Hogweed plants in the first year of vegetation grew very slowly during the spring-summer period. Higher intensity of growth was noted only in August. In the second half of September, average plant height was from 80 to 120 cm. In the second year of vegetation, plant development took place very early, right after the start of vegetation. This extraordinarily expansive plant formed a dense field in the place of its occurrence, thus eliminating other plant species.

First measurements of the height of hogweed plants (in the second year of vegetation) were conducted at the beginning of May on 10 randomly chosen plants. Average height of the analysed plants, measured from May 5 to 12 at all the stations oscillated between 40 and 60 cm. In the following period, namely from May 14 to 19, average plant height oscillated between 70 and 90 cm, and on the next date reached 100 to 130 cm. Between June 7 and 10, the plants reached the height of 170 to 220 cm, and between 15 and 17, their height increased to 210-270 cm. In late June, hogweed reached its final height of 280 to 340 cm (mean from the particular stations). The highest hogweed specimen was noted in Minikowo in 2004; its height was 467 cm. The smallest blooming hogweed (106 cm) was noted in 2002 on a railway embankment, also in Minikowo. Its stem was round, deeply furrowed, covered with protruding hair, and empty inside. The thickest evaluated stems reached the outer diameter of 12.4 cm at the base, 6.3 in mid-height, and 3.8 under the umbel. Leaves growing from the rosette were very big and reached the length of 94 to 128 cm. The higher on the stem they were situated, the smaller their size was. The bottom side of the leaves was slightly hairy (Fig. 6).

Fig. 6. Leaves of *Heracleum sosnowskyi*

First inflorescence buds, in the shape of a club, showed up on the turn of the first decade of June. The period of full blooming came in the second and third decade of June.

In 2002, one inflorescence was randomly chosen from every station. Later, they were all transported to a laboratory in order to measure and count the fruits. Hogweed inflorescences form umbels made of umbellules (Fig. 7).

Fig. 7. Inflorescence of *Heracleum sosnowskyi*

According to the taken measurements, the biggest umbels situated centrally had the diameter of 68 to 89 cm, and side umbels from 34 to 48 cm. On one inflorescence, in addition to the central umbel, on average 6 to 8 side umbels were noted. Central umbels contained from 107 to 125 umbellules, and side umbels from 44 to 75 ones. On average, on one plant in the main umbel 7360 fruits were noted, and on the side ones – 13523. Per one umbellule in the central inflorescence, there were on average 58.9 fruits, and in the side inflorescence – 26.6. Re-counting, per one umbel 20882.3 fruits were noted, which at the moment of maturation broke down to two flat olive diachenia. Dorsal side of the diachenia was hairy and four brown widened trails of oil conduits could be seen on it (Fig. 8).

Fig. 8. Fruits of *Heracleum sosnowskyi*

In total, one plant produced on average 41766 diachenia. Fruit maturation process started in mid-July, and after their production, the plants died a natural death. Assuming that only a part of them will germinate and give rise to new plants, this shows a huge reproductive potential of the plant. According to Stupnicka-Rodzynkiewicz and Klima (1996), flat diachenia are diffused hydrochorically and anemochoricly and maintain germinability for a few years. Climate of our country is conducive to abundant development of hogweed and to the production of mature fruits, which, after going through the necessary stratification period during winter, germinate perfectly in the spring (Lutyńska 1980).

Hogweed can grow practically everywhere but it develops best in fertile and damp sites. Most often, it finds such conditions in riverside areas, where its expansion reaches the greatest size (Krzemkowski 1995). Sosnowski's hogweed may be recognized as a weed fully settled, since it has grown in our country for almost 40 years.

Faunistical research conducted on *H. sosnowskyi* in 2002 and 2004 shows that the entomofauna of this plants abound with numerous arthropods (insects and arachnids). Among the faunistical material collected from the leaves and inflorescences of hogweed, insects dominated. In total, 4,749 (96.04%) insects and 196 arachnids (3.96%) were collected. Arthropods belonged to 10 orders and 26 families.

In the studied hogweed habitats, the total of 72 arthropod species was found (Table 1). Most insect species belonged to order *Coleoptera* (30), fewer to order *Heteroptera* (24). The richest in species was family *Miridae* (15) – Table 1.

Table 1. List of arthropod species occupying hogweed in the studied habitats; A – Minikowo, B – Mochełek, C – Topolno, D – Kacwin, E – Spišská Stará Ves

No.	Order – family – species	A	B	C	D	E
I	*DERMAPTERA*					
	Forficulidae					
1	*Forficula auricularia* (L.)	+	+	+	+	+
II	*THYSANOPTERA*					
	Thripidae					
2	*Thrips tabaci* (Lind.)	+	+	+	+	+
III	*HEMIPTERA – HOMOPTERA*					
	Aphididae					
3	*Aphis fabae* Scop. – complex	+	+	+		
4	*Cavariella theobaldi* (Gill.-Bragg.)	+	+	+	+	+
5	*Dysaphis laubertii* (Bőrn.)	+	+	+		+
6	*Paramyzus heraclei* (Bűrner)	+	+	+	+	+
	Dysaphis sp.	+		+		+
	Cercopidae					
7	*Philaenus spumarius* (L.)	+		+		+
	Triozidae					
8	*Trioza nigricornis* (Főrst.)	+	+	+		
9	*Trioza viridula* (Zett.)				+	
IV	*HEMIPTERA – HETEROPTERA*					
	Miridae					
10	*Orthops campestris* (L.)	+	+	+	+	+
11	*Orthops kalmi* (L.)	+	+	+	+	+
12	*Orthops basalis* (Costa)	+	+	+	+	+
13	*Lygus rugulipennis* (Popp.)	+	+	+		
14	*Lygus gemelatus* (H.S.)	+	+	+		
15	*Lygus punctatus* (Zett.)	+	+	+		
16	*Lygus pratensis* (L.)	+	+	+	+	+
17	*Lygus wagneri* (Rm.)					+
18	*Lygocoris spinolai* (Mey. D.)	+	+	+		
19	*Lygocoris lucorum* (Mey. D.)	+		+		
20	*Calocoris norvegicus* (Gemel.)	+	+	+		
21	*Calocoris roseomaculatus* (Deg.)	+	+	+		
22	*Orthotylus flavosparsus* (C.Sb.)	+		+	+	+
23	*Chlanydatus pullus* (Rt.)	+		+		
24	*Notostira erratica* (L.)	+	+	+		
	Miridae sp. larvae	+	+	+	+	+
	Pentatomidae					
25	*Palomena prasina* (L.)	+	+			
26	*Palomena viridissima* (Poda)	+	+	+		
27	*Graphosoma lineatum* (L.)	+	+	+		
28	*Eurydema oleracea* (L.)	+	+	+		
	Nabidae					
29	*Nabis ferus* (L.)	+	+	+	+	+
30	*Nabis pseudoferus* (Rm.)	+				
	Anthocoridae					
31	*Orius niger* (Wolff.)	+	+		+	+
32	*Orius minutus* (L.)	+	+	+		
33	*Anthocoris nemorum* (L.)	+	+	+		

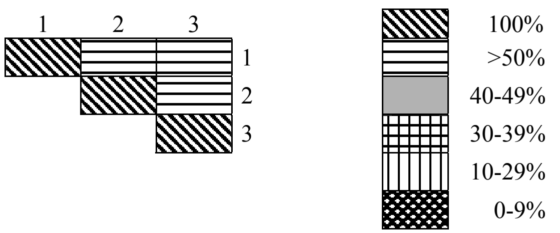
V	*NEUROPTERA*					
	Chrysopidae					
34	*Chrysopa vulgaris* (Schn.)	+	+	+	+	+
VI	*LEPIDOPTERA*					
	Oecophoridae					
35	*Depressaria pastinacella* (Dup.)	+	+			+
	Noctuidae					
36	*Autographa gamma* (L.)	+				
	Epermeniidae					
37	*Epermenia chaerophyllella* (Goeze)	+	+			
VII	*DIPTERA*					
	Agromyzidae					
38	*Phytomyza spondylii* (Robineau-Desvoidy)	+	+	+	+	+
39	*Phytomyza pastinacae* (Hendel)	+	+			+
	Trypetidae					
40	*Philophylla heraclei* (L.)	+	+	+	+	+
VIII	*HYMENOPTERA*					
	Apidae					
41	*Apis mellifica* (L.)	+	+	+	+	+
IX	*COLEOPTERA*					
	Anthicidae					
42	*Notoxus monoceros* (L.)	+	+	+		
	Cantharidae					
43	*Cantharis fusca* (L.)	+	+	+	+	+
44	*Cantharis rustica* (Fall.)	+	+			
45	*Cantharis rufus* (L.)					+
46	*Rhagonycha fulva* (Scop.)	+	+	+		
	Cerambycidae					
47	*Leptura maculata* (Poda)	+	+	+		
	Chrysomelidae					
48	*Altica oleracea* (L.)	+		+		
49	*Phyllotreta vittula* (Redt.)	+	+	+		
	Coccinellidae					
50	*Hippodamia variegata* (Goeze)	+	+	+		
51	*Adalia bipunctata* (L.)	+	+	+	+	+
52	*Calvia quatuordecimguttata* (L.)	+	+			
53	*Coccinella quinquepunctata* (L.)	+	+	+		
54	*Coccinella septempunctata* (L.)	+	+	+	+	+
55	*Coccinella quatuordecimpustulata* (L.)	+	+	+	+	+
56	*Propylea quatuordecimpunctata* (L.)	+	+	+		
57	*Psyllobora vigintiduopunctata* (L.)	+				
	Elateridae					
58	*Athous haemorrhoidalis* (F.)	+	+			+
59	*Agrypnus murinus* (L.)	+	+	+		
60	*Agriotes ustulatus* (Schall.)	+	+	+		
61	*Selatosomus aeneus* (L.)	+	+			
	Nitidulidae					
62	*Meligethes aeneus* (F.)	+	+	+	+	+
63	*Meligethes coracinus* (Strm.)	+	+	+		
64	*Meligethes viridescens* (F.)	+	+	+		
	Oedemeridae					
65	*Oedemera podagrariae* (L.)	+	+			
66	*Oedemera virescens* (L.)	+	+			

	Scarabaeidae					
67	*Phyllopertha horticola* (L.)	+	+	+		
68	*Cetonia aurata* (L.)	+	+	+	+	+
69	*Epicometis hirta* (Poda)				+	+
70	*Anomala dubia* (Scop.)	+	+	+		
	Tenebrionidae					
71	*Lagria hirta* (L.)	+	+	+		
X	*ACARIDA*					
	Tetranychidae					
72	*Tetranychus urticae* (Koch.)	+	+	+		

Analysis of the qualitative composition of the entomofauna collected form Sosnowski's hogweed was carried out using the Marczewski-Steinhaus similarity coefficient. Obtained results are shown graphically in the form of a Czekanowski's diagram (Klimaszewski et al. 1980).

Picture of similarities obtained with the use of the Marczewski-Steinhaus coefficient showed that a significant similarity exists between weed communities situated in the surroundings of Bydgoszcz (Fig. 9). This indicator for the stations in: Minikowo, Mochełek and Topolno oscillated between 66.7% and 86.4% (similarity border is assumed to be >50%). In connection with this, it was stated that the entomofaunistical composition in these habitats is species approximate.

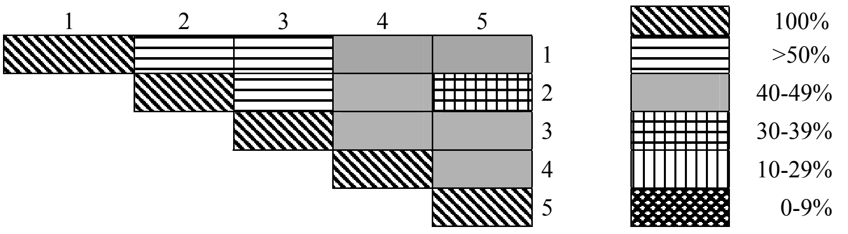
In addition, similarity coefficient of the species composition of arthropod fauna between the stations situated in the south of Poland and in a border location in Slovakia was compared and determined. To this end, data from two observations conducted in 2002 was chosen, during hogweed full blooming in Minikowo, Mochełek, and Topolno, and it was compared with the entomofauna collected during the same period in Kacwin and Spišská Stará Ves.



1 – Minikowo 2 – Mochełek 3 – Topolno

Fig. 9. Similarities diagram of the species composition of arthropods collected from *Heracleum sosnowskyi*

Figure 10 shows first of all a strong regional similarity of entomofauna that occupies Sosnowski's hogweed. Strongest species similarity occurs between the stations situated in Kuyavian-Pomeranian Province. Communities situated in south Poland and in Slovakia show insignificant differences in species similarity, whereas differences between the stations situated in Kuyavian-Pomeranian Province and those situated in south Poland and north Slovakia were observed.



1 – Minikowo 2 – Mochełek 3 – Topolno 4 – Kacwin 5 – Spišská Stará Ves

Fig. 10. Similarities diagram of the species composition of arthropods collected from *Heracleum sosnowskyi*

In the available literature, not much data concerning the entomofauna that occupies Sosnowski's hogweed can be found. In Poland, extensive research on the occurrence of insects on umbellifers cultivated as herbs and vegetables was conducted by Obarski (1960; 1961). He classified the collected insects from all the studied plants to 99 species. Kabysz (1985) on Sosnowski's hogweed in the Moscow district noted 14 species of insects that damaged the leaves and inflorescences. Jurek (1989; 1990), on the other hand, enumerated nine species feeding on the leaves and six species occupying hogweed inflorescences in Cracow, Grodkowice, and Niedzica. Lutyńska (1980) observed on this plant in Zakopane, Grodkowice, and Niedzica only two species. In Europe, within the research on the biological regulation of another invasive species of hogweed *Heracleum mantegazzianum*, occurrence of 60 insect species in Slovakia (Cagáň 2001), 46 in Switzerland (Bürki and Nentwig 1997), and 44 in Great Britain (Sampson 1994) was stated.

Sosnowski's hogweed is an example of a plant hastily introduced into cultivation with a hope of obtaining high yields. It still survives in places of cultivation and spreads spontaneously. At present, its occurrence is noted in the whole country. In places where it occurs, the plant has a negative influence on native species. Wrzesińska and Wawrzyniak (2008) suggest that phytophages that feed on Sosnowski's hogweed may have a certain effect on the weakening of its wholesomeness, and consequently may play an important role in the limitation of the weed population.

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ENTOMOFAUNA ON RAPESEED *Brassica napus* L.

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In Poland and in many European countries, rapeseed is the most important oilseed plant. It occurs in two forms: spring (*Brassica napus* var. *arvensis* f. *annua*) and winter (*Brassica napus* var. *arvensis* f. *biennis*). According to statistical data (Central Statistical Office 2008), the area of rapeseed and agrimony cultivation in 2008 amounted to 771.1 thousand ha and increased by 60.8% in relation to the mean from years 2001-2005. Obtained rapeseed and agrimony yields were higher than the ones from 2007 by 3.4% and estimated to be 27.6 $dt \cdot ha^{-1}$. Currently, a growing need for biofuels caused an increase in the area of rapeseed cultivation. With the entry into the European Union, Poland and other member states were obliged to increase the participation of liquid fuels in the energetic balance. Participation in 2010 ought to be 5.75%. In connection with this, a significant increase in the need for rapeseed oil is predicted. By 2010, rapeseed production should increase by ca. 1.5 million ton, which can be achieved by doubling the cultivation area and mean yield increase. Increase in the cultivation area of this plant may be reached by a decrease in the area of cereal and beet cultivation (Rosiak 2006).

In recent years, as a result of climatic and environmental changes, winter and spring rapeseed has been more often attacked by pests. In Polish conditions, average yield losses of this plant caused by phytophages are estimated to be 15-50%, and sometimes may be a cause of total plantation destruction (Mrówczyński 2003). In connection with this, an indispensable element of rapeseed cultivation technology is chemical protection, which, in turn, has a negative effect on useful insects.

The aim of the work was the recognition of entomofauna, domination structure, and number dynamics of the most numerous species of insects that occupy rapeseed.

Materials and methods

Research was conducted in years 2006-2007 in Kuyavian-Pomeranian Province throughout the entire vegetation period of *Brassica napus*. Observations of entomofauna on spring rapeseed were carried out in 2006 in the village of Knieja, and on winter rapeseed in 2007 in towns Koszanowo and Gołębin. Insects were collected with the use of traps and an entomological scoop. Every time, four tries were uptaken with the use of the entomological scoop, whilst calculating and shooing away honey bees beforehand.

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Only in the case of spring rapeseed the bees were not counted before shooing away. On the plantations, eight Moericke's traps were placed. These were yellow containers placed on stakes (at the height of the plants). Vessels were half full with a mixture of water and glycol with a few drops of a detergent that decreases the surface tension of liquids, so that the caught insects could not fly away. They were placed 20 meters away from the edges, on every side of the field. Vessels were controlled every 7 to 12 days. Caught insects were transported to the laboratory of the Department of Applied Entomology, where they were segregated and characterised in regard to quantity and quality, and the species were marked according to keys. In the studies, also specimen dominance (D) was determined, that is the percentage participation of a given species at given stations. For a descriptive presentation of the value of the D indicator, five domination classes were established:

- D5 – eudominants – over 10% of the total of the collected specimens of the compared taxonomic group,
- D4 – dominants – from 5.1 to 10%,
- D3 – subdominants – from 2.1 to 5%,
- D2 – recedents – from 1.1 to 2%,
- D1 – subrecedents – under 1%.

Results and discussion

Analysis of the collected faunistical material in the studied winter and spring rapeseed habitats showed the occurrence of 56 insect species that belonged to five orders: *Coleoptera*, *Hemiptera*, *Hymenoptera*, *Diptera*, and *Lepidoptera.* The highest number of species (39) was collected in 2006 from spring rapeseed situated in the village of Knieja, a little bit less in 2007 from winter rapeseed in Gołębin (30), and the least in Koszanowo (24) – Table 1. In Poland, studies on the occurrence of insects on winter rapeseed were conducted by Mrówczyński et al. (2006). They concluded that ca. 30 pest species fly on rapeseed, and they attack the plants starting from the rise until the end of the vegetation period. Also on spring rapeseed numerous phytophages occur with regard to both quality and species (Murawa et al. 1996; Sądej et al. 1996). These plants are also occupied by many useful insect species, as well as by species that do not pose any threat. These are natural enemies of pests that limit their numbers, pollinating insects, and also species indifferent to rapeseed, which develop on growing weeds (Mrówczyński 2003).

As results from Table 1, in the collected material, phytophage species were dominant (22), whereas zoophages were fewer (14).

On spring rapeseed, 23 phytophage species and 14 zoophage species were fund, and on winter rapeseed, at both stations, the most numerous group was also phytophages: in Gołębin 21 species were noted and in Koszanowo – 16. Zoophages occurred less numerously: in Gołębin 7 species were noted and in Koszanowo – 6.

On the spring rapeseed plantation, the greatest number of species from orders *Hemiptera* and *Coleoptera* was noted, whereas on the winter rapeseed plantations, the order richest in species was beetle.

Table 1. List of insect species caught with the entomological scoop into Moericke's traps; P1 – spring rapeseed, station in Knieja 2006, P2 – winter rapeseed, station in Gołębin 2007, P3 – winter rapeseed, station in Koszanowo 2007, F – phytophages, Z – zoophages, U – useful (pollinators), S – feeding on spawn

No.	Order/family/species	P1	P2	P3	Feeding group
I	*COLEOPTERA*				
	Coccinellidae				
1	*Adalia bipunctata* L.	+	+	+	Z
2	*Coccinella septempunctata* L.	+	+	+	Z
3	*Coccinella quinquepunctata* L.	+			Z
4	*Coccinella quatuordecimpustulata* L.	+			Z
5	*Psyllobora vigintiduopunctata* L.	+			S
	Carabidae				
6	*Amara aenea* L.		+	+	F
	Nitidulidae				
7	*Cryptarcha strigata* F.		+	+	F
8	*Meligethes aeneus* F.	+	+	+	F
	Contharidae				
9	*Cantharis fusca* L.	+	+	+	Z
10	*Rhagonycha fulva* Scop.	+			Z
	Malachiidae				
11	*Malachius bipustulatus*	+			Z
	Curcurlionidae				
12	*Ceutorhynchus sulcicollis* Payk.		+	+	F
13	*Ceutorhynchus quadridens* Marsh.		+		F
14	*Ceutorhynchus assimilis* Payk.	+	+	+	F
15	*Ceutorhynchus pleurostigma* Marsh.			+	F
	Chrysomelidae				
16	*Psylliodes chrysocephala* L.		+	+	F
17	*Phyllotreta nemorum* F.	+			F
18	*Phyllotreta undulata* F.	+			F
19	*Phyllotreta atra* F.	+			F
20	*Oulema melanopa* L.	+			F
	Elateridae				
21	*Agriotes lineatus* L.		+		F
II	*HEMIPTERA*				
	Heteroptera				
	Miridae				
22	*Lygus pratensis* L.	+	+		F
23	*Lygus rugulipensis* Popp.	+	+	+	F
24	*Lygocoris lucorum* Mey.-D.	+			F
	Pentatomidae				
25	*Corpocoris fuscispinus*		+	+	F
26	*Aelia acuminata* L.	+	+		F
27	*Eurydema oleraceum* L.	+	+	+	F
28	*Eurydema ornatum* L.	+			F
29	*Pentatoma rufipes* L.	+			F
30	*Coreus marginatus* L.	+			F
31	*Dolycoris baccarum* L.	+			F
	Nabidae				
32	*Nabis ferus* L.	+			Z
33	*Nubis* (*Himacerus*) *apterus* F.	+			Z

	Anthocoridae				
34	*Orius minutus* L.	+			Z
35	*Orius niger* Wolff.	+			Z
36	*Anthocoris nemorum* L.	+		+	Z
	Homoptera				
	Aphididae				
37	*Brevicoryne brassicae* L.	+			F
	Jassidae				
38	*Macrosteles laevis* Rib.	+	+	+	F
39	*Empoasca pteridis* Dahlbom	+			
IV	*HYMENOPTERA*				
	Apidae				
40	*Apis mellifera* L.	+	+	+	U
	Ichneumonidae				
41	*Phradis interstitialis* Thomson	+	+	+	Z
42	*Phradis morionellus* Hol.				Z
43	*Tresilochus heterocerus* Th.		+	+	Z
	Pteromalidae				
44	*Prosactogaster* sp.		+		Z
	Tenthredinidae				
45	*Athalia colibri* Christ.	+			F
V	*DIPTERA*				
	Cecidomyiidae				
46	*Dasyneura brassicae* Winn.	+	+	+	F
	Anthomyiidae				
47	*Phorbia brassicae* Bche.		+		F
	Chloropidae				
48	*Oscinella frit* L.		+	+	F
49	*Chlorops pumilionis* Bjerk.		+	+	F
	Syrphidae				
50	*Myathropa florea* L.		+	+	U
51	*Episyrphus balteatus* Deg.	+	+		Z
52	*Metasyrphus corollae* F.	+			Z
	Bibionidae				
53	*Bibio hortulanus* L.		+		F
VI	*LEPIDOPTERA*				
	Plutellidae				
54	*Plutella xylostella* L.		+	+	F
	Noctuidae				
55	*Agrotis segetum* Schiff.	+	+	+	F
	Pieridae				
56	*Pieris rapae* L.	+			F

In Table 2, specimen dominance (D) is shown of the insects that occupy the analysed plants. From the collected 56 species, 1% threshold was surpassed only by eight species. The most important phytophages of winter and spring rapeseed were three species: *Meligethes aeneus*, *Dasyneura brassicae*, and *Ceutorhynchus assimilis*, which surpassed the 5% number threshold. Klukowski et al. (2006) also recognized these species as important rapeseed pests.

Table 2. Specimen dominance; D5 – eudominants, D4 – dominants, D3 – subdominants, D2 – recedents, D1 – subrecedents

D Dominance class	Knieja spring rapeseed		Gołębin winter rapeseed		Koszanowo winter rapeseed	
	species name	%	species name	%	species name	%
D5 >10%	*Meligethes aeneus*	70.9	*Dasyneura brassicae* *Meligethes aeneus*	37.0 23.1	*Meligethes aeneus* *Dasyneura brassicae*	33.1 24.3
D4 5.1-10%	*Ceutorhynchus assimilis*	5.3	*Apis mellifera*	9.7	*Apis mellifera*	5.3
D3 2.1-5.0%	*Dasyneura brassicae*	2.3	*Bibo hortulanus*	2.2	none	
D2 1.1-2.0%	*Phradis morionellus*	1.2	none		*Psylliades chrysocephala*	1.2
D1 <1%	34 species		26 species		20 species	

Pollen beetle was included in the class of eudominants (>10%) at all the stations, and on the plantation of winter rapeseed in Koszanowo and Gołębin – also brassica pod midge. In Poland, pollen beetle is classified as one of the most dangerous rapeseed pests, which can lower seed yield even by 30% (Sądej et al. 1996; Korbas et al. 2008). Walczak et al. (2009), through the analysis of the average pollen beetle harmfulness in the country, stated that in years 1997-2008 it did not surpass the long-term average of ca. 12%. Authors suggest that the weather conditions present for many years in the majority of the area were not conducive to the development of this pest. Following the harmfulness of brassica pod midge (Walczak et al. 2009), in comparison with the long-term value of 4%, the authors noted it at the level of 3.6% in year 2007 and minimally higher in year 2008.

In the dominants group on winter rapeseed, honey bee could be found, and on spring rapeseed – seed weevil. Honey bee is a very important pollinator, since it is characterized by "flower fidelity", which consists in visiting the flowers of only one plant species by nectar and pollen collectors. They move to others only when rapeseed flowers cease blooming. Thanks to this, they are very productive pollinators, as they carry proper pollen from flower to flower (Jabłoński 1998). Cross pollination contributes to the earlier and even maturation of lowland meadow, which facilitates harvest and counteracts rapeseed capsule dropping (Kelm et al. 2003). In many regions of Poland, a decrease in rapeseed yield as a result of the damage of forming capsules by seed weevil and brassica pod midge may be observed. Larvae of those pests occur in capsules at the same time, and therefore the conducted operations fight both pests simultaneously. Average in the country capsule damage in 2008 was 4.3% and was slightly higher than in 2007 (3.6%; Walczak et al. 2009).

Species classified as subdominants are brassica pod midge, which occupies spring rapeseed plantations, and Bibio hortulanus caught in Gołębin on winter rapeseed. Bibio hortulanus are only sporadically found on cultivated plants but after a long-term break, their mass occurrence has been found in some regions. They occur the most numerously on plants cultivated on fresh dung whose smell attracts flies even from rather long distances (Wrzesińska 2007).

Among recedents, two species were distinguished: in Knieja *Phradis morionellus*, and in Koszanowo cabbage stem flea beetle. Parasitoids *P. morionellus* were caught numerously during rapeseed full blooming. They belong, next to *P. interstitialis*, to the most well-known pollen beetle parasites. Studies by Wiliams (2006) and Klukowski (2008) showed that on rapeseed plantations *P. interstitialis* appears the earliest, and in the middle of blooming – *P. morionellus*. They damage pollen beetle larvae by lying eggs inside them. Parasitoids develop in the host until they reach maturity (Billqvist and Ekbom 2003; Wiliams 2006).

Species classified as subrecedents, that is not numerous, whose percentage participation was lower than 1%, were not analysed. In Knieja, there were 34 such species, in Gołębin – 26, and in Koszanowo – 20 (Table 2).

Dynamics of number of the dominant insects is presented in Figures 1-6. The most numerous species that occurred on rapeseed at all three stations was pollen beetle (Figs. 1-3). The most beetles were caught using scooping, fewer with the use of Moericke's traps. Together, on spring rapeseed 2150 beetles were collected, and on winter rapeseed, at both stations – 1379.

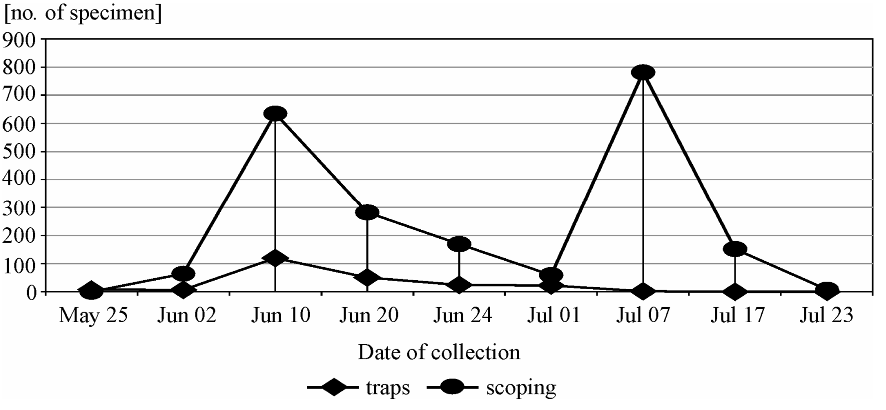

Fig. 1. Dynamics of number of *Meligethes aeneus* F. collected with the use of an entomological scoop and Moericke's traps in the village of Knieja (in 2006)

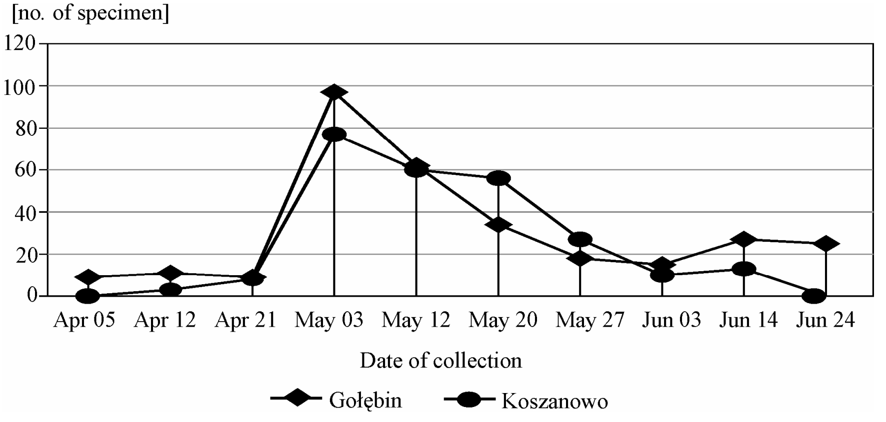

Fig. 2. Dynamics of number of *Meligethes aeneus* F. on winter rapeseed in Koszanowo and Gołębin caught in Moericke's traps (in 2007)

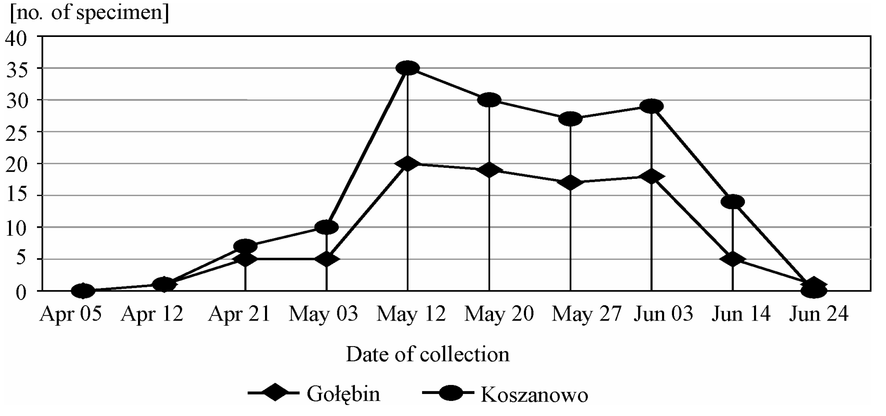

Fig. 3. Dynamics of number of *Meligethes aeneus* F. on winter rapeseed in Koszanowo and Gołębin caught with the use of an entomological scoop (in 2008)

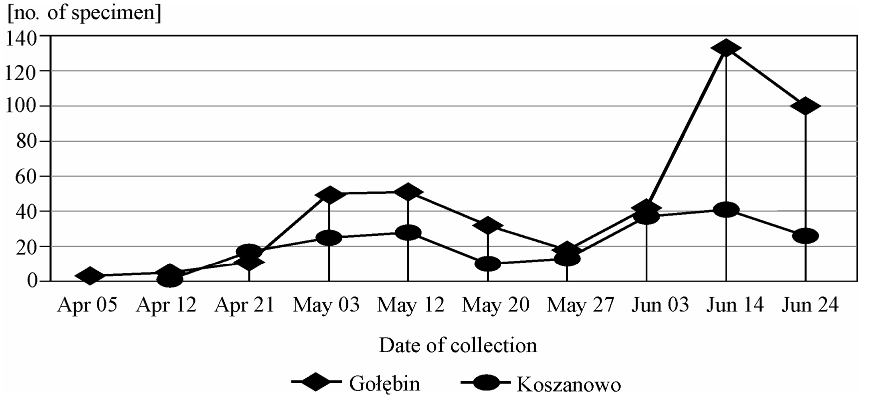

Fig. 4. Dynamics of number of *Dasyneura brassicae* in Koszanowo and Gołębin caught in Moericke's traps (in 2006)

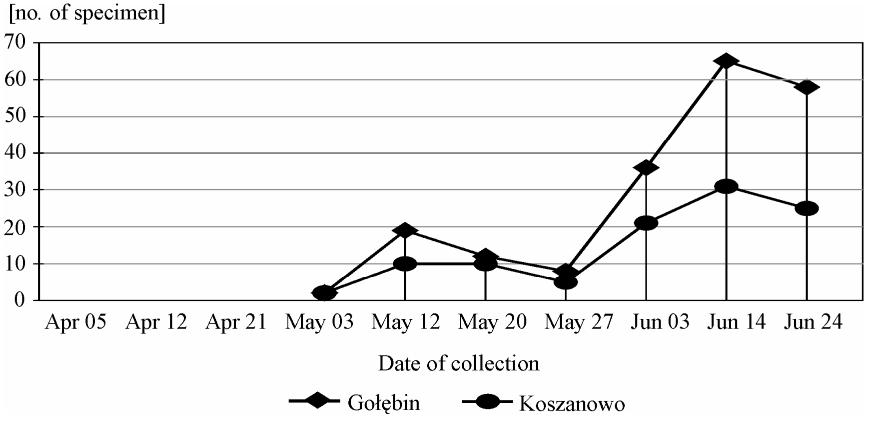

Fig. 5. Dynamics of number of *Dasyneura brassicae* in Koszanowo and Gołębin caught with the use of an entomological scoop (in 2007)

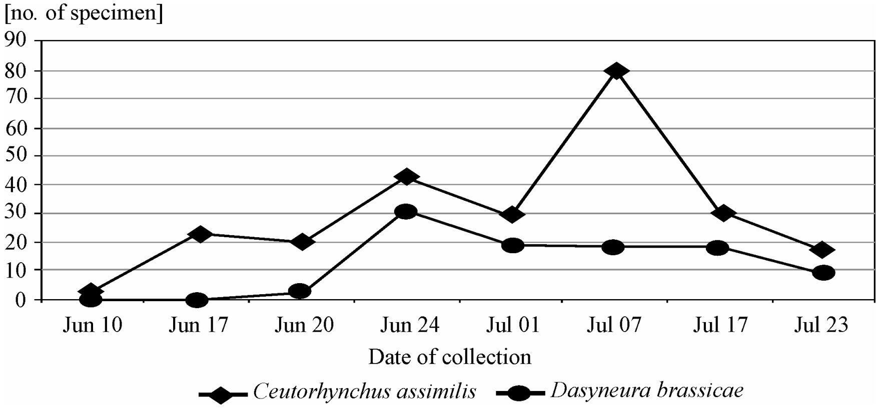

Fig. 6. Dynamics of number of *Ceutorhynchus assimilis* and *Dasyneura brassicae* on spring rapeseed in the village of Knieja (in 2006)

First pollen beetles on spring rapeseed appeared in water traps when the plants were in the two leaves phase. Intensive imagines run started when rapeseed was in the close bud phase. On June 17, 635 adult specimens were found in one trial caught with the use of an entomological scoop. Therefore, in fear of rapeseed further growth and development, chemical control was applied. After the operation, an increase in the number of the pest was noted, which lasted until July 7. On the following days, an increase in the number was noted (781 beetles). Rapeseed at that time had already developed capsules, and therefore imagines did not pose a threat to it any more. Later, the number of the pest started to decrease drastically (Fig. 1). Studies by Sądej et al. (1996) confirm the significant participation of pollen beetle and its great intensification during rapeseed bud forming. Also the studies by Murawa et al. (1996) show the numerical dominance of pollen beetles.

On winter rapeseed at both stations, significantly fewer pollen beetles were caught than on spring rapeseed. In Moericke's traps on the plantation in Gołębin and Koszanowo, the total of 565 specimens were found, and in the trials conducted with the use of an entomological scoop – 814 specimens. First imagines were observed in the rapeseed close bud phase (Fig. 2). The most numerous run was ascertained in the second decade of May. In the following trials, the number of imagines slowly started to decrease. Beetle number distribution at both stations was similar (Figs. 2 and 3). The most pollen beetles, in scoop trials, were collected on the plantation in Koszanowo, and fewer in Gołębin (Fig. 3).

The most numerous species on the winter rapeseed plantation in Gołębin was brassica pod midge, which made up 37.0% of the total collected entomofauna, whereas in Koszanowo it came second after pollen beetle (24.3%; Table 2). Adult flies appeared during winter rapeseed full blooming, that is in the first decade of May. Their most numerous run took place when the plants reached technical maturity, that is in the second decade of June. In the studied locations, fly number distribution was similar up to the beginning of seed maturity. In the following developmental phases, an increase in the brassica pod midge population was observed only in Gołębin. Starting from the technical maturity phase, a sudden decrease in the number of the pest took place (Figs. 4 and 5).

On the spring rapeseed plantation, second most numerous species was seed weevil. Its participation made up 5.3% of all the collected insects. Seed weevil appeared in the bud-forming phase. Its highest number was present when ca. 50% of the capsules reached their typical size. Later, the number of seed weevil started to decrease gradually. During the same period, also brassica pod midge appeared. Brassica pod midge participation amounted to 2.3% (Fig. 6). According to Mrówczyński et al. (2007b), the enumerated capsule pests cause the greatest damage to spring rapeseed. Moreover, spring rapeseed undergoes greater damage than winter rapeseed and does not have an equally great ability to compensate for the resultant losses as the winter form (Mrówczyński et al. 2005).

Pałosz et al. (1997) and Mrówczyński et al. (2005; 2007a) underscore the significance and utility of useful plants for keeping ecological balance. They claim that the presence of parasitoids and predators often contributes to keeping the populations of some pests in limited numbers. Even though entomophages are not able to reduce harmful insects sufficiently, they play a role of an auxiliary factor and utmost should be done in order for the number of these insects not to diminish. Also rapeseed pollination by bees and other insects is one of the most important elements in integrated plant protection.

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ENVIRONMENTAL REQUIREMENTS FOR DEVELOPMENT OF AGRICULTURAL PRODUCTION AND OF RURAL AREAS IN THE KUYAVIAN-POMERANIAN PROVINCE

OCCURRENCE OF PIGMENTS IN THE LEAVES OF *Lamiaceae* COVER PERENNIALS DEPENDING ON THE CULTIVATION STAND OF PLANTS

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The perennials suggested for planting in the ground are more and more frequently represented by, besides flowering plants, species and cultivars with ornamental leaves. And although the colour pallet of that plant group is not that wide as in the case of plants producing flowers, it is a variety of leaf shapes and the growth method and, finally, the forms assumed by plants, which are attractive. Similarly, depending on the stand they are grown in, they can differ not only in their height or habit but also in the leaf colour. The colour depends on the occurrence of anthocyanins, carotenoids and chlorophylls and their ratios in leaves. The aim of the present paper was to provide the qualitative and quantitative analysis of anthocyanins and carotenoids which occur in the leaves of selected perennial species representing *Lamiaceae*, defining their chart colour as well as determining the leaf greening index for plants grown in sunny and semi-shady stands.

Materials and methods

The study involved *Lamiaceae* perennial species and cultivars currently used as cover crops: spotted deadnettle (*Lamium maculatum* L.) 'Beacon Silver' and 'Golden Anniversary', origanum (*Origanum vulgare* L.) 'Aureum' and 'Variegatum', garden sage (*Salvia officinalis* L.) 'Aurea' and 'Tricolor' as well as garden thyme (*Thymus hybridus*) 'Donne Valley' and 'Gold'. Rooted cuttings growing in the peat-and-coconut substrate were planted on May 16, 2005 in the sunny and semi-shady stands at the row spacing of 40 x 50 cm. The semi-shady stand was created by green shade-providing net spreading with the use of 190 cm high pillars. On both stands the phytophotometer was applied to measure quantum irradiance, at the beginning of each month (June through October), always on a sunny day, at noon (Table 1).

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In September 2005 and 2006 there was defined the occurrence of anthocyanins and carotenoids in plant leaves and in 2005 there was additionally measured the leaf greening index (SPAD), namely the chlorophyll content index, also referred to as green colour intensity index. It was defined using Chlorophyll Meter SPAD-502 (Soil and Plant Analysis Development) by Minolta.

Table 1. Quantum irradiance intensity in the sunny and semi-shady stand, measured during plant growing in the ground in 2005 and 2006

Term of measurement	Quantum irradiance [μmol·m^{-2}·s^{-1}]			
	Sunny stand		Semi-shady stand	
	Year 2005	Year 2006	Year 2005	Year 2006
June	1640	1660	610	840
July	1780	1703	740	980
August	1270	1480	490	540
September	1150	1240	460	500
October	730	830	160	270

The analysis involved fresh leaves of randomly selected 8 plants growing in the sunny and semi-shady stand, collected from the second pair of leaves counted from the top of the stem. For each cultivar six weighted portions from the sunny and 6 from the semi-shady stands were prepared; three 100 mg weighted portions were allocated for carotenoid analyses, and the other three 200 mg weighted portions – for anthocyanins analysis. The material was weighed using the analytical balance offering the accuracy up to 0.1 mg. Tissue homogenation was carried out in the porcelain mortar with about 24 mg quartz sand added. Carotenoids were extracted following the Wettstein's method (1957) in which 100% acetone was used and about 24 mg $CaCO_3$ was added, while for anthocyanins the Harborne's method (1967) was used with 1% HCl in methanol. The extracts were filtered through the filtering funnel to the volumetric flask with the capacity of 10 cm^3. The tissue residue in the mortar was rinsed with small portions of solvent filtering the extract to the same flask until the desired volume was obtained. The spectrophotometric extracts analysis was made in a two-beam spectrophotometer UV- VIS 1601- PC SHIMADZU. Absorbance was measured in quartz cuvettes 1 cm in width, at the wavelength range from λ = 500 to 550 nm for anthocyanins and 400-500 nm for carotenoids. Adequate solvents were applied as zero solutions for the extraction of a given group of pigments. The results were analysed with the standard spectrophotometer software for spectrum analysis. Absorption maxima were determined at the wavelength (λ_{max}) characteristic for a given pigment and the average absorbance at a given absorption maximum was calculated.

The quantitative determination of anthocyanins was performed using the algebraic method applying the following formula:

$$c = A/h \cdot k \ [g \cdot dm^{-3}]$$

where:

A – absorbance at the wavelength λ characteristic for a given anthocyanin,
h – layer thickness [cm],
k – specific absorption coefficient.

The calculations made provided the concentration for the sum of anthocyanins converted into cyanidin-3-glucoside. To calculate the specific extinction coefficient, the molar extinction coefficient λ = 26,900 for cyanidin-3-glucoside with the absorption maximum at the wavelength of λ_{max} = 530 nm was applied.

Concentrations of carotenoids were calculated using the coefficient from the Wettstein's (1957) equation:

$$c = 4.695 \cdot A_{440} \,[\mathrm{mg \cdot dm^{-3}}]$$

where:

c – carotenoid concentration,
A_{440} – absorbance at the wavelength of 440 nm.

The results were verified statistically with the analysis of variance for single-factor experiments, separately for each cultivar, and the means were grouped using the Student's t-test at the significance level of p = 0.05.

Additionally, in August 2006 the colour of young and old leaves (in garden sage – also the margin and the middle of the leaf blade) were visually evaluated according to the RHS Colour Chart (1966).

Results

The average concentration of carotenoids, for two study years, in leaves *L. maculatum* 'Beacon Silver', *O. vulgare* 'Aureum', *S. officinalis* 'Tricolor', and *T. hybridus* 'Donne Valley' was higher when the plants were grown in the semi-shady stand. However, in *O. vulgare* a higher carotenoid level occurred in the sunny stand. Only in *T. hybridus* 'Gold' and in *S. officinalis* 'Aurea' no differences in the concentration of these pigments depending on the stand were noted (Table 2). The average concentration of anthocyanins for two study years in perennial leaves representing *Lamiaceae* did not depend on the stand.

The content of pigments in leaves reflected the anthocyanin and carotenoid pigment absorbance level. Due to a considerable number of results, absorption spectra with characteristic absorption maxima are given only in sample Figures 1-2. The presence of carotenoids and anthocyanins was observed by the absorption maximum of characteristic wavelength λ_{max}, in the figures marked with an arrow. Based on that, it was noted that in all the cultivars studied, except for *O. vulgare* 'Aureum' growing in the sunny stand (in 2005), there occured anthocyanins (at the absorption maximum λ = 530 nm) and in all of them – carotenoids (at the absorption maximum λ = 430 nm). In the first year of growing in all the cultivars studied, except for *T. hybridus* 'Gold', there were differences in the level of absorbance of carotenoid extracts from the leaves of plants grown in the sunny and semi-shady stands. Higher absorbance values occurred in plants cultivated in the semi-shady stand and in the sunny stand – only in *O. vulgare* 'Variegatum'. In the second year of cultivation a higher carotenoid absorbance, as compared with the first year of cultivation, in the semi-shady stand was recorded in *S. officinalis* 'Aurea' and *T. hybridus* 'Gold', and over two-fold higher in *O. vulgare* 'Aureum'. In the sunny stand *O. vulgare* 'Variegatum' was the only one which demonstrated higher absorbance values than in the semi-shady stand. *T. hybridus* 'Donne Valley' showed higher absorbance when it was growing in the semi-shady stand.

Table 2. Concentration of carotenoids and anthocyanins, expressed [mg·dm^{-3}] per 1 g of fresh weight, in the leaves collected from eight perennial cultivars grown over 2005-2006 in the ground in the sunny and semi-shady stand, the leaf greening index (SPAD) in the first year of cultivation in the ground (September 2005) and the colour according to the RHS Colour Chart; y – young leaves, o – old leaves, ma – margin of the leaf blade, mi – middle of the leaf blade

Species	Cultivar	Carotenoids		Anthocyanins		Leaf greening index		Colour code	
		stand		stand		stand		stand	
		sunny	semi-shady	sunny	semi-shady	sunny	semi-shady	sunny	semi-shady
L. maculatum	'Beacon Silver'	51.31 a*	71.75 b	33.81 a	27.61 a	24.73 a	25.97 a	137 C (y) 138 C (o)	137 A (y) 138 D (o)
	'Golden Anniversary'	–	–	–	–	28.70 a	25.57 a	–	–
O. vulgare	'Aureum'	27.37 a	52.97 b	13.88 a	28.60 a	0.20 a	18.60 b	11 B (y) 144 A (o)	8 C (y) 138 A (o)
	'Variegatum'	61.78 b	49.90 a	28.05 a	27.71 a	40.23 a	40.24 a	8 C (y) 137 C (o)	144 B (y, o)
S. officinalis	'Aurea'	39.18 a	47.64 a	18.14 a	19.12 a	25.53 a	31.17 b	139 C (mi) 7 A (ma)	144 B (mi) 137 C (ma)
	'Tricolor'	47.00 a	60.56 b	26.51 a	24.78 a	34.53 a	34.10 a	186 ABCD (ma, y) 202 A (mi, y) 2 D (ma, o) 137 A (mi, o)	38 CA (ma, y) 147 A (mi) 18 C (ma, o)
T. hybridus	'Donne Valley'	58.52 a	73.35 b	33.16 a	33.13 a	44.43 a	45.77 a	139 A (y, o) 146 A, 177 A (ma, y)	139 A (y, o)
	'Gold'	42.90 a	50.37 a	19.17 a	22.96 a	25.77 a	26.30 a	144 A (y) 154 B, 165 B (o)	143 A (y, o)

* means within one cultivars marked with the same letter do not differ significantly (p = 0.05)

Differences in the content of pigments in leaves depending on the stand were also confirmed with the RHS Colour Chart (1966). The plants studied differed to a greater or smaller extent in the leaf colour depending on the stand, which reflects the pigment level in leaves (Table 2). There were found no differences only in *T. hybridus* 'Donne Valley', in which the chart colour both in the sunny and in the semi-shady stand was identified as 139 A, however, additionally, the leaf margins in the sunny stand in that cultivar differed in the colour identified as 146 A and 177 A.

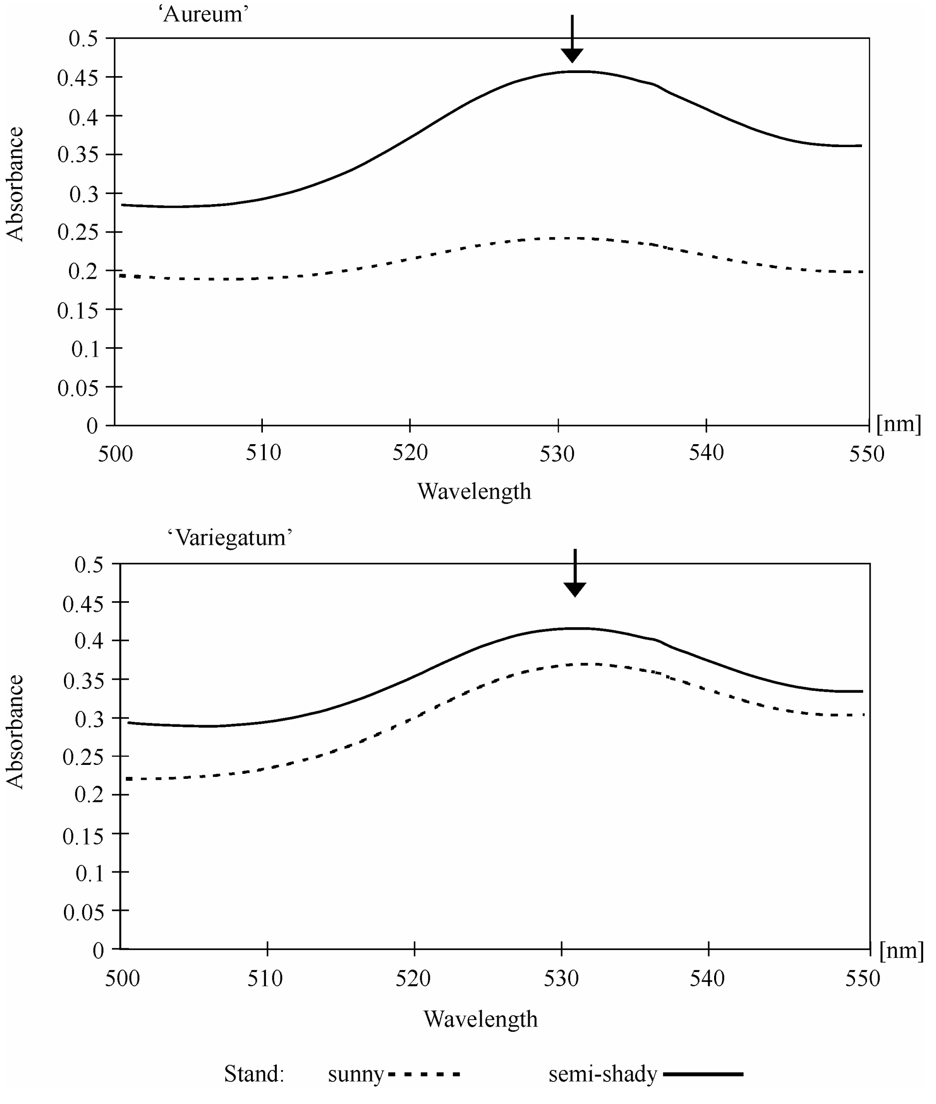

Fig. 1. Absorption spectrum with characteristic absorption maximum for anthocyanins (λ = 530 nm) in two *O. vulgare* cultivars in the second year of cultivation (2006) depending on the stand

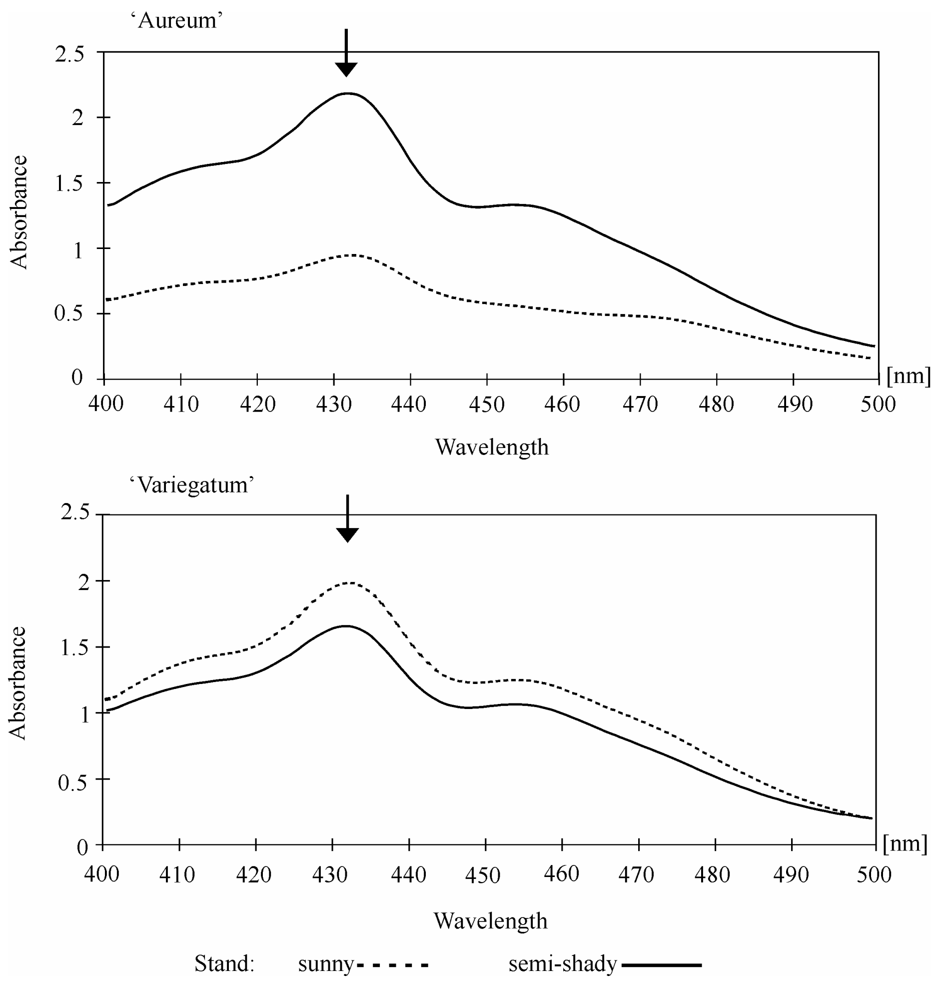

Fig. 2. Absorption spectrum with an absorption maximum characteristic for carotenoids (λ = 430 nm) in two *O. vulgare* L. cultivars in the second year of cultivation (2006) depending on the stand

The assessment of the colour change, depending on the stand, was also facilitated by the measurement of correlated with the content of chlorophyll. Almost 100-fold higher stay-green rating value was recorded in *O. vulgare* 'Aureum' grown in the semi-shady stand. Similarly the leaf greening index value in *S. officinalis* 'Aurea' was also higher (Table 2).

Discussion

According to Solecka (1987), it is possible to determine the plant colour precisely using the colorimetric or spectrophotometric and liquid chromatography methods. Defining the colour with the Hunter colorimeter is based on the measurement of lightness, content of red colour, or possibly green or yellow, or possibly blue colour. Liquid chromatography, according to Solecka (1987), is applied to determine the colour of the cultivars covered by the patent. The spectrophotometric method developed for the first time by Shibata (1958) is objective, accurate and relatively simple. Identifications based on the composition of pigments which occur in ligulate florets of ornamental plants, using the spectrophotometric method, have been performed by Kawase and Tsukamoto (1974; 1976), Datta and Gupta (1983), Asen (1984), Solecka (1987), Olszewska-Kaczyńska and Chmiel (2002) as well as Lema-Rumińska (2004; 2005), thus allowing for identifying and differentiating between many ornamental plant cultivars of a very similar inflorescence colour.

However, the applicable literature offers no reports on the occurrence of pigments in ornamental plant leaves. In the present experiment, thanks to the spectrophotometric method, it was found that each of the cultivars studied of *L. maculatum*, *O. vulgare*, *S. officinalis*, and *T. hybridus* has the same set of pigments which occur at characteristic wavelengths. Over two study years the general absorbance level changed, however absorption maxima at specific wavelengths remained the same. Changes in the absorbance level according to Lema-Rumińska (2004; 2005) can be due to different light conditions over growing. Griesbach (1992) and Bach et al. (1997) also report on the biosynthesis of anthocyanins being stimulated by light and temperature. In the present experiment selected *Lamiaceae* perennial cultivars were grown in the sunny and semi-shady stands. The stand was identified not to have a significant effect on the quantitative anthocyanins composition in the leaves of the cultivars studied. One can assume that the amount of pigments in florets or leaves is considerably affected by the genetic information. Zalewska et al. (2002) report on the kind and amount of pigments in the inflorescence in *Dendranthema grandiflora* Tzvelev being mainly determined by the genetic information contained in respective kinds of buds since in the cultivars studied they were formed under similar photothermal conditions but they differed significantly in the quantitative anthocyanin composition. Similarly Holton and Cornish (1995) claim that the pigment distribution is most frequently the effect of gene expression controlled by promoters reacting to the light intensity or the irradiation quality. A lack of significant differences in the concentration of anthocyanins in the leaves of plants selected for the experiment, however, does not necessarily mean that the anthocyanins cannot affect the leaf colour. On shall bear in mind the specific copigmentation which can occur between respective anthocyanidins and carotenoids. Olszewska-Kaczyńska and Chmiel (2002) defined the content and distribution of chlorophylls, carotenoids and anthocyanins in fresh leaves of the perianth in five clones *Hippeastrum* x *chmielii* and concluded that the differences in the colour intensity of their flowers are mostly attributed to the copigmentation between the kinds of anthocyanidis and carotenoids. Griesbach and Batdorf (1995), investigating the qualitative and quantitative composition of pigments in *Hemerocallis fulva* L. determined the content of anthocyanins and carotenoids by applying additionally thin-layer chromatography (TLC) method, which made it possible for them to notice that the differences in the flower colour in *H. fulva* cultivars were mainly due to different ratios of anthocyanidin and carotenoids as well as the kind of anthocyanidin. Yamaguchi et al. (1990), however, observed that the intensive red flower colour in *Zinnia elegans* Jacq is mostly conditioned by pelargonidin. Bearing that in mind, it seems justifiable to perform further research to determine the qualitative and quantitative anthocyanins composition in the leaves of perennials selected for the present study.

The following cultivars: *L. maculatum* 'Beacon Silver', *O. vulgare* 'Aureum' and *S. officinalis* 'Tricolor', and *T. hybridus* 'Donne Valley' grown in the semi-shady stand demonstrated significantly higher content of carotenoids than in the sunny stand. Presumably significantly higher content of carotenoids in the leaves of these cultivars can be related to the function of ‘power antenna’ played by carotenoids next to chlorophylls in chloroplasts, also in the situation when the light access is limited. Dżugan (2006) stresses that chlorophylls together with carotenoids participate in the process of absorption of light energy and its transformation to chemical energy, used in the endoergic synthesis of organic compounds from simple substances: CO_2 and H_2O. In the present experiment *O. vulgare* ‘Variegatum’ was the only one which showed a higher content of carotenoids when it was growing in the sunny stand. One can assume that it is a cultivar-specific trait connected with the correlation which occurs between chlorophyll and carotenoids during green pigment breakdown. As reported by Perucka (2004), the breakdown of chlorophylls and a parallel decrease in the carotenoid synthesis is connected with the morphological desorganization of chloroplasts which get transformed into chromoplasts, followed by intensified carotenoid synthesis thanks to the phytol released by chlorophylase; phytol is a compound partially participating in the biosynthesis of carotenoids.

In the present study there was also determined the leaf greening index correlated with the content of chlorophyll with the use of chlorophyll meter. It is applied both in the horticultural practice and by scientists (Janowska and Zakrzewski 2005; Startek et al. 2006). The measurements demonstrated that only in *O. vulgare* ‘Aureum’ and *S. officinalis* ‘Aurea’ the leaf greening index assumed higher value when they were grown in the semi-shady stand. One shall assume that chlorophylls in the leaves of plants selected for the experiment as the least persistent plant pigments, easily undergoing changes due to many factors, e.g. high temperature and light, and thus difficult to provide objective investigation and description for, should undergo further and more thorough and more targeted study.

It can be assumed that in the case of leaves the evaluation of the qualitative and quantitative pigment composition will not be used to identify cultivars with ornamental leaves since their differences can be assessed visually using the RHS Colour Chart (1966). Such analysis, however, can be applied in practice to evaluate the leaf colour in ornamental plants growing in different stands, e.g. the sunny and the semi-shady ones since it was demonstrated in a vast majority of *Lamiaceae* cultivars that the stand had a significant effect on the amount of pigments in leaves and, indirectly, on the plant colour.

Conclusions

1. The concentration of carotenoids depended on the stand, and was higher in many cultivars, when the plants were grown in the semi-shady stand.
2. The concentration of anthocyanins did not depend on the stand.
3. The leaf greening index (SPAD) only in two cultivars studied depended on the stand.

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SPATIAL VARIABILITY OF SOILS OF THE KUYAVIAN-POMERANIAN REGION IN THE ASPECT OF TRACE ELEMENTS CONTENT AND AVAILABILITY

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According to the physiographic division, the Kuyavian-Pomeranian region is located in the young glacial area of the South-Baltic Lake Districts (Fig. 1). Its distinctive feature is the occurrence of landscape with a large number of interior hollows and lakes, where hilly morainic plateaus and outwash plains can be distinguished. Regional diversity results from the layout of marginal forms of particular stages of glaciation period and fragmentation of plateaus by valleys of main rivers and their tributaries, as well as from differences of geographical position. Main geomorphological forms are flood cut-and-built and accumulation terraces, meadow cut-and-built terraces, bottoms of river valleys and old river-beds, alluvial cones and outwash and fluvioglacial plains. Moreover, in these valleys occur peat-gyttja plains, small valleys, flat-bottomed accumulation valleys, long slopes, hollows formed after dead ice, plains of dune sands, denudation valleys and small valleys etc. (Listkowska 1988; Kozłowska and Kozłowski 1990, 1992; Kondracki 2000).

Large geomorphological differentiation of the Kuyavian-Pomeranian region is reflected in the spatial variety of the soil cover. Soils that occur on this territory involve podzol soils, lessivé soils, cambisols, black earths, alluvial soils, mud-mineral soils, mud-peat soils, peat soils and muck-peat soils (Arenosols, Luvisols, Cambisols, Phaeozems, Fluvisols, Histosols – acc. to Word Reference Base for Soil Resources). The communes with the highest typological diversity are as follows: Gąsawa, Kcynia, Łabiszyn, Nakło, Pakość, Pruszcz, Szubin, Tuchola and Warlubie (Dąbkowska-Naskręt 1998).

Climate prevailing in the area of the Kuyavian-Pomeranian Province is classified as transitional climate of temperate zone, and its territorial variability is small, coming up to 6%. The mean yearly temperature amounts to 7.8°C and is characterized by parallel distribution (lower temperatures in the north). The length of the thermal winter (temperature below 0°C) is 75 days, and that of the thermal summer (above 15°C) is 89 days. The length of growing season (above 5°C) amounts to 216 days. In this period from 60 to 64% annual precipitation are recorded, the mean annual amount of which (mean of 30 years) is 535 mm. The most rainy months of the year are June and July, and

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the lowest precipitation is observed in February. Thermal and energy conditions of the region are good, and the rate of total solar radiation is within the range from 830 to 850 kWh·m^{-2}. Long-term data indicate the prevalence of westerly winds (Peszek 1996; Żarski and Dudek 2000). According to the division of Poland into climatic regions, the Kuyavian-Pomeranian Province includes 4 regions: East-Pomeranian, Low Vistula, Chełmno-Toruń and Middle-Greater Poland (Woś 1999).

For many years the Kuyavian-Pomeranian region has been an area under intensive study of soil cover. In the Department of Soil Science and Soil Protection UTP research on the content and availability of trace elements in the soils of the Kuyavian--Pomeranian region has been carried out since the middle of 1970s. The subject of this research was soils used in agriculture and forest soils as well as the areas of urban agglomerations and lands potentially exposed to pollution. Complex results obtained from the analysis of surface, subsurface and profile samples of the majority of soil types in this region make it possible to assess not only the state and rate of changes occurring in these soils and also to estimate the range and direction of further studies. This is particularly essential due to the effect of changing soil use and environmental pollution. The type of agriculture is connected mostly with the type of crop (monocultures, mixed crop system) and the amount of expenditures, as well as the method of management and land property system (private, tenancy) (Bockstaller et al. 1997; Dąbkowska-Naskręt and Długosz 2002). This involves also an application of different doses of mineral fertilizers, slurry, liquid or stable manure and utilization of wastes of different origin for soil fertilization (Kluczek et al. 1989; Kucharski 1989; Bartoszewicz 1994). Moreover, changes occurring in the soils of the region result from pollution with toxic dusts and gases emitted by industry, transport and motorization as well as from the action of landfills of solid and liquid municipal wastes (Dąbkowska-Naskręt and Długosz 2002).

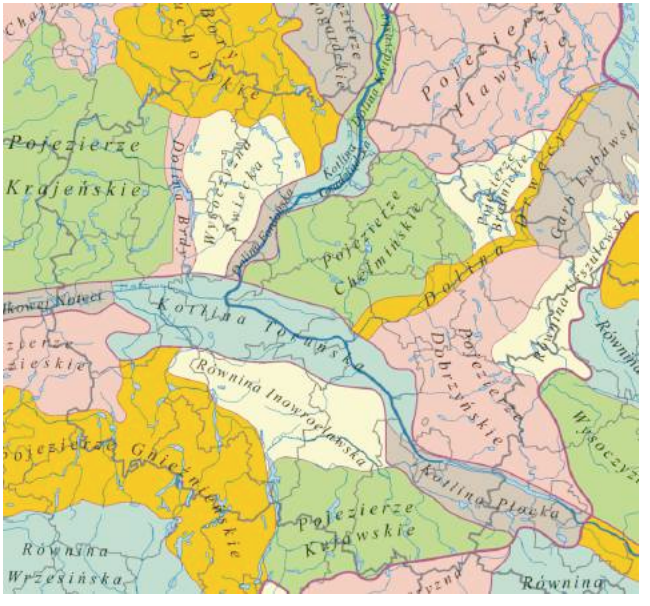

Fig. 1. Kuyavian-Pomeranian Province on the background of physico-geographical regionalization of Poland (Kondracki 2000)

The study carried out in the Kuyavian-Pomeranian region concerns trace elements such as zinc, copper, lead, nickel, cadmium, chromium, mercury and selenium in soils.

Zinc

The total content of zinc in the soils of the region is highly varied. In arable and forest soils this content ranges from 2.81 to 532.09 mg·kg^{-1}, not exceeding on average 50 mg·kg^{-1} (Cieśla et al. 1994; Dąbkowska-Naskręt 1994; Dąbkowska-Naskręt et al. 1996a, 1996b, 2000a, 2000b; Dąbkowska-Naskręt and Kędzia 1996a; Dąbkowska--Naskręt and Jaworska 1997b; Jaworska et al. 2002a, 2002b; Różański 2006). These values mostly classify the tested soils as not polluted soils with the natural content of zinc (Kabata-Pendias et al. 1993; Regulation of Ministry of Environment 2002). Most often the soils of the region are characterized by zinc content corresponding to geochemical background values, which according to different authors is from 5.0 to 59.0 (on average 30) mg·kg^{-1} (Czarnowska 1996) and from 6 to 150 (on average 36) mg·kg^{-1} (Czarnowska and Gworek 1987). Such wide ranges are connected with a large typological diversity of soils and different origin of the parent material. These factors along with the distance from pollution sources had predominant effect on the spatial variability of zinc content and its profile distribution in the tested region.

The highest zinc content was observed both in the surface horizons of arable soils and in surface organic horizons of forest soils (Malczyk 1996b; Dąbkowska-Naskręt and Bartkowiak 2001; Różański 2006). Relatively high, and in some cases the highest in the profile, contents of zinc were also found in soil enrichment horizons (lessivé soils, cambisols, black earths) (Dąbkowska-Naskręt et al. 1996b; Dąbkowska-Naskręt and Jaworska 1997b; Jaworska et al. 2002b; Różański 2006). Parent material horizons of most soils and eluvial horizons of Haplic Luvisols, Haplic Arenosols and Haplic Podzols were characterized by the lowest content of this element (Dąbkowska-Naskręt et al. 1996b; Malczyk 1996b; Dąbkowska-Naskręt and Bartkowiak 2001; Różański 2006). Alluvial soils were the soils of the highest variability in zinc content, both spatial and profile. The extreme content of this element was recorded in alluvial soils of the Low Vistula Valley, mainly according to the location (distance from the river bed) and texture. Furthermore, the specific genesis of soils formed from alluvial deposits (processes of sedimentation) affected the profile differentiation of zinc (Dąbkowska--Naskręt 1990, 1994; Dąbkowska-Naskręt and Kędzia 1996a; Różański 2006).

Spatial differentiation of total zinc content in the studied region is also dependent on the distance from pollution sources. Large accumulation of this metal was found in the soils of urban agglomerations. These are mostly urbanozems and culturozems occurring in cities within parks, squares and allotment gardens. The total contents of zinc in these soils remarkably exceed geochemical background values (20.02-896.25 mg·kg^{-1}), and the soils are classified as 1, 2 and even 3 degree of pollution with this metal (Kabata-Pendias et al. 1993; Malczyk et al. 1996; Dąbkowska-Naskręt and Kobierski 1997, 1998; Dąbkowska-Naskręt and Różański 2002, 2006).

The second group consists of arable and forest soils located in the vicinity of industrial plants. The content of zinc in these soils is higher as compared with soils of the same type distant from point pollution sources. In the soils of the neighborhood of the cement and lime industry plant (Bielawy), the nitrogen fertilizers plant (Włocławek) or the soda plants (Janikowo, Mątwy), instead of the high content of trace elements in emitted dusts, the content of zinc slightly exceeds the natural content, and these soils are classified as soils unpolluted with this element (Kabata-Pendias et al. 1993; Dąbkowska-Naskręt and Jaworska 1997a). This content is within the range from 6.0 to 65.0 mg·kg^{-1}, most often not exceeding 40 mg·kg^{-1} (Dąbkowska-Naskręt and Dymińska 1996; Malczyk 1996a; Dąbkowska-Naskręt et al. 1997; Dąbkowska-Naskręt et al. 2002; Jaworska et al. 2002a, 2002b).

The third group of soils with an increased zinc content are soils located along traffic routes. The study carried out indicated an increased zinc content in soils in the immediate vicinity of roads. At a distance more than 100 m in the majority of these soils the natural content of this metal was found (Malczyk and Kędzia 1996b; Dąbkowska-Naskręt and Bartkowiak 2000).

Due to a high differantiation of zinc content in soils and different land use (in the studied region, mostly agricultural), it is essential to determine the proportion of mobile and phytoavailable forms in the total content of this metal. Content of mobile forms allows the determination of deficiency of a given element for plants, as well as threats resulting from its excess in the event of pollution. The study carried out made it possible to state that zinc availability in the soils tested was not related exclusively with the total content of this metal, but also with the content of organic matter, soil pH, texture and the content of iron and manganese oxides (Dąbkowska-Naskręt and Dymińska 1996; Dąbkowska-Naskręt and Kędzia 1996a; Dąbkowska-Naskręt and Bartkowiak 2001).

In arable soils, the content of zinc in forms available to plants was within the range from 0.1 to 15.7 mg·kg^{-1}, which accounts for 0.4 to 17.4% the total content (Dąbkowska-Naskręt 1994; Dąbkowska-Naskręt and Kędzia 1996a; Dąbkowska-Naskręt and Jaworska 1997b; Dąbkowska-Naskręt et al. 2000a; Dąbkowska-Naskręt and Bartkowiak 2001). Such content of phytoavailable zinc in most soils constitutes the sufficient amount of this element in plant nutrition (Dąbkowska-Naskręt and Jaworska 1997b). There are, however, areas in the region where deficiencies of this element may occur (Cieśla et al. 1994). The lowest content of mobile forms of zinc was found in soils adjacent to the cement and lime plant (0.42-2.9 mg·kg^{-1}). This was mostly caused by alkalization of the soils as a result of cement dust deposition (Dąbkowska-Naskręt and Dymińska 1996; Dąbkowska-Naskręt et al. 1997). The highest zinc concentration and at the same time the largest proportion in the total content of this metal was observed in urban soils and along the roads (0.5-142.3 mg·kg^{-1}, 3.0-87%). This results from different composition and properties of these soils, often completely transformed by man (mixing and translocation of soil material, mineral fertilization, fertilization with composts and wastes, deposition of impurities of different origin etc.) (Malczyk et al. 1996; Dąbkowska-Naskręt and Kobierski 1997; Dąbkowska-Naskręt and Bartkowiak 1998, 2000; Dąbkowska-Naskręt and Różański 2002, 2006).

Copper

Copper is an element which is necessary for proper functioning of plants, and it is taken up in direct proportion to its concentration in soil (Kabata-Pendias and Pendias 1999). Therefore, it is essential to know both the total content of this metal and the fraction of easily soluble and exchangeable forms.

The total copper content in the arable soils of the Kuyavian-Pomeranian region ranges from 0.41 to 76.2 mg·kg^{-1} (Cieśla et al. 1994; Dąbkowska-Naskręt 1994; Jaworska 1996; Dąbkowska-Naskręt et al. 1996a, 1996b, 2000a; Dąbkowska-Naskręt and Kędzia 1996a, 1996b; Malczyk and Kędzia 1996a; Dąbkowska-Naskręt and

Jaworska 1997b; Różański 2006). All these soils are classified as not polluted with copper (Kabata-Pendias et al. 1993; Regulation of the Ministry of Environment 2002), and the majority of them are soils with the natural content of this metal not exceeding 10 $mg \cdot kg^{-1}$ (Czarnowska and Gworek 1987; Czarnowska 1996). Copper is an element that is strongly bound by soil organic matter and clay minerals (Kabata-Pendias and Pendias 1999). This is reflected in profile distribution of copper in the soils of the studied regions. Surface horizons of both forest (up to 100 $mg \cdot kg^{-1}$) and arable soils (up to 25.5 $mg \cdot kg^{-1}$) were characterized by the highest copper content (Dąbkowska-Naskręt and Kędzia 1996b; Malczyk 1996b; Dąbkowska-Naskręt et al. 2000a; Różański 2006), as well as enrichment horizons of lessivé soils – up to 27.9 $mg \cdot kg^{-1}$ (Jaworska 1996; Dąbkowska-Naskręt et al. 1996b; Dąbkowska-Naskręt and Kędzia 1996b; Różański 2006). In spatial aspect, the soils of the highest total copper content were alluvial soils of the Low Vistula Valley (up to 76.2 $mg \cdot kg^{-1}$) (Dąbkowska-Naskręt 1994; Dąbkowska-Naskręt and Kędzia 1996a; Różański 2006).

In the arable soils potentially exposed to pollution, located in the vicinity of the industrial plants of the region, copper content found was not higher than geochemical background. Monitoring studies of these soils conducted for many years indicate that copper content ranges from 2 to 30 $mg \cdot kg^{-1}$, of which the highest values were found in the organic horizons of forest soils (Dąbkowska-Naskręt and Dymińska 1996; Malczyk 1996a; Dąbkowska-Naskręt et al. 1997, 2002; Dąbkowska-Naskręt and Jaworska 1997a; Jaworska 2006). Similar values (8-39 $mg \cdot kg^{-1}$) were determined in soils along the traffic routes, where in samples collected from points located at different distance from the road no values exceeding the natural level for copper were found (Malczyk and Kędzia 1996b).

In contrast to other trace elements, the total content of copper in the soils of urban agglomerations does not exceed values found in unpolluted arable soils, ranging from 1.7 to 47.6 $mg \cdot kg^{-1}$ (Dąbkowska-Naskręt and Kobierski 1997, 1998; Dąbkowska-Naskręt and Różański 2002, 2006).

In spite of relatively even distribution of copper content in all the soils of the Kuyavian-Pomeranian region, differences in content of the mobile forms of this metal are quite clearly visible. The lowest content of phytoavailable forms of copper was observed in soils adjacent to industrial plants (from 0.1 to 2.2 $mg \cdot kg^{-1}$). The values are characteristic for soils with alkaline reaction (reaching 8.2 pH in the tested soils) and are close to the critical level in relation to plant nutrient requirements (Dąbkowska-Naskręt and Dymińska 1996; Dąbkowska-Naskręt et al. 1997, 2002). Apart from the impact of industrial plant (cement and lime) emissions, the content of copper forms available to plants exceeds the critical (deficit) values ranging from 0.1 to 5.9 $mg \cdot kg^{-1}$ (0.3-32.5%) (Dąbkowska-Naskręt 1994; Dąbkowska-Naskręt et al. 1996b, 2000a, 2000b; Dąbkowska-Naskręt and Kędzia 1996a; Dąbkowska-Naskręt and Jaworska 1997b). However, there are areas in the Kuyavian-Pomeranian Province where the content of copper available for plants is at the deficit level (Cieśla et al. 1994). The highest contents of mobile forms, remarkably exceeding plant nutrient requirements, were found in the urbanozems of the region (0.1-16.9 $mg \cdot kg^{-1}$) (Kabata-Pendias and Pendias 1999; Dąbkowska-Naskręt and Różański 2002, 2006). This poses a risk of the metal migration into the soil profile and constitutes a potential threat for plants and soil organisms.

Lead

Due to the intensive anthropogenic introduction of lead into the environment and its poor migration, the exact determination of its natural content in soils is quite difficult, and the value given in the literature are often overestimated (Kabata-Pendias and Pendias 1999). The values of geochemical background for Poland soils were determined on average at a level of 9.8 mg·kg^{-1} (Czarnowska 1996) and 10.3 mg·kg^{-1} (Czarnowska and Gworek 1987), and the so-called natural content at a level of 18 mg·kg^{-1} (Kabata-Pendias and Pendias 1999).

The total lead content in arable and forest soils of the Kuyavian-Pomeranian region is within the range from several to 184.3 mg·kg^{-1} (Cieśla et al. 1993; 1994; Malczyk 1996a; 1998; 2000a; Jaworska and Kobierski 1998). Most soils of the region have the natural content of lead (0 pollution level – to 70 mg·kg^{-1}). Small areas it is uncontaminated soils, but with lead content above the natural level, whereas only single samples from the province area can be considered as slightly contaminated, according to IUNG (Kabata-Pendias et al. 1993).

The content of lead in soils surrounding the nitrogen fertilizers plant in Włocławek and the cement and lime plant in Bielawy was similar (6-82 mg·kg^{-1}), but most of them were characterized by a higher content than those commonly found in soils of Kuyavian-Pomeranian region (Malczyk 1996a; Dąbkowska-Naskręt et al. 1997; Dąbkowska-Naskręt and Jaworska 1997a).

Areas with the highest lead content (4.5-288.1 mg·kg^{-1}) in the Kuyavian-Pomeranian region are urban agglomerations and the vicinity of roads with heavy traffic (Malczyk et al. 1996; Malczyk and Kędzia 1996b; Dąbkowska-Naskręt and Kobierski 1997, 1998; Dąbkowska-Naskręt and Różański 2002, 2006). It is worthy of note that areas with the highest content of lead include allotment gardens with fruit and vegetable cultivation (Dąbkowska-Naskręt and Kobierski 1997, 1998). In this situation, research on estimation of trace elements bioavailability level as well as on determination of their content in plants seem to be particularly necessary and justified. The content of mobile forms of lead in soils of allotments in Inowrocław reached up to 28.5% the total content of this element, and its content in lettuce leaves were even 4-times higher than that in plants cultivated in unpolluted area (Dąbkowska-Naskręt and Kobierski 1997, 1998). Such results indicate a need to eliminate these lands from arable use. Also the study of heavy metal content in soil along the roads show an elevated (approximately 100 mg·kg^{-1}) lead content, which should be taken into account when making decision about using of these regions (Malczyk and Kędzia 1996b; Dąbkowska-Naskręt and Różański 2006).

Nickel

The content of nickel in soils is a result of the type of parent material and soil texture as well as its high affinity to organic substances and iron and manganese hydroxides in soil. It particularly easily binds to organic compounds, which results in its high content in fossil fuels. In ashes of some coals, Ni content can even reach up to 1000 mg·kg^{-1}, thus anthropogenic mobilization of the metal is high (Kabata-Pendias and Pendias 1999).

The total content of nickel in the parent material of the soils of Poland ranges from 0.5 to 28.5 mg·kg^{-1} (Czarnowska 1996), and the range from 2.4 to 41.3 mg·kg^{-1} is considered as the natural contents in surface horizons (Czarnowska and Gworek 1987).

Arable and forest soils of Kuyavian-Pomeranian Province belong to soils uncontaminated with nickel and most often are characterized by its natural content. The total Ni content in surface horizons of these soils is within the range 0.9-80 mg·kg^{-1}, whereas in parent material of sandy soils it often assumes values at the detection limit (Cieśla et al. 1993,; 1994; Dąbkowska-Naskręt and Kędzia 1996a; Malczyk 1996b). In mineral horizons of sandy forest soils, the total nickel content often does not exceed 10 mg·kg^{-1}, while in overlying humus horizons it usually is 2-3 times higher (Malczyk 1996a). The highest contents of Ni in soils agriculturally used were found in surface horizons of soils in the area of Dobrzyń upon Vistula, in soils in the area of Chwaliszewo (west part of the Toruń Basin) and in alluvial soils of the Low Vistula Valley (Cieśla et al. 1993, 1994; Dąbkowska-Naskręt and Kędzia 1996a).

In soils adjacent to nitrogen and cement and lime factories, the total contents of nickel were similar, within the range 2 to 35 mg·kg^{-1} (Dąbkowska-Naskręt and Dymińska 1996; Malczyk 1996b; Dąbkowska-Naskręt et al. 1997; Dąbkowska-Naskręt and Jaworska 1997b).

Soils of the Bydgoszcz agglomeration showed certain accumulation of this metal. Considerable part of city soils exhibits an increased Ni content even up to 30 mg·kg^{-1}, and the content found in the small green area in the west part of the agglomeration classifies these soils to 2nd degree of pollution (Malczyk et al. 1996; Kabata-Pendias and Pendias 1999). No pollution with nickel, however, was found in soils of allotment gardens in Inowrocław, where this content ranged from 8.5 to 18.3 mg·kg^{-1} (Dąbkowska-Naskręt and Kobierski 1997, 1998).

In all the tested soils of the region, the content of phytoavailable forms of nickel did not exceed 3.1 mg·kg^{-1} (to 15.7%). With a value of 20 mg·kg^{-1} assumed as toxicity threshold, this permits to state that this amount is not excessive for plants (Dąbkowska--Naskręt and Kędzia 1996a; Dąbkowska-Naskręt et al. 1997).

Cadmium

In the total cadmium content a large proportion constitutes cadmium of anthropogenic origin in soils. It is a metal of the highest accumulation in soils in relation to geochemical background values (Kabata-Pendias and Pendias 1999). In contrast to the majority of trace elements, biogeochemical properties of cadmium are related to a decrease in its sorption with an increase of soil alkalinity; presumably, as a result of its displacing from the sorption complex by cations of alkaline metals, e.g. Ca^{2+}, Mg^{2+} (Laxen 1985). This may pose a problem e.g. with land reclamation, since methods applied to limit the toxicity of other trace metals in soils appear to be not very efficient in the event of pollution with cadmium (Kabata-Pendias and Pendias 1999).

Anthropogenic enrichment of urban soils (especially allotment gardens) with cadmium reaching up to 3.5 mg·kg^{-1} is observed in Inowrocław. This is related to the risk of excessive mobilization of this metal from soils (Dąbkowska-Naskręt and Kobierski 1997; 1998), cadmium translocation deep into the soil profile and incorporating into the food chain (agricultural products). In the soils of Bydgoszcz, the total cadmium content in some areas exceeds even 4 mg·kg^{-1}, and forms available to plants account for up to 31.2% of the total content of this metal (Malczyk et al. 1996; Dąbkowska-Naskręt and Różański 2002, 2006).

A high cadmium content is also observed in soils close to the roads (0.4-2.7 mg·kg^{-1}). It is worthy of note that in studies conducted over several years, an increase of cadmium content was observed in these soils, as well as its elevated (to 1.8 mg·kg^{-1}) level even at a distance of 150 m of the road, which may indicate other emission sources of this metal (Malczyk and Kędzia 1996b).

In general, the majority of arable and forest soils of the Kuyavian-Pomeranian region, also those potentially exposed to pollution, belong to soils with natural cadmium content (up to 1 mg·kg^{-1}) (Kabata-Pendias et al. 1993; Czarnowska 1996). This content ranges from values close to zero to 3 mg·kg^{-1}, and the content of mobile forms does not exceed 0.3 mg·kg^{-1}. Only in soils adjacent to industrial works the mean content of cadmium is slightly higher than that commonly occurred in unpolluted soils (Malczyk 1996a, b; Dąbkowska-Naskręt et al. 1997; Dąbkowska-Naskręt and Jaworska 1997a).

Chromium

Chromium belongs to elements which are not very mobile in soils, mostly due to its occurrence in a slightly soluble form at +3 oxidation state. Considerably smaller amount includes readily soluble compounds Cr^{6+} (Kabata-Pendias and Pendias 1999). Geochemical background for the soils of Poland ranges from 2 to 64 mg·kg^{-1} (on average 27 mg·kg^{-1}), and its contents in soils unpolluted with chromium usually do not exceed 80 mg·kg^{-1} (Czarnowska 1996; Kabata-Pendias and Pendias 1999).

Surface horizons of arable and forest soils of Kuyavian-Pomeranian region contain from 0.9 to 63 mg·kg^{-1}, and the content in parent material ranges from 0 to 27.6 mg·kg^{-1} (Cieśla et al. 1993, 1994; Malczyk 1996a, b). An elevated content of this metal was not found in the studied arable soils or in forests, in contrast to the soils of Bydgoszcz, where in some points it was higher than 100 mg·kg^{-1}. Spatial distribution of chromium in the city was similar to that of nickel and corresponded to the location of pollution sources (mostly roads, heat and power stations, industrial works) (Malczyk et al. 1996). Cr content in profiles of those soils decreased with the depth, below 90 cm ranging from 8 to 28.3 mg·kg^{-1} (Dąbkowska-Naskręt and Różański 2006). Allotment gardens in the area of urban agglomerations corresponded to 0 degree of pollution with chromium, not exceeding 18 mg·kg^{-1} (Dąbkowska-Naskręt and Kobierski 1997, 1998).

Mercury

Mercury is one of heavy metals of the highest toxicity for living organisms. Mercury toxicity is related to the form in which it occurs in the environment. Organic compounds of mercury (mostly methyl- and ethyl mercury), as compared with mineral ones, are noxious at 10 to 100 times lower concentrations for the same organisms (Boening 2000; Gochfeld 2003). From a global perspective, this metal mostly penetrates into the atmosphere, where in the form of gas, fine dusts or aerosols can be transported at very long distances (Lindqvist et al. 1991; Kabata-Pendias 1992). This phenomenon poses a hazard on areas which are potentially unexposed to pollution with this metal. Natural mercury content in the surface horizons of the soils of Poland ranges from 0.008 to 1.11 mg·kg^{-1} (Kabata-Pendias and Pendias 1999).

The soils of the city of Bydgoszcz were characterized by the highest total content of mercury, particularly in the vicinity of heat and power plants and along the roads with heavy traffic. In surface and subsurface samples (to 30 cm) mercury content ranged from 21.49 to 1876.0 $\mu g \cdot kg^{-1}$ (Dąbkowska-Naskręt and Różański 2007). These are increased values in relation to the natural ones, but according to the Regulation of Ministry of Environment (2002), they classify these soils as unpolluted with this metal – i.e. below 2000 $\mu g \cdot kg^{-1}$. Remarkably lower values were found in soils of the city allotment gardens, located far away from the downtown and point pollution sources. In all the research sites mercury content was higher in surface horizons, which proves that it is the fall of dusts and aerosols which is the main source of enrichment in this element. Moreover, it has been proved that mercury in those soils is mostly bound to organic matter (from 24.4 to 75.1%; Dąbkowska-Naskręt and Różański 2002).

Arable soils of Kuyavian-Pomeranian region are unpolluted with mercury, most often containing natural amounts of this metal. In surface horizons, the total content of mercury ranged from 3.06 to 89.11 $\mu g \cdot kg^{-1}$, whereas in subsurface horizons, between 2.69 and 149.53 $\mu g \cdot kg^{-1}$ (Dąbkowska-Naskręt et al. 1999, 2008). Such distribution of mercury confirms its natural (lithogenic) character in the analysed soils. Parent material of cambisols, lessivé soils and black earths of this region, with medium and fine texture, contain from 7.64 to 44.66 $\mu g \cdot kg^{-1}$ of mercury (Dąbkowska-Naskręt et al. 1999).

In forest soils the predominant role of organic matter in mercury binding is particularly clear (Malczyk 2000b). Its total content in organic horizons (93.58-284.36 $\mu g \cdot kg^{-1}$) was several times higher than that in mineral horizons (3.35-167.0 $\mu g \cdot kg^{-1}$) of the soil profile (Dąbkowska-Naskręt et al. 1999, 2008). This is also confirmed by the results of studies which indicate that mercury bound to organic carbon in soil accounts for from 11.83 to 89.9% of the total content of this metal (Dąbkowska-Naskręt et al. 1999).

Potential phytoavailability of mercury determined in arable soils is on average at a level of about 4% of the total content, and the maximal contents of these mercury forms do not exceed 1.32 $\mu g \cdot kg^{-1}$ (Dąbkowska-Naskręt et al. 2008).

Selenium

Selenium is an essential element for animal organisms. Therefore, it is necessary to estimate the abundance of selenium, particularly in soils intended for growing of fodder crops. In the majority of soils, mostly with neutral and acid pH, deficiencies of this element can be observed, mainly due to its low availability (Dudka 1992; Kabata-Pendias and Pendias 1999).

In the Kuyavian-Pomeranian region, detailed studies of selenium contents were conducted in soils in the area of the Bydgoszcz province (old administrative division). Based on a rigid net with a side of 15 km, 47 surface mean samples from arable soils and 13 from forest soils were collected, in which the total content of the element was determined. In spite of rather big differences in respect of texture and organic matter content in soils, selenium content stays within the range 0.10-0.115 $mg \cdot kg^{-1}$. Also from a regional perspective, greater differences are not observed (Krajeńska Plateau, Pałuki, Kuyavia). However, a small upward tendency occurs in Kuyavia (0.127 $mg \cdot kg^{-1}$). By contrast with the low selenium content in arable soils, forest soils, in which selenium was accumulated in overlying humus, distinguish themselves. The mean total content of selenium is 0.556 $mg \cdot kg^{-1}$, staying within the range 0.383-0.936 $mg \cdot kg^{-1}$ (Borowska et al. 1994).

Summary

The Kuyavian-Pomeranian Province includes 65.8% of agriculturally used area and 24.2% of forest lands (GUS 2008). Apart from few sites with elevated content of metals, the soils of this region are uncontaminated with trace elements and mostly characterized by their natural content. The basic factors determining the content and profile distribution of the tested elements in soils were parent material and the type of soil-forming process. Their highest contents were found in soils formed from alluvial sediments and glacial till, and the lowest in soils formed from sands. In profiles of those soils, surface horizons (particularly of forest soils) and enrichment horizons were characterized by the highest concentration. Elevated contents, particularly of zinc, copper, lead and cadmium, were observed mostly in the area of urban agglomerations and in the vicinity of point pollution sources.

In general, the availability to plants of the studied elements is small, which may result in deficiencies, mainly of zinc, copper and selenium, in some parts of the Kuyavian-Pomeranian region. At the same time, the threat of migration of these metals deep into the soil profile is small, even in regions of their higher content.

Pollution with some metals was only found in the urban agglomerations, particularly in the vicinity of industrial plants and traffic routes. Due to this fact, cultivating vegetables and fruit in allotment gardens in Bydgoszcz and Inowrocław should be eliminated.

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PRODUCTION ABILITIES OF PASTURES IN THE NOTEĆ CANAL VALLEY

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In the course of the study carried out (1998-2007), considerable changes took place in Polish agriculture, including permanent grasslands. From the beginning of the 21st century until 2007, their proportion in agriculturally utilized area decreased from 21.7 to 20.2%, and the area from about 3,872 to 3,271 thousand hectares. Such a trend can be partially explained with a general fall of agricultural acreage. However, definitely larger transformation involves the method of permanent grassland utilization. The area of meadows, whose acreage in the years 2000 and 2001 was 2,503 and 2,492, respectively, and in 2007 – 2,497 thousand hectares, practically has not changed during that time. Instead, the area of pastures decreased from about 1,370 thousand hectares in the years 2000 and 2001 to 856 thousand hectares in 2006 and less than 774 thousand hectares in 2007. One can have an impression that cattle feeding on pastures is the least popular form of raising cows and fat stock nowadays. This is in part confirmed by statistic data concerning milk yield per cow, which at that time increased from 3,668 to 4,292 litres. This progress largely results from utilization of ready-made complete concentrated feeds supplemented with silages from forage grasses or maize in cattle feeding and is related to higher production costs (Zastawny et al. 2001; Goliński 2008).

The reason for this situation is a prevailing belief about the small effectiveness of pasture feeding. This results from difficult assessment of pasture efficiency, whose production, as the only one of agriculturally utilized area, is not measurable, since green forage taken in by grazing animals is only an intermediate, not a final product. For this reason, the methods for pasture evaluation used, i.e. analytic and zootechnical, make it possible to obtain approximate results which are difficult to direct comparison. The former method is based on the assessment of green forage produced, and in the latter, the pasture efficiency is concluded from the animal production obtained (Filipek 1983). Both methods are rarely applied on farms, mostly due to the lack of methodically simple patterns of their use. The zootechnic method, definitely less laborious and giving results translating into profit from animal production, requires working out an accessible application scheme.

Low milk prices in relation to growing production costs should encourage a part of producers for applying in cattle feeding pastures of good quality, ensuring the highest quality of green forage. From all the results and balance sheets published so far it follows

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that grazing is the cheapest method for summer cow feeding, at the same time improving their condition and health (Kostuch 2000; Okularczyk 2001; Goliński 2008). At properly balanced supplementary feeding, it also ensures obtaining satisfactory yields of 6000--7000 litres of milk per cow. Moreover, it guarantees very effective utilization of soil complexes which are of little use for ploughing, and the yields obtained expressed in energy units often exceed the effects of field crops at a lower level of outlays.

The aim of this study was to estimate the efficiency of a pasture providing the base of summer feeding of a milk cow stock, situated on strongly mineralised organogenic soils typical of the Noteć Canal Valley.

Methods and habitat conditions

The pasture valuated in the years 1998-2007 is an important element of summer cow feeding on the farm specializing in milk production for almost forty years. Due to the location of the farm in the immediate vicinity of the Noteć Canal, in the village of Nowe Dąbie in the Łabiszyn commune, on strongly mineralised hydrogenic soils, the major part of the area is permanently covered with grass. Legume-grass mixtures have always been the basis of cattle feeding on the farm. The attempts made to cultivate cereal crops and lupines on the weak and unreliable post-bog soils in the years of research did not guarantee suitable effects. For the last five years, maize soilage has been the only supplementary bulky feed produced on the farm.

The pasture with an area of 12.5 hectares (only in the first research year its area was 14.0 ha) being the subject of the study surrounded farm buildings from all the sides. It consisted of five grazing plots, whose borders coincided with the borders of geodesic lots. Within the plots, areas were separated providing feed for 2-4 days of grazing. On the whole pasture, a muck horizon with a thickness from 25 to 40 cm occurred on loose sand. The soil reaction was on average 6.8 pH, ranging from 6.4 to 7.0. Phosphorus content was varied and remained within the range of low and medium values, from 3.18 to 6.50 mg $P \cdot 100\ g^{-1}$, potassium content was low and amounted from 2.16 to 2.99 mg $K \cdot 100\ g^{-1}$, and magnesium content was high, ranging from 2.64 to 2.99 mg $Mg \cdot 100\ g^{-1}$. Almost all the area was classified as the weakest soils, including: 50.7% of soils quality class V, 45.5% – class VI, and only 3.8% – class IV. Due to poor ascension of ground water, with the table in the grazing part remained at a level of 80-100 cm for most part of the growing season, partial plant withering was observed in the periods of rainfall deficit in the highest areas. At the same time, the large permeability of subsoil provided an ability to graze from the end of April until the end of the pasture season, irrespective of the amount and distribution of precipitation.

The factors determining the production level were the systematic renovation of sward with legume-grass mixtures and fertilization. In the years 1998-2007 all the grazing plots were renovated, some of them twice. Fertilization level until 2001 was quite changeable and relatively low. In the pre-access period (2002-2003) owing to settling individual milk quotas, and in the years 2004-2006, it was stabilized and ranged from 100 to 120 kg nitrogen in the form of ammonium saltpetre, nitrochalk or, less frequently, urea, 24-36 kg K and 13-22 kg P per hectare. In the last research year, due to a considerable growth of fertilizer prices, potassium and phosphorus application was abandoned, and nitrogen fertilization was reduced to 60 $kg \cdot ha^{-1}$. Stable manure produced on the farm was fully utilized for grassland renovation, less often for meadow top-dressing.

The assessment of pasture efficiency was conducted with the zootechnic method (Filipek 1983) by means of French standards of ruminants feeding, using the net energy balance of milk production expressed with feed milk production units (MPU) (Antoniewicz and Żebrowska 1997; Strzetelski et al. 1997).

Feed chemical composition determinations concerning the contents of total protein, crude fibre, water-soluble sugars, phosphorus and calcium were made in successive years in the Department of Animal Nutrition and Feed Management Economy of the University of Technology and Life Sciences in Bydgoszcz with the near-infrared spectroscopy method with the InfraAnalyzer 450.

Botanical composition was evaluated with the valuation method (Filipek 1983). On the basis of usefulness value number (UVN); (Filipek 1973), synthetic indexes of pasture sward value were calculated, which gave the base for pasture floristic valuation.

Results and discussion

As a consequence of selective sward intake by animals, well planned and properly utilized plotted pastures can provide animals with green forage of the best feed parameters, which ensures satisfying cows nutritional needs. Due to the ten-year study period, and a relatively large area of the pasture with a strong floristic variety, the sward quality was evaluated on the basis of usefulness value number, expressed the average yearly value for particular plots (Table 1). In the first two years, on the pasture which had not been renovated for many years, the sward composition was highly varied. 11 species of agricultural grasses, 7 species of non-agricultural grasses, 5 species of legumes, 4 species of sedges and rushes and 29 of other botanical families occurred at that time. The proportions of *Deschampsia caespitosa*, *Carex gracilis*, *C. acutiformis* and *C. hirta*, *Juncus conglomerates* and some dicotyledonous plants including *Ranunculus acris*, *R. repens*, *Potentilla anserina*, *Capsella bursa-pastoris*, *Conyza canadensis*, *Arabis arenosa* and *Polygonum persicaria* reduced use value to the level of poor sward, which, according to classification by Filipek (1973), was within the range from 3.1 to 6.0 UVN. It may be assumed that on average in the first two years, pasture green forage could not provide the optimal feeding parameters. At a relatively small cattle stock per ha the animals had, however, a higher possibility of selective sward intake than in the later years.

Table 1. Valuation of pasture sward based on usefulness value number (UVN) according to Filipek

Year	Grazing plots					Mean
	1	2	3	4	5	
1998	6.55	5.73	5.99	3.95	7.32	5.91
1999	4.64	6.23	6.45	5.23	6.66	5.84
2000	8.59	7.08	7.19	5.21	8.34	7.28
2001	8.31	7.07	7.17	6.38	8.15	7.41
2002	8.02	7.81	7.19	8.18	8.20	7.88
2003	7.68	7.98	8.47	8.03	8.17	8.07
2004	8.65	7.54	8.28	7.56	7.45	7.90
2005	8.21	8.95	8.18	7.54	8.79	8.33
2006	8.04	8.63	7.59	7.02	8.51	7.96
2007	8.02	8.11	7.55	8.80	8.41	8.18
Mean	7.67	7.51	7.41	6.79	8.00	7.48

Pasture renovation started in the second half of 1999 resulted in a considerable improvement of the synthetic index of sward quality. Its parameters in the successive years lay within the range determining good (6.1-8.0 UVN) and very good sward (8.1--10.0). *D. caespitosa*, *C. gracilis*, *C. acutiformis*, *J. conglomeratus* and the majority of dicotyledonous plants of little value completely vanished from the area. Although some of them, such as *C. bursa-pastoris* or *C. canadensis*, appeared shortly after sowing, being terophytes, they quickly vanished under the influence of grazing and topping of the pasture. In spite of a considerable reduction of species number, sward diversity from the point of view of fodder was relatively large. Apart from grasses, *Trifolium repens*, which usually accounted for 20 to 30% of the seed material applied, remained in large amounts. This species is explicitly evaluated as a necessary component of grasslands, and particularly of pastures (Goliński 1998; Szoszkiewicz et al. 2003). Under conditions of a growing intensity of grazing, the most valuable dicotyledonous forage herbs occurred in the sward, including *Taraxacum officinale, Plantago lanceolata, Achillea millefolium*, and in less amounts, *Leontodon autumnalis* and *Rumex acetosa*. They exert a beneficial effect on the taste and quality parameters of green forage (Kacorzyk and Szewczyk 2008). However, forage grasses of the best fodder parameters became predominant, mostly *Lolium perenne*, considered by Baryła and Drozd (2000) as a species which fits for peat-muck soils as well as *L. multiflorum*, which is short-lived but very intensive. A very important component was also *Dactylis glomerata*, which to the least extent, of all the mixture components applied for renovation of next plots of the pasture, responded to deficient amounts of rainfall and high air temperatures typical of this region and tolerated intensive grazing very well. Repeated unfavourable climate conditions, particularly in the years 2000, 2001 as well as 2004 and 2006, resulted from definitely insufficient amounts of rainfall in the growing seasons (Table 2).

Table 2. Air temperatures and total precipitations according to Meteorological Point at Mochełek

Period	Year										Mean
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
Temperatures [ºC]											
Apr-Sep	13.8	14.2	15.1	14.5	13.9	15.2	14.9	13.4	14.1	15.1	14.8
Jan-Dec	7.7	7.8	8.7	9.0	7.7	8.3	7.7	7.5	7.8	8.1	8.7
Precipitation [mm]											
Apr-Sep	302	397	284	275	476	367	208	358	243	353	380.6
Jan-Dec	449	582	487	463	637	641	327	625	439	479	611.0

It should be stressed that only in 2002 the total precipitation was close to the optimum necessary for pasture sward. Such unfavourable conditions were partially eliminated by the microclimate created by the Noteć Canal bordering on the eastern edge of the pasture. In this area, only surfaces of quickly drying hydrogenic soils, permanently covered with grasses, guaranteed the utilization of rainfalls occurring after the warmest summer periods and allowed to feed a growing stock of ruminants.

Table 3. Some parameters of pasture efficiency

Specification	Year										Mean
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
Grazing season [days]	143	153	173	172	153	148	169	168	167	167	161
Pasture area [ha]	14.0	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.7
Number of cows fed on pasture	21	23	28	28	32	34	33	32	38	38	30.7
Cattle stock [LSU·ha^{-1}]	1.74	1.84	2.45	2.58	3.05	3.32	3.24	3.00	3.60	3.60	2.84
Milk from 1 cow [l]											
in calendar year	5796	5703	5479	6092	5530	6061	6120	6153	5681	4949	5756
in grazing season	2698	3015	3229	3501	3084	2880	3169	2951	2852	2435	2981
beyond grazing season	3098	2688	2250	2591	2446	3181	2951	3202	2829	2514	2775
Milk production per cow per day											
in calendar year	15.9	15.6	15.0	16.7	15.2	16.5	16.8	16.9	15.6	13.6	15.8
in grazing season	18.9	19.7	18.7	20.4	20.2	19.5	18.8	17.6	17.1	14.6	18.5
beyond grazing season	14.0	12.7	11.7	13.4	11.5	14.5	15.1	16.3	14.3	12.7	13.6
Effects of pasture feeding											
pasture proportion in summer feeding [%]	54.7	52.3	52.0	55.2	72.5	74.1	70.5	70.9	67.9	63.6	63.4
milk from 1 ha of pasture [l]	2423	2649	3761	4328	5017	5810	5908	5363	5885	4705	4585
milk from 1 cow per day [l]	10.3	10.3	9.7	11.2	14.6	14.4	13.2	12.5	11.6	9.3	11.7
efficiency [UFL·ha^{-1}]	1893	2002	3694	4008	4447	4489	4422	4196	4707	3985	3784

Grazing season began on the first days of May and lasted on average for 161 days (Table 3). Exceptions to this rule in 1998 and 2003 resulted from starting grazing later in order to feed hay-silage from an opened bunker silo and empty it before harvesting the first cut. On the other hand, high air temperatures in October, which in 2000 and 2001 amounted to 10.8 and 10.0ºC, respectively, favoured prolonging of grazing, which was beneficial in terms of economy and organization (Goliński 2008).

Apart from slight fluctuations, a constant growth in number of cows fed on pasture was recorded during the ten-year period. For this reason, the cattle stock increased as well, eventually reaching a value of 3.6 LSU (Livestock Unit) per hectare. Such a large number of pastured cows, at well balanced fertilization, made it possible to achieve in 2006 the highest unit yield per 1 ha ever recorded, amounting to 4707 UFL (Feed Unit for Lactation), yet at the expense of decreasing unit yield per cow. At the lower fertilization level in the following year, this relation was ever more noticeable, both in the yield of energy units per hectare and of litres of milk per cow. Thus it can be assumed that the border of pasture efficiency was exceeded and in order to further increase milk production in grazing season it would be right and economically justified to increase the pasture area and to adapt the nearest meadows for grazing. This is in accordance with the recommended trend of low-expenditure management on permanent grasslands (Goliński 2008), since fertilization costs have the greatest effect on the profitability of feed production on permanent grasslands (Zastawny et al. 2001). Another, less justified solution might be to reduce the proportion of pasture in summer feeding. Many authors indicate an increase in costs resulting from transport of green forages or application of previously preserved bulk feeds. An increase in the proportion of concentrated feeds could be even more expensive (Okularczyk 2001).

From the evaluation of milk production level both per cow and per pasture area unit, it may be assumed that the best results were obtained in the years 2002-2006 (Fig. 1). For the habitat conditions in question, the livestock at a level of 3.0 LSU·ha^{-1} seems to be optimal (Fig. 2 and 3). The yield of one hectare of the pasture at the time was on average about 4,390 UFL and 5,600 litres of milk at a daily unit yield per cow of 18.6 litres of milk. In this period, the percentage of pasture in summer cow feeding amounted to 70%, thus on the basis of direct grazing, the cows produced about 13 litres of milk daily.

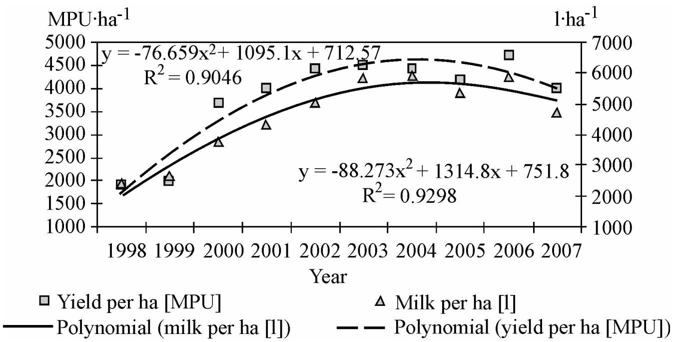

Fig. 1. Relations between pasture efficiency expressed in energy units and milk production from 1 ha of pasture

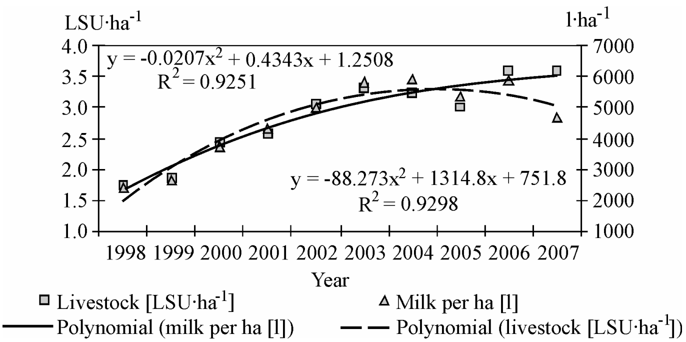

Fig. 2. Relation between growth of stocking rate and milk production from 1 ha of pasture

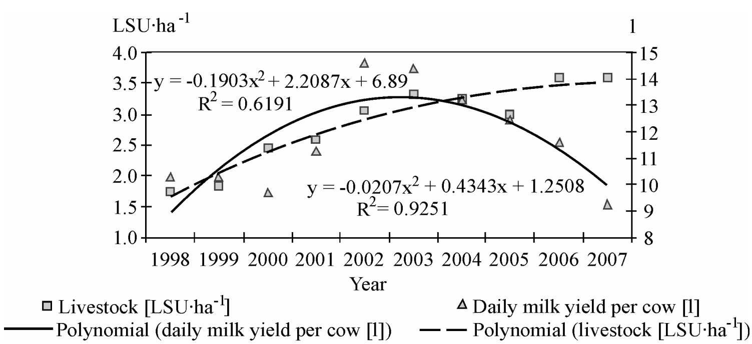

Fig. 3. Relation between growth of stocking rate and daily milk production from a cow based on green forage

Changing price relationships after 2006, resulting from an increase in prices of means of production, mostly fertilizers, and at the same time, from a relatively stable price of milk, indicate the need for reducing outlays and returning to a less intensive fertilization level. One of the solutions may be the introduction of larger amounts of legumes, which could have a higher permanence at the less competition of grasses (Goliński 1998; Szoszkiewicz et al. 2003).

The concentrations of protein, as well as phosphorus and calcium, as elements essential for milk production, are important parameters of sward intended for cow feeding according to recommendations of INRA feeding standards (Strzetelski et al. 1997). Only in the first year of study, the content of total protein in sward was running about the lower limits of permissible standards for good pasture sward (Table 4). In the other years, particularly from 2000, it was very high according to the standards adopted (Choromański et al. 1991; Antoniewicz and Żebrowska 1997). Under such conditions, balancing of the feed ration with starchy feeds is recommended. Over 2000-2004, these were mainly ground grains produced on the farm, and from 2005, growing amounts of ready-made complete concentrated feeds were used for supplementary feeding.

Table 4. Sward chemical composition – on average in grazing season [$g \cdot kg^{-1}$]

Specification	Year									Mean
	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Total protein	169	219	227	242	245	248	247	251	258	234
Crude fibre	246	222	219	228	223	225	217	228	224	226
Crude fat	26.5	26.2	24.8	32.4	30.8	31.6	29.1	32.4	31.1	29.4
Soluble sugars	117	119	118	141	135	143	128	131	134	130
Crude ash	63.2	52.9	57.6	80.6	81.2	78.7	62.8	67.1	71.1	68.4
P	2.10	3.10	5.10	5.44	5.31	5.50	5.18	5.30	6.02	4.78
Ca	8.5	9.7	11.2	16.6	16.5	16.6	16.3	16.8	17.3	14.4

Low crude fibre content resulted from good organization of grazing. Its primary assumption is to start grazing at the stage of grazing maturity and a growing proportion of the most valuable forage grasses in the successive years. With proper organization of grazing, even a high proportion of early and semi-early cultivars of *D. glomerata*, famous for a fast growth rate and high fibre concentration in flowering branches (Łyszczarz and Dembek 2003), did not cause the worsening of green forage quality, and thus lowering of feed digestibility coefficient. Green forage obtained was characterized by a high concentration of water-soluble sugars. Such a level and favourable growth of this component resulted from a high proportion of ryegrasses in the mass taken in. According to Falkowski et al. (2000), both *L. perenne* and *L. multiflorum* are species of grasses with the highest concentration of sugars. Grasses are not plants rich in lipids, thus a level of crude fat in the area of 30 $g \cdot kg^{-1}$ may be considered as typical of valuable pasture green forage.

In the first year, phosphorus and potassium concentration, essential for satisfying cattle needs, was too low. A considerable change occurred as early as in 1999, and from 2000, the green forage obtained can be considered as very abundant in these elements. The reasons for such improvement were phosphorus fertilization applied and utilization of nitrochalk, containing both calcium and nitrogen, for pasture fertilization. High concentration of these components is also found in *T. repens,* commonly growing in this pasture (Antoniewicz and Żebrowska 1997) as well as in the most valuable forage herbs

(Kacorzyk and Szewczyk 2008). Sporadically made analyses of magnesium and potassium contents, not included in the study, indicated low K content, on average about 9.6 $g \cdot kg^{-1}$, however, considered by Falkowski et al. (2000) as sufficient for ruminants and a very high magnesium content, ranging from 4.0 to 5.4 $g \cdot kg^{-1}$.

Conclusions

1. Regularly renovated and properly fertilized pastures situated on strongly mineralized organogenic soils can be the source of valuable green forage applied in feeding of milk-cow stock.
2. Sward with a predominance of *Lolium perenne* and *Dactylis glomerata* supplemented with *Trifolium repens* and spontaneously reviving, valuable forage herbs is characterized by both high parameters in the scale of fodder value score and a very well concentration of all essential macroelements.
3. Optimal level of cattle stock for this area should not exceed 3 LSU per hectare.
4. Well planned and rationally utilized pastures allow obtaining the yield at a level of 4,400 MPU and 5,600 litres of milk per hectare.
5. Economic, organizational and animal hygiene reasons indicate the need for restoring the importance of pasture feeding. There is a need for working out and popularizing simple methods for valuation of pasture efficiency, which will allow the evaluation of pasture feeding effects.

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CHARACTERISTICS OF OCCURRENCE OF GROWING SEASON FROSTS IN THE BYDGOSZCZ REGION

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In climatology, the number of frost days, besides the number of freezing, cool or warm days, constitutes an indicator evaluating thermal conditions over a given area (Woś 1999). Agroclimatology deals with frosts mostly during growing season, rating them among unfavourable climatic factors that lower plant production effects (Bac et al. 1998).

Frosts are one of most frequently, although irregularly, occurring phenomena that are harmful for plants in their growing season. Its definitions are not always explicit, but mostly the term describes the air temperature exceeding a threshold of 0°C during the day. In the available literature, one can find three definitions of frost: 1) a decrease in air temperature below the water freezing point in plant growing period, 2) a decrease in air temperature below 0°C in the period of common occurrence of positive mean daily temperature, 3) a decrease in minimum air temperature below 0°C during maximum positive daily temperature (Niedźwiedź 2003). Frosts can be divided in terms of the way of origin and intensity. According to their origin, they are divided into: radiative – occurring during bright and windless nights, caused by strong radiation of heat from the ground, advective – induced by an inflow of cool (cold) mass of air and mixed (advective-radiative) – induced by an inflow of arctic air accompanied by the loss of warmth due to disappearance of clouds. Radiative frosts are felt most near the ground, whereas advective may be characterized by a considerable decrease in temperature at greater heights, and mixed are definitely the most dangerous, since inflowing cool air is additionally cooled from the ground.

A division of frosts in terms of intensity involves separating days with a decrease in temperature. In the range from -0.1 to -1.9°C a frost is slight or mild, if a decrease in temperature is -1.9 to -3.9°C we deal with a moderate frost, and below -3.9°C, with a strong one. A degree of the harmful effect of a decrease in temperature below 0^{o}C depends on the time of occurrence and intensity of frost, duration of a decrease in temperature, the weather immediately before the occurrence of the phenomenon, the kind and growth stage of the plant. Generally, the warmer it is immediately before the occurrence of frost, the more sensitive the plant, and the higher intensity of temperature decrease and its duration, the higher losses are recorded.

In Poland, frosts are phenomena that occur practically in each growing season. These are either spring frosts, occurring at the end of winter and in spring, or autumn

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frosts, which can be noted as early as in September. Spring frosts are believed to be of greater importance, since sowings and emergences of not resistant seedlings, as well as bud formation and flowering of fruit trees and bushes occur in this period, which poses a risk of freezing. In autumn, the harmful effect of frost events is usually incomparably less. In order to mitigate losses brought about by frost events, cultivation of not resistant plants in regions with a high probability of their occurrence should be avoided in the first place (Koźmiński and Michalska 2001).

The aim of this study was to carry out the agroclimatologic characteristics of the frost events recorded near the ground and at a height of a weather screen (2 m above the ground level), during the growing season in the Bydgoszcz region.

Materials and methods

The study was prepared on the basis of daily meteorological data collected from an agrometeorological measurement point located in Mochełek near Bydgoszcz. The point has been working since 1949 and for many years it has provided the meteorological support of field experiments carried out by the researchers of the Faculty of Agriculture of the University of Technology and Life Sciences in Bydgoszcz. It was established and it functions according to the guidelines of the Institute of Meteorology and Water Management for meteorological stations and posts in Poland. This means that its location and observations carried out are in accordance with the principle of comparability of meteorological measurements and observations, which allows the application of measuring data for the climatic and agroclimatic characteristics of the Bydgoszcz region.

The initial material included mean daily values of air temperature and daily minimal temperatures at a height of 2 m (at the weather screen) and daily minimal temperatures measured at a height of 5 cm above the ground level for the years 1971--2005. The calculations were made for the plant growing season covering the period from April to October.

Frosts were determined on days which were characterized by a mean daily temperature higher than 0°C and a minimal temperature lower than 0°C. Such a method was adopted both with reference to the air temperature measured near the ground (5 cm) and at a height of the weather screen (200 cm). Determined frosts were divided into three types in respect of intensity (from -0.1 to -1.9°C, from -2.0 to -3.9°C, below -3.9°C) and categorized into particular 10-day periods of each month, calculating their number, percentage and frequency of frost-free years. Moreover, sequences of frost days were determined for 3, 5, 7 and 10-day periods without considering the division as regards intensity. In each intensity range, mean and extreme dates of the occurrence of the last spring and the first autumn frosts, as well as mean and extreme lengths of frost-free periods were determined. Using data from 35-year constant series of measurements, trends of variation in basic characteristics of frosts in the years 1971-2005 were determined with the linear regression method (Garnier 1996).

Results and discussion

On average, in the years 1971-2005 in Mochełek there were 19.77 days with frost at a level of 5 cm above the ground, whereas at a height of the weather screen they amounted to 12.80, i.e. 7 days less (Table 1). Frosts were observed most frequently in

April (11.47 and 7.82 days, respectively) and in October (5.15 and 3.89 days). In other months they occurred considerably less frequently, but at a level of 5 cm above the ground, on average 2.28 frost days were found in May (only 0.89 at a level of the screen) and 0.58 in September (only 0.20 at 200 cm). Single decreases in air temperature below 0^{o}C were also recorded in June and August, but near the ground only.

Days with light frost (-0.1 to -1.9°C) occurred definitely most often, this was 9.45 and 6.68 events in the season, respectively, moderate (-2.0 to -3.9°C) occurred much less frequently – 6.77 and 3.99 days and strong (below -3.9°C) occurred sporadically, on average 3.55 near the ground and 2.13 at a level of the weather screen.

Table 1. Mean number of frost days in Mochełek during growing season over 1971-2005

Month	Decade	Temperature [^{o}C]							
		-0.1 to -1.9		-2.0 to -3.9		Below -3.9		Total	
		Height above the ground [cm]							
		5	200	5	200	5	200	5	200
Apr	I	1.89	1.60	1.51	0.63	0.89	0.46	4.29	2.69
	II	2.09	1.68	1.40	1.11	0.86	0.46	4.35	3.25
	III	1.03	0.91	1.06	0.57	0.74	0.40	2.83	1.88
	I-III	5.01	4.19	3.97	2.31	2.49	1.32	11.47	7.82
May	I	0.63	0.43	0.28	0.11	0.11	0.03	1.02	0.57
	II	0.43	0.17	0.26	0.06	–	–	0.69	0.23
	III	0.54	0.09	0.03	–	–	–	0.57	0.09
	I-III	1.60	0.69	0.57	0.17	0.11	0.03	2.28	0.89
Jun	I	0.11	–	0.06	–	–	–	0.17	–
	II	0.06	–	-	–	–	–	0.06	–
	I-III	0.17	–	0.06	–	–	–	0.23	–
Aug	III	0.06	–	–	–	–	–	0.06	–
Sep	I	0.03	–	–	–	–	–	0.03	–
	II	0.09	–	0.11	–	–	–	0.20	–
	III	0.20	0.17	0.09	0.03	0.06	–	0.35	0.20
	I-III	0.32	0.17	0.20	0.03	0.06	–	0.58	0.20
Oct	I	0.49	0.26	0.17	0.20	0.09	0.06	0.75	0.52
	II	0.77	0.51	0.74	0.37	0.31	0.26	1.82	1.14
	III	1.03	0.86	1.06	0.91	0.49	0.46	2.58	2.23
	I-III	2.29	1.63	1.97	1.48	0.89	0.78	5.15	3.89
Apr-Oct		9.45	6.68	6.77	3.99	3.55	2.13	19.77	12.80

April was the month with the highest frost hazard. Light frosts predominated (5.01 and 4.19 days), accounting for 25.4% of all the events near the ground and still more, namely 32.7%, at a level of the weather screen (Table 2). The month was characterized also by the largest frequency of moderate frosts (20.1% and 18.0%, respectively) and strong frosts (12.6% and 10.3%). As a result, as many as 58.0% of all days with frost occurring near the ground and 61.1% at a height of 200cm were recorded in April.

The second month dangerous for crops due to temperature decreases below 0^{o}C was October, when on average 5.15 and 3.89 days with frost were recorded (Table 1). Expressing these amounts in relative numbers permits to determine the proportion of October in the total number of frost days in the Bydgoszcz region at a level of 26.1% near the ground and 30.4% at 200 cm (Table 2).

A similar course and monthly distribution of frost days in the Bydgoszcz region was presented in earlier agroclimatic studies (Żarski et al. 1988; Koźmiński et al. 1990; Woś 1994).

The frosts of May, often referred to as 'the cold gardeners', are the most dangerous for plants. They are caused by advection of arctic air (the curiosity of Poland's climate). In Mochełek they occurred relatively rarely, but in all decades of the month, with a marked tendency to a decrease in amount and intensity with time. The majority of May frosts in all the classes of intensity occurred in decade I, particularly near the ground, accounting for 5.2%, and in the screen, 4.4%. The next decades of May were characterized already by the considerably reduced number of frosts in all classes of intensity. Moderate frosts at a height of 200 cm never occurred in the 3rd part of May, whereas strong frosts were not recorded at any height both in decades II and III (Tables 1 and 2).

Table 2. Structure of frost day occurrence during growing season over 1971-2005 [%]

Month	Decade	Temperatures [°C]							
		-0.1 to -1.9		-2.0 to -3.9		Below -3.9		Total	
		Height above the ground [cm]							
		5	200	5	200	5	200	5	200
Apr	I	9.5	12.5	7.6	4.9	4.5	3.6	21.7	21.0
	II	10.6	13.1	7.1	8.7	4.4	3.6	22.0	25.4
	III	5.2	7.1	5.4	4.4	3.7	3.1	14.3	14.7
	I-III	25.3	32.7	20.1	18.0	12.6	10.3	58.0	61.1
May	I	3.2	3.4	1.4	0.9	0.6	0.2	5.2	4.4
	II	2.2	1.3	1.3	0.4	–	–	3.5	1.8
	III	2.7	0.7	0.1	–	–	–	2.9	0.7
	I-III	8.1	5.4	2.8	1.3	0.6	0.2	11.6	6.9
Jun	I	0.6	–	0.3	–	–	–	0.9	–
	II	0.3	–	–	–	–	–	0.3	–
	I-III	0.9	–	0.3	–	–	–	1.2	–
Aug	III	0.3	–	–	–	–	–	0.3	–
Sep	I	0.1	–	–	–	–	–	–	–
	II	0.5	–	0.5	–	–	–	1.0	–
	III	1.0	1.3	0.5	0.2	0.3	–	1.8	1.6
	I-III	1.6	1.3	1.0	0.2	0.3	–	2.8	1.6
Oct	I	2.5	2.0	0.9	1.6	0.4	0.5	3.8	4.1
	II	3.9	4.0	3.7	2.9	1.6	2.0	9.2	8.9
	III	5.2	6.7	5.4	7.1	2.5	3.6	13.1	17.4
	I-III	11.6	12.7	10.0	11.6	4.5	6.1	26.1	30.4
Apr-Oct		47.8	52.2	34.2	31.2	18.0	16.6	100.0	100.0

On average, more May frosts were recorded in other regions of Poland. In the vicinity of Szczecin, this was caused by the earlier beginning of spring (Koźmiński and Michalska 2000), in Warmia and Masuria, by the rich lie of the land (Dragańska et al. 2004), and in the Lublin region, by a greater influence of continental air (Kołodziej et al. 2004; Lorenc 2005).

Sporadically, frosts occurred in decades I and II of June, but only in the air layer near the ground and they were mostly light frosts. The events of August frosts were even less frequent and occurred only in the decade III at the slightest decrease in temperature below 0°C (Table 1). In the history of agrometeorological measurements in Mochełek, covering the years from 1949 to 2005, frost has never been recorded in July (Żarski et al. 1988), as well as in the whole lowland part of the country (Koźmiński et al. 1990; Koźmiński and Michalska 2001).

Also decades I and II of September appeared to be free of frosts recorded at a height of 200 cm, and decreases in temperature near the ground occurred sporadically. In decade III of September, no strong frosts were observed at the height of the weather screen (Table 1).

The percentage of decades and months without frost presented in Table 3 indicates that no years which were totally free of this phenomenon occurred in the examined period 1971-2005. Each year was characterized by decreases in temperature near the ground in two first classes of intensity, whereas 14% of years had no strong frosts. At a height of the weather screen, there were no moderate frosts in 6% of years and strong in 17% of years.

Frosts occurred least frequently in August, when during the whole 35-year period only two events of their occurrence were recorded, i.e. on August 26 and 27, 1973 (-1.5°C and -0.6°C). Frosts occurred rarely also in June (6 events in decade I and 2 in decade II) and only at a height of 5 cm above the ground level; however, a decrease in temperature below -2.0°C was recorded twice. At a height of the weather screen June was free of frost. In September, the frequency of years without frosts was high and decreased with time and the intensity of the event. Also in this month, a considerably higher frequency of frost-free periods was recorded at a height of 200 cm.

Table 3. Frequency of frost-free years (%) according to 10-day periods and months in Mochełek

Month	Decade	Temperature [°C]							
		-0.1 to -1.9		-2.0 to -3.9		Below -3.9		Total	
		Height above the ground [cm]							
		5	200	5	200	5	200	5	200
Apr	I	20	23	17	57	51	60	6	14
	II	23	29	17	31	57	69	6	9
	III	40	49	51	66	66	74	23	43
	I-III	3	3	3	17	31	34	0	3
May	I	57	71	83	91	94	97	57	69
	II	74	86	86	94	100	100	69	83
	III	66	94	97	100	100	100	68	94
	I-III	34	80	77	89	91	97	34	63
Jun	I	89	100	94	100	100	100	89	100
	II	94	100	100	100	100	100	97	100
	I-III	89	100	97	100	100	100	86	100
Aug	III	97	100	100	100	100	100	97	100
Sep	I	97	100	100	100	100	100	97	100
	II	91	100	89	100	100	100	89	100
	III	83	91	91	97	94	100	80	91
	I-III	71	91	91	97	97	100	71	91
Oct	I	74	80	88	86	94	94	69	74
	II	66	60	66	71	83	83	46	51
	III	37	43	43	54	71	74	17	29
	I-III	20	23	29	37	60	60	6	14
Apr-Oct		0	0	0	6	14	17	0	0

The number of frost-free decades decreased remarkably in the course of October, concerning particularly the events of a decrease in temperature with the least intensity. However, a definitely less percentage was observed in April, both near the ground and in the weather screen. Over 1971-2005 only in one April there was no frost at a height of 200 cm (in 1989).

A possibility of crop hazard is often to greater extent determined by the duration of the unfavourable factor than by a single, even very intensive, decrease in temperature (Koźmiński and Michalska 2001). Constant sequences of days with frost determined during the study, irrespective of intensity, were particularly typical of the extreme months – April and October (Table 4). In April, on average the most of 3-day sequences (1.29), and the least of 10-day sequences (0.18) were recorded near the ground. This means that approximately at least one 3-day sequence occurred every year, one 5-day sequence in 63% of years, one 7-day sequence every 2.5 years and a 10-day period may be expected in 18% of years. At a height of the weather screen, the number of these sequences was slightly less in April, but all the events occurred as well; for instance, on average each year was characterized by 3-day sequences, whereas 10-day sequences occurred only 4 times.

In May, in the whole 35-year period, 10 frost day sequences were recorded at a height of 5 cm: seven the shortest, two 5-day and one 7-day long sequences. In the screen there were only 4 events of 3-day sequences, three in decades I and II. In September, only one 3-day sequence was noted in decade III at both heights. October, just as April, was characterized by a higher number of the frost sequences noted, particularly 3- and 5-day long. Periods of successive 7 frost days were recorded only in decades I and III of this month, and the longest, 10-day long, did not occur.

Table 4. Mean number of day sequences with frost of a given length in Mochełek during growing season over 1971-2005

Month	Decade	Day sequences with frost [days]									
		3		5		7		10		Total	
		Height above the ground [cm]									
		5	200	5	200	5	200	5	200	5	200
Apr	I	0.60	0.51	0.26	0.23	0.20	0.11	0.03	0.03	1.09	0.88
	II	0.40	0.34	0.17	0.14	0.09	0.09	0.06	0.06	0.72	0.63
	III	0.29	0.23	0.20	0.11	0.11	0.06	0.09	0.03	0.69	0.43
	I-III	1.29	1.08	0.63	0.48	0.40	0.26	0.18	0.12	2.50	1.94
May	I	0.09	0.09	–	–	–	–	–	–	0.09	0.09
	II	0.09	0.03	0.06	–	0.03	–	–	–	0.18	0.03
	III	0.03	–	–	–	–	–	–	–	0.03	–
	I-III	0.21	0.12	0.06	–	0.03	–	–	–	0.30	0.12
Sep	III	0.03	0.03	–	–	–	–	–	–	0.03	0.03
Oct	I	0.06	0.03	0.03	0.03	0.03	0.03	–	–	0.12	0.09
	II	0.31	0.31	0.09	0.09	–	–	–	–	0.40	0.40
	III	0.40	0.40	0.14	0.11	0.03	0.03	–	–	0.57	0.54
	I-III	0.77	0.74	0.26	0.23	0.06	0.06	–	–	1.09	1.03
Apr-Oct		2.30	1.97	0.95	0.71	0.49	0.32	0.18	0.12	3.92	3.12

The time between the last spring frost and the first autumn frost is referred to as a frost-free period. The longer it is, the better conditions for plant growth and development it creates. The dates of the occurrence of the last spring frost depended on its intensity and the height above the ground level; the time of the last frost was earlier with the growth in height and event intensity. The mean time of the last light frost near the ground fell on May 12 in the Bydgoszcz region, and in the other cases it was moved to April (Table 5). In particular years, a very large variability of the time of the last spring frost was recorded, including the period from the last week of February (strong frost 5 cm February 26, 1983) to the middle of June (light frost near the ground on June 17, 1978). Changes in dates with years during the period from 1971 to 2005 were presented in Figure 1A (near the ground) and 2A (in the screen). A downward tendency was marked at both heights, indicating the gradually earlier occurrence of the last spring frost, but only one event (moderate frost near the ground) was characterized by significant dependence.

The first frost in autumn occurred on average in October, irrespective of the height above the ground and intensity, except for a strong frost at a height of the weather screen that only occurred in November (Table 5). In successive years, just as in the case of the last spring frost, a very high variability was noted.

Table 5. Mean and extreme times of occurrence of the last spring frost and first autumn frost in Mochełek in growing season 1971-2005

Height above ground level [cm]	Intensity of frost	Last spring frost			First autumn frost		
		Mean	Earliest	Latest	Mean	Earliest	Latest
5	-0.1 to -1.9°C	May 12	Apr 13 (2003)	Jun 17 (1978)	Oct 8	Aug 26 (1973)	Nov 14 (1984)
	-2.0 to -3.9°C	Apr 28	Mar 20 (1994)	Jun 1 (1977)	Oct 20	Sep 14 (1973)	Dec 2 (1986)
	below -4.0°C	Apr 9	Feb 26 (1983)	May 5 (1978)	Oct 30	Sep 27 (1977)	Dec 3 (1986)
200	-0.1 to -1.9°C	Apr 26	Mar 20 (1999)	May 23 (1995)	Oct 20	Sep 24 (2002)	Nov 15 (1975)
	-2.0 to -3.9°C	Apr 17	Mar 19 (1999)	May 15 (1995)	Oct 26	Sep 25 (2002)	Dec 14 (1986)
	below -4.0°C	Apr 8	Mar 10 (1993)	May 1 (1971)	Nov 10	Oct 6 (1972)	Dec 21 (1986)

A light autumn frost near the ground in 1973 occurred the earliest (August 26), the other events occurred in September of October and the latest times fell in the late autumn (November) or already in winter. The trends determined do not show the occurrence of significant changes in dates of the first autumn frost (Figs 1B, 2B). The dates are to a great extent in accordance with those presented in the literature and typical of the central part of the country, but earlier than those in the west and later than in the north-east regions (Koźmiński et al. 1990; Koźmiński and Michalska 2001; Dragańska et al. 2004).

The length of frost-free periods near the ground amounted to on average 148 days and was 28 days shorter than that in the weather screen. In the successive years of the period 1971-2005, a very large variation in the date range occurred between the last spring frost and the first autumn frost (Table 6). The shortest frost-free period, lasting 98 days, occurred near the ground in 1973 and at a height of the screen in 1995 and lasted 130 days. The longest lasted respectively 190 (1984) and 213 (1999) days. Even more differences occurred in the case of moderate and strong frosts. On the basis of the duration of the frost-free period in the course of time, it can be stated that this period tended to prolong at a height of 5 cm above the ground (Figs 1C, 2C). Similar results can be found in studies describing thermal conditions in the north-east part of the country, where frost-free periods were slightly shorter (Dragańska et al. 2004) and in the Szczecin Lowland (Koźmiński and Michalska 2001). Both in the Bydgoszcz region and in other regions of some European countries (Czech Republic, Switzerland, Finland, Belarus), a tendency has been observed for a decrease in number of days with frost in the last sixty years (Heino et al. 1999; Loginov et al. 2007).

Table 6. Mean and extreme lengths of frost-free period occurrence in Mochełek during growing period over 1971-2005

Height above ground level [cm]	Intensity of frost	Frost-free period [days]		
		Mean	Longest	Shortest
5	-0.1 to -1.9°C	148	190 (1984)	98 (1973)
	-2.0 to -3.9°C	174	232 (1986)	108 (1977)
	below -4.0°C	203	261 (1983, 1994)	162 (1972)
200	-0.1 to -1.9°C	176	213 (1999)	130 (1995)
	-2.0 to -3.9°C	191	244 (1986)	142 (1995)
	below -4.0°C	214	266 (1987)	164 (1972)

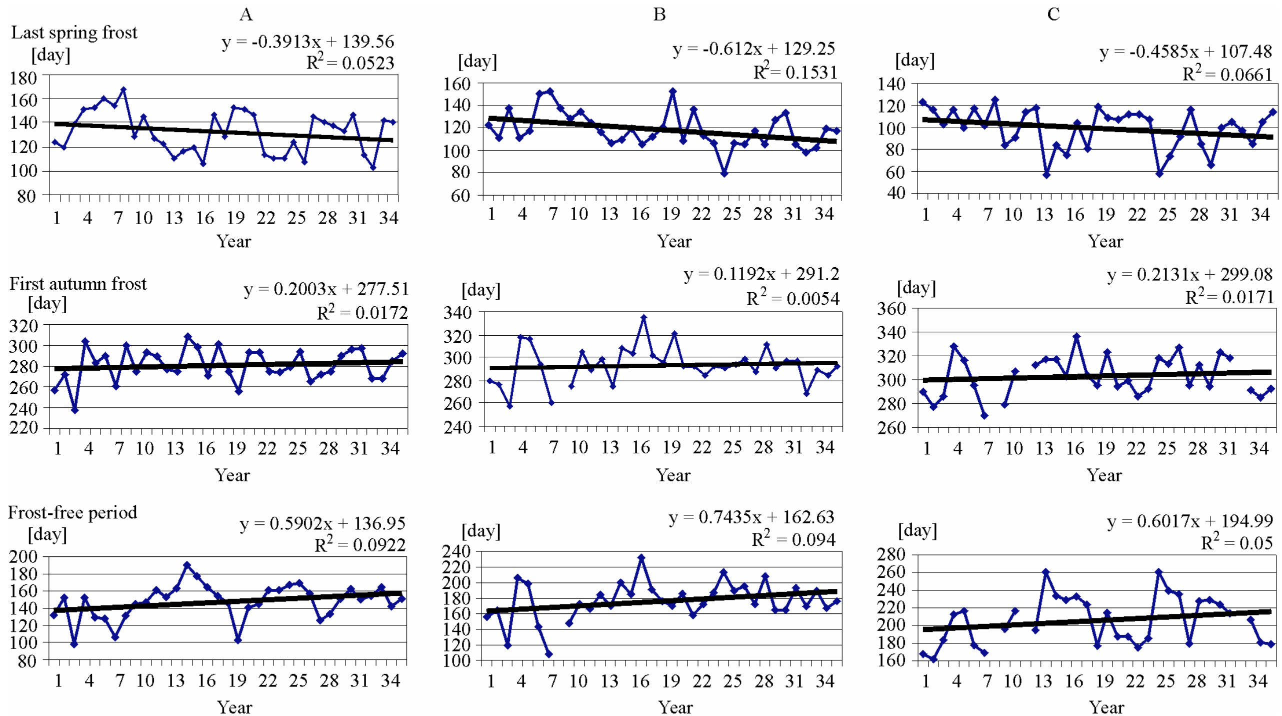

Fig. 1. Trends for time variability of the occurrence of last spring frost, first autumn frost and duration of frost-free period in Mochełek at a height of 5 cm in three classes of intensity: A – light, B – moderate, C – strong

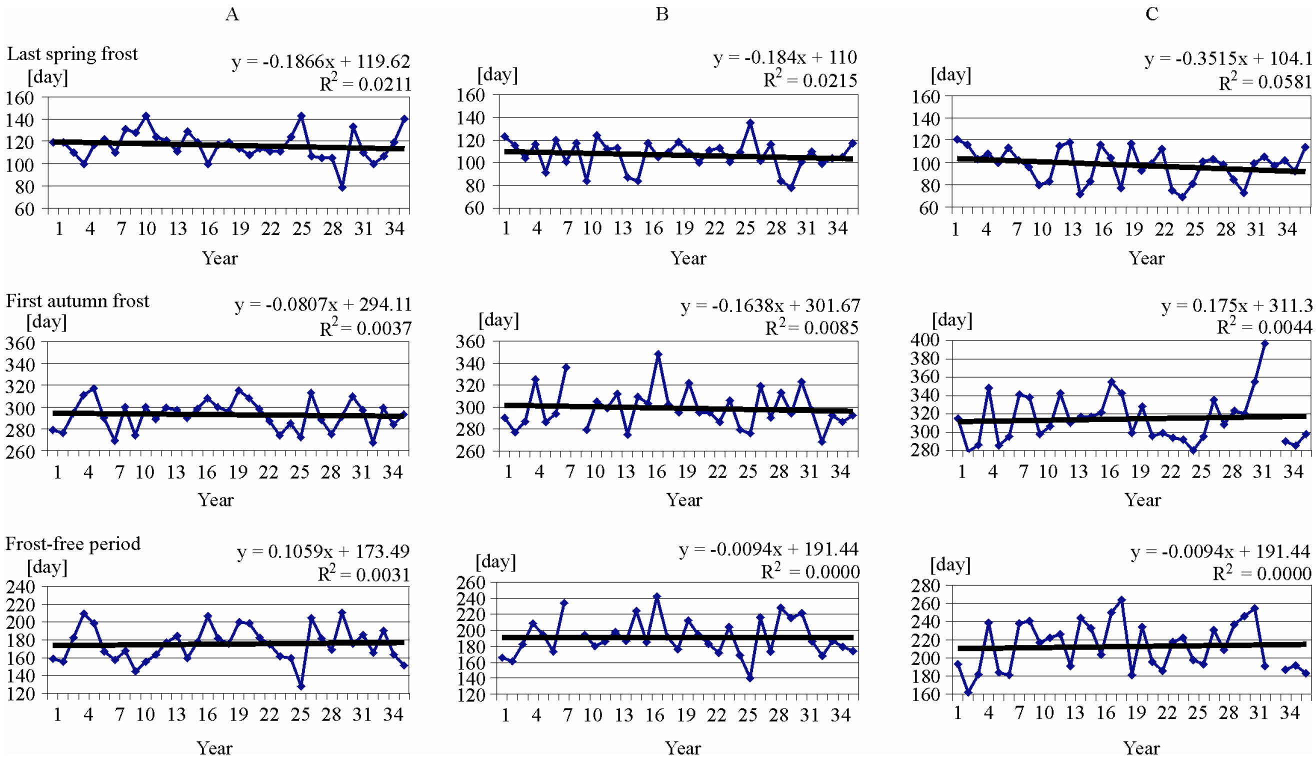

Fig. 2. Trends for time variability of the occurrence of the last spring frost, first autumn frost and duration of frost-free period at a height of 200 cm in three classes of intensity: A – light, B – moderate, C – strong

Conclusions

1. On average, 19.77 days with ground frost and 12.80 days with frost at the height of the weather screen were recorded during the growing season in the Bydgoszcz region.
2. Days with light frost occurred most frequently, accounting for about 50% of all decreases in the air temperature below 0^oC. Proportion of moderate frosts in their total number was more than 30%, and that of strong frosts, about 20%.
3. At a height of 5 cm above ground 58.0% frosts occurred in April, 26.1% in October, 11.6% in May and 2.8% in September. Sporadically, they also occurred in June and August. The structure of frost occurrence at a height of the weather screen was: 61.1% in April, 30.4% in October, 6.9% in May and 1.6% in September.
4. July was the only month of the growing season which was totally free of frosts.
5. The number of frost day sequences decreased with a growth of the sequence length and the height above ground level. The majority of sequences were recorded near the ground in April.
6. The mean date of the last spring frost near the ground fell on May 12 and was later by about 2 weeks in relation to the last frost recorded at a height of the weather screen. Moderate ground frosts stopped on average on April 28 and strong on April 9.
7. Mean date of the first frost in autumn near the ground fell on October 8 and delayed with the growth in height at which the frost was recorded and an increase in intensity of temperature decrease below 0^oC.
8. The length of frost-free period near the ground was 148 days, at a height of the weather screen it was 28 days longer. The length of the frost-free period increased with the growth in frost intensity level.
9. The trends calculated indicated that in the course of time, the date of the last spring frost became earlier, and that of the first autumn frost became later. Consequently, the duration of periods without frost prolonged slightly. However, a significant trend referred to only one of 18 regressions analysed – i.e. the date of the last spring moderate frost near the ground.

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VARIATION IN THE PLANT COVER IN THE LOWER BRDA RIVER AND ITS EVALUATION

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The Brda River starts in the zone of terminal moraines, east from Miastko flowing into Lake Smołowe 181 m above sea level. It flows through the Charzykowy Plain, Tuchola Forest, the Brda Valley, into the Vistula River in the Torun Valley as a left-bank tributary. It drains moraine areas and sandur fields formed in glacier foreground over the Pomerania stage of the last glaciation. The river is 238 km long and the area of its basin is 4627.2 km^2 (Choiński 2002). According to the regionalization by Kondracki (1988), the lower Brda River Valley is part of the Toruń-Eberswalde Ice-Marginal Valley (Noteć and Warta Ice Marginal Valley) and to the north it is a separate physiographic unit: the Brda River Valley. From the north it is adjacent to Krajna Lakes and from the east – to Świecie Upland. Geomorphology-wise, the Brda Valley shows terrace flattening of erosion or erosion-accumulation type with the eastward inclination (Galon 1953). The upper edges of the ice marginal valley (terraces V-VII) in its lower section are made up of drift clays and fluvioglacial formations at the absolute height of 50-70 m above sea level (sandur height in the vicinity of Koronowo is 90 m above sea level). Lower terraces of the Brda Valley (terraces I-IV) take up a relatively small area in its catchment and they are quite strongly diversified. Their foundation is mostly made up of fluvioglacial sandy drift clay formations with some Pliocene clays. The recesses separating the terraces demonstrate quite a high geomorphological variation. The last terrace in its lower section is small, which is due to its numerous meanders. The ice-marginal valley slopes often exceed the relative height of 40 m and their walls go down often at an angle of more than 45°. In many places they are cut by numerous ravines and smaller erosion scraps.

The hydrographic qualities of the river, including a large area of the river basin, a considerable slope (average of 0.65 m·km^{-1}), a high retention potential (the Brda River goes through 72 lakes) have, in the lower reaches of the river, given rise to dams (with the biggest Koronowo Reservoir) and water power stations at Samociążek, Tryszczyn, and Smukała.

The lower Brda River (25 km long), especially over the last 50 years, has undergone considerable transformations as a result of anthropogenic impact. The location of the city of Bydgoszcz and numerous hydrotechnical infrastructure and developing housing estates, a vast service and commercial infrastructure at the mouth of the river result in considerable changes in the build-up of the closest surroundings of the

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river. The anthropogenic transformations of this area and the river protection as the source of drinking water for the city make it necessary to get to know its current flora resources and the degree of their degradation.

Materials and methods

As a result of flora-phytosociological studies performed over 2003-2007, the current state of the plant cover from Smukala to the dam in Koronowo (at Lake Koronowo) has been determined. The flora studies were made with the commonly applied Braun-Blanquet (Wysocki and Sikorski 2002 after Braun-Blanguet) phytosociological image method. In total over 300 phytosociological images were made, of which about 200 were used for present studies. The plant names and their phytosociological reference were developed based on the currently applicable keys and guides (Rutkowski 2004; Matuszkiewicz 2008). The present research has made it possible to specify the areas ecologically threatened, which require an active protection and defining the degree of anthropogenic pressure in the area.

Results

As a result of the phytosociological studies the leading plant communities and their range were identified and broken down from water plants to forest and ruderal communities.

Water plant communities

Class: *Lemnetea minoris* R. TX.1955
Order: *Lemnetalia minoris* R. TX.1955
Alliance: *Lemnion gibbae* R. TX. et A. SCHWABE 1974 in. R. TX. 1974
Assemblage: *Lemnetum giabbae* MIY. et J. TX. 1960

The *Spirodela-Lemnetum minoris* community in the area researched covers small areas, especially in the strong river current. It is passively floated there, frequently, under the cover of reed beds in the retention reservoirs in the vicinity of Tryszczyn and Smukała and in the slow current of the river from the dam at Koronowo to the water power station at Samociążek; that community is quite abundant, especially in sheltered bends.

Class: *Potametea* R. Tx. et PRSG
Order: *Potametalia* KOCH 1926
Alliance: *Potamion* KOCH 1926 em. OBERD.1957
Assemblage: *Elodeetum canadensis* (PIGN. 1953) PASS. 1964

The community of *Elodea canadensis* is abundant neither in the strong river current nor in its slow-flowing parts. It develops more intensively in the river within Koronowo where its more intensified eutrophication occurs.

Assemblage: *Potametum lucentis* HUECK 1931

The community of *Potamogeton lucens* is found dispersed and at a varied intensity throughout the river section researched. The companion species, especially in slower-flowing water and in small river bends, are other species of order *Potametalia*, including *Ceratophyllum sumbersum*, *C. demersum*, *Potamogeton nataus*, *P. pectinatus*, *P. gramineus*, and the species of *Nymphaeion* alliance with its main representative: *Nuphar luteum*.

Alliance: *Nymphaeion* OBERD 1953
Assemblage: *Nupharo-Nymphaeetum albae* TOMASZ. 1977

The community of *Nuphar luteum* and *Nymphaea alba* occur sporadically, mainly in the dam bends and the so-called dead river in the vicinity of Koronowo. In the waters of faster current *Nuphar luteum* does not form flowers but only leaf rosettes. In this community also *Potamogeton nataus*, *Elodea canadensis* are quite abundant, whereas *Polygonum amphibium* – is sporadic.

The communities of reed bed, marsh and meadow plants

Class: *Phragmitetea* R. TX. et PRSG 1942
Order: *Phragmitetalia* KOCH 1926
Alliance: *Phragmition* KOCH 1926
Assemblage: *Phragmitetetum australis* (GAMS 1927) SCHMALE 1939

Phragmitetetum australis forms inconsiderably extensive communities due to a variable water level in the river caused by hydro-electric power plants operating interchangeably. Wider belts of reed beds are present in the places where lower stream terrace of the river is more extensive. The biggest clusters of this community are present in the vicinity of Smukała, Janowo, and Bożenkowo. The species abundance of the community is inconsiderable, however, in many fragments there are present bigger clusters of companion species such as: *Equisetum fluviatile*, *Acorus calamus*, *Caricetum gracilis*, *Rumex hydrolapathum*, *Typha angustifolia* and others.

An interesting form of assemblage *P. australis* are the communities located in the second and third flood terrace, raised over the river by 10-20 m of relative height which are currently on the western side of the ice-marginal valley in the vicinity of Tryszczyn and Gościeradz. They are formed in terrain hollows which show a constant high ground waters level supplied with precipitation waters or spring clusters at the foot of escarpments. Although the main species building these communities is reed (60-80% of the cover), the properties of the subsoil and the presence of companion species demonstrate that it is more likely not to be a fully developed community representing class *Scheuchzerio-Coricetea nigre* Nordh. 1936, namely low-sedge lowland and transitional bogs. The species characteristic for that class are represented by common *Eriophorum angustifolium*, *Menyanthes trifoliata*, *Pedicularis palustris*, *Calamagrostis sticta*, *Carex nigra*, and *Agrostis canina*.

Alliance: *Magnocaricion* KOCH 1926
Assemblage: *Caricetum gracilis* (GRABEN. et HUECK 1931) R. TX. 1937

The rush of slim sedge, present both in the river and inconsiderably abundant in dams in slow-flowing waters. The companion species in this assemblage inconsiderably abundant: *Iris pseudoacorus*, *Equisetum fluviatile*, *Alisma plantago-aquatica*, *Lisimachia thyrsiflora*, *Poa palustris*, *Phalaris arundinaceae*, *Rumex hydrolapathum*, *Galium palustre*, *Carex gracilis*, *Agrostis stolonifera.*

Class: *Molinio-Arrhenatheretea* R. TX. 1937
Order: *Molinietalia* KOCH 1926
Alliance: *Filipendulion ulmariae* SEGAL 1966
Assemblage: *Filipendulo-Geranietum* KOCH 1926

The communities of *Filipendula ulmaria* and *Geranium palustre* develop in high-moisture content places in the close vicinity of the river and raised places of constant or periodical high moisture content (Smukała, Janowo, Tryszczyn, Gościeradz, Koronowo). They often border with the communities of alder riparian forests, distinguishable by their considerable species richness, including such characteristic species as: *Lisimachia vulgaris*, *Lythrum salicaria*, *Lychnis flos-cuculi*, *Sanguisorba officinalis*, *Galium uliginosum*, *Deschampsia caespitosa*, *Equisetum palustre*, *Cirsium palustre*, *Carex gracilis.*

Alliance: *Calthion palustris* OBERD 1957
Assemblage: *Angelico-Cirsietum oleracei* R. TX. 1937 em. OBERD. 1967

The community present in places with periodically high moisture content, mainly located in higher river terraces in the vicinity of Opławiec, Tryszczyn, Koronowo. The patches of the assemblage are differentiated by a high number of species and they offer good environment for the development of common *Dactylorhiza majalis*. The species characteristic for that assemblage is *Cirsium oleraceum.* Similarly *Juncus effusus*, *Dactylis glomerata*, *Polygonum bistorta*, *Geum rivale*, *Avenula pubescens*, *Ranunculus acris*, *Lychnis flos-cuculi* are also abundant there.

Class: *Festuco-Brometea* BR.-BL. et R. TX. 1943
Order: *Festucetalia valesiacae* BR.-BL. et R. TX. 1943
Alliance: *Festuco-Stipion* (KLIKA 1931) KRAUSCH1961
Assemblage: *Potentillo-Stipetum capillatae* LIBB. 1933 em. KRAUSCH 1960

The assemblage is present on steep escarpments of southern exposure and it is one of the more interesting ones in the area. It requires a through botanical analysis since in many aspects it forms an impoverished form of vegetation referring to assemblage *Adonido-Brachypodietum pinnati* Krausch 1961, described by Cejnowa (1968) in xerothermal vegetation reserves in the Vistula Valley. Sporadically the community borders with outstandingly xeromorphic assemblage *Thalictro-Salvietum pratensis* MEDW.-KORN. 1959 with an abundant share of *Salvia pratensis*. The community occurs in steep escarpments at Tryszczyn, Samociążek and in the vicinity of Koronowo and it is distinguished by the presence of the following species: *Avenula pratensis*, *Dianthus deltoides*, *Viscaria vulgaris*, etc. As a result of soil variation, it forms miltispecific clusters in which the share of grasses and perennials varies and covers 70--80% of soil. Until recently the areas taken control of by this community were used as extensive pasture land and today the areas are overgrown with *Pinus sylvestris*, *Betula verrucusa* and *Rosa canina* and *Prunus spinosa* shrubs. On the escarpments at Tryszczyn in the community one can find *Jovibarba* species increasingly rare in the country – *Jovibarba sobolifera*.

Class: *Koelerio Glauce-Corynephoretea canescentis* KLIKA in KLIKA et NOVAK 1941
Order: *Corynophoretalia canescentis* KLIKA 1934
Alliance: *Vicio lathyroidis-Potentillon argenteae argenteae* BRZEG in BRZEG et M. WOJT. 1996
Assemblage: *Diantho-Armerietum elongate* KRAUSCH 1959

The widely extended community present in sandy subsoil in the vicinity of Koronowo, especially to the north. In a poorer form it occurs also at Opławiec, Janowo and Tryszczyn. The main species building that assemblage are *Corynephorus canescens*, *Festuca ovina*, *Agrostis vulgaris*, *Thymus serpyllum*, *Hieracium pirosella*, *Dianthus deltoides* and *Galium vernum*. The communities are accompanied by numerous species of xerophytic bryophytes and lichens.

Thicket and forest communities

Class: *Rhamno-Prunetea* RIVAS GODAY et GARB. 1961
Order: *Prunetalia spinosae* R. TX. 1952
Alliance: *Berberidion* BR.-BL. (1947) 1950
Assemblage: *Pruno-Ligustretum* R. Tx. 1952 nom. Inv. OBERD. 1970

Within the area researched the community develops especially in steep slopes sloping eastwards of the left-bank ice-marginal valley, mostly the vicinity of Tryszczyn, Gościeradz, Samociążek, and Koronowo. The physiognomy and the flora composition of this community depend on the abundance of *Prunus spinosa* and *Ligustrum vulgare* shrubs. Other shrubs present in this community are: *Crataegus monogyna*, *Rosa canina*, and *Cornus sanguinea*. In the herbaceous layer, which covers 35 to 60% of the area, there are found mostly the species of *Festuco-Brometea* class.

Class: *Alnetea glutinosae* BR.-BL. et R. TX. 1943
Order: *Alnetalia glutinosae* R. TX. 1937
Alliance: *Alnion glutinosae* (MALC. 1929) MEIJER DREES 1936
Assemblage: *Ribeso nigri-Alnetum* SOL.-GÓRN (1975) 1987

This community occurs in a relatively narrow belt along the river reaches on both of its banks which at its high water stage is often flooded. The species distinguishable are as follows: *Ribes nigrum*, *Solanum dulcamara*, *Padus avium* and *Urtica dioica*. In spring, rich herbaceous vegetation is developed, with *Ranunculus ficaria* dominating.

Class: *Querco-Fagetea* BR.-BL. et VLIEG. 1937
Order: *Fagetalia sylvaticae* PAWŁ. in PAWŁ., SOKOŁ. et WALL. 1928
Alliance: *Carpinion betuli* ISSL. 1931 em. OBERD. 1953
Assemblage: *Tilio cordatae-Carpinetum betuli* TRACZ. 1962

The richest and most precious community in the area researched has been preserved in deep gorges and ravines in the close vicinity of the river. In its most typical form it is present in the vicinity of Tryszczyn, Bożenkowo and 'Grabina' hills close to Koronowo. Broad-leaved forests in many parts of the valley have maintained their specific character sometimes even up to the upper edges of the ice-marginal valley. It is rich in eutrophic species specific to alliance *Carpinion betuli*, such as: *Paris quadrifolia*, *Phyteuma spicantum*, *Dryopteris filix-mas*, *Pulmonaria obscura*, *Stachys silvatica*. In this community there were found most protected species, including: *Daphne mezerum*, *Lilium mortagon*, *Hedera helix* (Opławiec), *Asarum europaeum* (Opławiec, Tryszczyn), *Hepatica nobilis*, *Galium odoratum* (Tryszczyn). In many of these communities, especially in the vicinity of Opławiec, Tryszczyn Forest, the tree layer is dominated by impressive oaks and linden trees, whereas the undergrowth is rich in the species representing geophytes and hemicryptophytes groups.

Order: *Quercetalia pubescenti-petraeae* KLIKA 1933 corr. MORAVEC in BEG. et THEURILL 1984
Alliance: *Potentillo albae-Quercion petraeae* ZÓL et JAKUCS n. nov. JAKUCS 1967
Assemblage: *Potentillo albe-Quercetum* LIBB. 1933

The community of *Potentillo albae-Quercetum* LIBB. oak forest is most clearly developed in the vicinity of Opławiec and Tryszczyn. The stand of oak wood is mostly built by *Quercus robur* with a considerable additive of *Pinus silvestris*. The shrub layer is poorly developed and made up mostly of *Frangula alnus*, *Crataegus monogyna*, *Berberis vulgaris*. The distinctive species include species which although of low abundance but defining the character of oak forest: *Potentilla alba*, *Campanula persicifolia*, *Primula veris*, *Melica nutans*, *Anemone nemorose.*

Class: *Vaccinio-Piceetea* BR.-BL. 1939
Order: *Cladonio-Vaccinietalia* KIELL.-LUND 1967
Alliance: *Dicrano-Pinion* LIBB. 1933
Assemblage: *Cladonio- Pinetum* JURASZEK 1927

The community forms in dry and poor habitats in the subsoil of coarse-grain loose sands in character, mainly in the vicinity of Bożenkowo and Samociążek and in the sandur fields south from Koronowo. The dominant species in the tree stand is *Pinus sylvestris* of low grading value. The undergrowth includes *Festuca ovina*, *Hieracium pirosella*, *Rumex acetosella*, *Calamagrostis epigejos*. The mossy layer in the community is dominated by xerophytic bryophytes and lichens of *Cladonia* genus.

Assemblage: *Peucedano-Pinetum* W. MAT. (1962) 1973

The tree stand of this community is made up by Scots pine with some additive of silver birch. In the canopy layer *Sorbus aucuparia* and *Frangula alnus* are abundant with sporadic understory of *Quercus robur*. The undergrowth layer is usually dense and well-developed with dominant *Vaccinum myrillus* and *Vaccinium vitis-idaea* as well as mesophilic mosses: *Dieranum polysetum*, *Hylocomium splendens*, *Pleurozium schreberi*. There are also present *Convallaria majalis*, *Solidago virgaurea*, *Peucedanum oreoselinum*, *Anthericum ramosum*. The community is found in the areas more distant from the river and it covers mainly the right-bank edges of the ice-marginal valley (Smukała, Janowo, Bożenkowo).

Ruderal communities

Class: *Artemisietea vulgaris* LOHM, PRSG. et R. TX. in R. TX. 1950
Order: *Onopordetalia acanthii* BR.-BL et R. TX. 1943 em GÖRS 1966
Alliance: *Dauco-Melilotenion* GÖRS 1966
Assemblage: *Echio-Melliotetum* R. TX. 1947

The present community in permeable soils in the close vicinity of assemblage *Potentillo albe - Quercetum* (Opławiec, Smukała, Janowo, Tryszczyn, Samociążek, Koronowo), with an advantage of such species as: *Mellilothus albus*, *Mellilothus officinalis*, *Echium vulgare*, *Oenothera biennis*, *Cirsium vulgare*, *Artemisia absinthium*, *Daucus carota*, *Medicago lupulina*, *Verbascum phlomoides*, *Verbascum thapsus*. In many parts of this community there are observed clusters of Scots pine and silver birch. The community has been forming for a relatively short time (about 15-20 years) and it is a result of secondary succession once the agricultural activity was given up in these areas. In the nearest future the areas will be covered by housing estates.

Class: *Stelarietea mediae* LOHM. et PRSG. 1950
Order: *Centauretalia cyani* R. TX. 1950
Alliance: *Aphanenion arvensis* R. TX. et J. TX. 1960
Assemblage: *Vicietum tetraspermae* (KRUSEM. et VLIEG. 1939) KORNAŚ 1950

A distinctive community present in less and less abundant farmland in the Brda River Valley. Due to its low fertility, mostly cereals are grown there (oat, rye, barley). This assemblage in drier and warmer soils neighbours with a well-developed assemblage of *Papaveretum argemones* (LIBB. 1932) KRUSEM. et VLIEG. 1939.

Discussion

The above review of essential communities in the area investigated depends mostly on the soil type, the moisture content, physiographic factors of the ice-marginal valley (the origin, landform features and exposure), climatic conditions, both the macro and microclimate, and anthropogenic factors (Brzeg i Wojterska 2001).

As a result of the 2003-2007 study in the field, it was found that in the lower part of the Brda River, despite a strong anthropogenic effect, there are many interesting communities which, in many cases are more likely to undergo successions degrading in character. Despite frequently not sufficiently clear distinguishing characters, there were identified and determined 18 major plant assemblages which are characteristic for water, reed bed, meadow, forest and ruderal vegetation habitats. The communities connected with water and reed bed vegetation are exposed to the most drastic negative changes since throughout its section investigated, the Brda River has lost its natural character due to hydrotechnical structures causing regular changes in the water table level daily by an average of 0.5 m. The Brda River in its section from the dam at Koronowo all the way to the power plant at Samociążek is practically a dead river; its water flow is very slow. Down the power plant at Samociążek, on the other hand, the river current changes, being raised or lowered by dams at Tryszczyn and Smukała.

The best preserved and rich in flora are the forest communities which, especially in the lower terraces of the river, occupy places unfavourable to their penetration and intensive forest management. Interestingly, partial cutting in the forest of the river basin of recent years has enhanced the species biodiversity in the communities. A special protection should cover very interesting, from the environmental perspective, low broadleaved forests present in the close vicinity of the river and located in gorges and deep ravines. Such communities are present mainly in the vicinity of Tryszczyn and Gościeradz as well as in 'Grabina' nature reserve in the vicinity of Koronowo.

Yet another group of plant communities worth protecting are xerothermic plant assemblages which, as reported by Ceynowa (1968), are the most northward communities of relict vegetation of the south-eastern European steppes and forest steppes. Up till now such type of vegetation has been described mainly in the Vistula River Valley (Płutowo) and the Noteć River Valley (Ślesin), however there has been little coverage available on these communities in the Brda River. The need to investigate this type of vegetation has already been reported on by Czubiński (1950), Czyżewska (1992) and Filipek (1974). Interestingly, they have been preserved mainly in the researched section of the ice-marginal valley since above Koronowo and the dam of Lake Koronowo there occur mostly compact forest complexes (Tuchola Forest) with no southward-exposed slopes formed from loamy sands of alkaline reaction. A heavy anthropogenic effect on these communities, by treading, fencing off, wasteful gravel and sand acquisition, littering, giving up extensive pasturage, strong self-sown tree and shrub growth, results in a loss of their natural character. Therefore synthetic stock-taking and developing the protection plan are needed. The xerothermic vegetation assemblages identified mostly fall within the vicinity of the upper terraces of the basin in the vicinity of Tryszczyn, Samociążek and Koronowo. The other plant assemblages identified in the Brda Valley, especially meadow and ruderal vegetation, frequently do not show clear diagnostic features due to the close vicinity of other communities and mutual species penetration. The state of these communities is also deteriorated by structural transformations; from the agricultural and forest function into service-and-housing complexes, especially in the districts of Bydgoszcz, such as Opławiec and Smukała as well as developing villages and housing estates of Tryszczyn, Bożenkowo, Samociążek, and Koronowo. The human activity in these areas will contribute to the spread of moderately xerothermic and ruderal species, mostly representing *Prunetalia* order.

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QUINOA (*Chenopodium quinoa* Willd.) GROWING AND APPLICATION POTENTIAL IN POLAND

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Introduction

The agriculture and food economy, both globally and in Poland, call for seeking new roads, including possibilities of enriching and diversifying foods. It is mostly due to a decrease in the number of plant species used in processing, mostly as a result of agriculture intensification, and thus an interest in plants most easy to cultivate and most prolific. As a result of such activities today's plants account for a great percentage of commonly known species, and only few of them supply over 90% of foods of plant origin. It leads to many complications, production surplus of many plants (e.g. cereals in the US) triggering, through soil degradation and contamination, natural environment degradation, food depletion to spread of diseases of civilisation (Haber 1996).

Looking for possibilities of enhancing the existing condition, an interest in plants once grown at a large scale and forgotten today has been resumed (Johnson and Ward 1993). Such plants include quinoa (*Chenopodium quinoa* Willd.), commonly known as quinoa (Ritter 1986; Risi and Galwey 1989; Whali 1990; Jacobsen et al. 1992; Nalborczyk 1995; Gęsiński and Kwiatkowska 1999a, b; Gęsiński 2000). That species is referred to as alternative crop or pseudocereal (Alkamper 1991).

Origin

Quinoa is an ancient crop, originating from Ecuador, Peru, and Bolivia, grown at least since the beginning of our era by American Indians, where it was brought to Argentina and Chile from. There is assumed that quinoa was pseudocereal of cultural origin, which is also considered to be the cause of its variation, similarly as amaranth variation (Heiser and Nelson 1974). Quinoa seeds constituted the basic diet component for poor people and therefore once America was conquered by the Spanish, the plant was not appreciated by them. Growing quinoa underwent regress and it was finally given up in the 19th century as a result of the import of cheap cereals from the US and Canada. Subsidized industrial wheat production resulted in the destruction of that ancient crop and, as a result, it was almost totally forgotten and, in those times, grown only on a few hundred hectares of land on the territory of Peru, Bolivia, and Chile.

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Quinoa plantations have survived on inaccessible highlands where due to unfavourable climatic conditions its plantations could not be replaced with e.g. barley or wheat. The interest in that ancient crop was resumed only at the beginning of the 20th century (Tripp 1990), which must have been affected by a growing vegetarianism fashion, which made people look for new valuable raw materials of plant origin to enrich the human diet and search for animal feed raw-material. That interest also considerably resulted from comprehensive applications of quinoa since not only its seeds, but also leaves and young shoots constitute precious raw material (Dębski and Gralak 2001).

The environmental scope of quinoa ranges from 2^o northern altitude in Columbia, to 40^o of southern altitude in Chile (Risi and Galwey 1989). It shows high tolerance to cold; it can stand the ground frosts to -5^{o}C. High yield occurs when minimal rainfall is not lower than 400 mm (Whali 1990). Thanks to its resistance to long-term drought and inconsiderable soil requirements, it yields even on rocky plots in the mountains at the height up to 4300 meters above sea level where no cereals can grow any longer (Dębski and Gralak 2001). Its advantage, besides low soil and climate requirements, is its high competitiveness towards most weeds, thanks to which the application of chemical treatments becomes unnecessary (Jacobsen et al. 1992). Such valuable characters of unusual resistance and ecological flexibility as well as high nutritive value of quinoa triggered interest in that species in European countries (Risi and Galwey 1989; Jacobsen et al. 1992, Ohlsson and Dahlstedt 1999; Iliadis and Karyotis 2000), also in Poland (Nalborczyk 1996, Grochowski 1998, Gęsiński and Kwiatkowska 1999a,b). Research supported by FAO and EEC aims at launching the cultivation of quinoa as an alternative crop and the source of 'health food' (Gęsiński 2000, 2001).

Characteristics

Quinoa is an annual plant the look of which depends considerably on the environment. The colours of the plant are determined by the form; there occur different shades of green. The plant can be also red or violet in colour. The plant height ranges from 0.2 to 2 m. The stem is cylindrical, over ripening it becomes empty, especially in lower parts. The root is a tap root with numerous branches, reaching the depth over 60 cm. The shape of leaves varies; similarly as the size, the shape depends on the location on the stem. Lower leaves are bigger and with thick serrations, while the upper ones – smaller, lanceshaped, in many forms red or violet. The number of serrations is an important classification character. On the bottom side young leaves are covered with mealy coating. Flowers are inconspicuous anemophilous, mostly hermaphrodite, sometimes female. The perianth is made up of five leaves, there occur five stamens and the unilocular ovary with a single embryo, flattened from the top (Grochowski 1996). The axis of the stem has a large compact terminal racemose inflorescence (Fig. 1).

Fig. 1. Quinoa inflorescence

The quinoa fruit is a nutlet 1.8-2.6 mm in diameter and 1 mm thick, breaking first during germination with the top. Its colour depends on the coloration of the fruit-seed coat and it can be white, yellow, creamy, coffee, brown or black (Fig. 2). The thousand seed weight ranges from 1.85 to 5.08 g.

Fig. 2. Quinoa seeds

Quinoa is morphologically similar to white goosefoot. They belong to the same family and to the same genus. Thus, from the taxonomic perspective, they are located very close to one another and hence many similarities. However, some differences can be found. White goosefoot is a common ruderal plant throughout Poland (Misiewicz 1985), an unusually persistent weed (Wehsarg 1961; Mowszowicz 1975). However, its seeds were used with other seeds of weeds and rye for baking the so-called hunger bread. As shown by archaeological investigations, our ancestors consumed not only quinoa seeds but also young shoots well replaced vegetables. Such an application of that species has been reported quite recently; over difficult war times when it was consumed because of valuable protein and, as reported in literature, it has been still grown in Asia (Podbielkowski 1989; Grochowski 1996). The above examples, however, are inferior to quinoa which has been long referred to as the mother of cereals. Today, however, it is included in the crop selection of not only many countries of America but also Europe, and the interest in it, recently especially, has been growing. Hence the question: what characters were crucial for the superiority and use of quinoa? With that in mind, research has been taken up to compare quinoa and goosefoot. The analysis concerned the morphological structure of the stem, inflorescence and characters connected with its prolificacy as well as the stem anatomy, including the pattern of the tissues and their development direction in the organs researched. Significant differences in the stem morphology, as well as the stem anatomy of the species analyzed were found (Gęsiński 2004). Significantly more branches were found in white goosefoot (5), in quinoa there are, on average, only 1.6 of them. Plants of white goosefoot are not only more branched but also their inflorescence is bigger. The inflorescence diameter of white goosefoot was 17.8 cm and of quinoa 5.07 cm. Similar relationships were observed for the inflorescence length. A longer inflorescence was reported for white goosefoot (55.6 cm) than quinoa (21.03 cm). In contrast, the average thousand seed weight in quinoa was much higher (2.1 g) than in white goosefoot (0.57 g). Quinoa seeds were a few-fold bigger than white goosefoot. Significant differences in the stem anatomy were also found. A greater share of colenchyma and pericycle in the stem of white goosefoot makes the plant structure stronger and the plant itself stronger and more resistant. A higher content of parenchyma, primary cortex, and pith were found in quinoa. The proportion of those tissues makes the stem structure more delicate and predisposes it for growing for green mater. One can, therefore, claim that the internal structure of quinoa as well as the morphological structure (smaller stem branches, compact terminal inflorescences, higher thousand seed weight) demonstrate a superior functional value than the characters of white goosefoot and, at the same time, offer a greater application potential of that species.

Growth and flowering of quinoa

To evaluate the growth and flowering of quinoa under Polish conditions, two cultivars which originated from two different breeding regions, America and Europe, were analyzed. From the American cultivar group ‘Kancolla’, bred in Peru and from the European cultivar group, E-DK-4-PQCIP bred in Denmark were selected. Growth models of these cultivars differed significantly (Gęsiński 2006a). In Polish environmental conditions, cultivar E-DK-4-PQCIP reached all the development stages until fully-developed seeds were produced, and ‘Kancolla’ – only the milk stage of seeds. Cultivar E-DK-4-PQCIP showed a higher growth rate at the beginning of the vegetation period, reaching the height of 120 cm. 'Kancolla' cultivar showed a lower-rate but continuous linear growth, until the end of vegetation when it reached 180 cm. Cultivar E-DK-4-PQCIP demonstrated short compact inflorescence which developed fast, completed the flowering period and was bearing fruit. 'Kancolla' showed a slow but continuous growth and loose and big-in-size inflorescence. In cultivar E-DK-4-PQCIP the flowering period was short, unlike in 'Kancolla'. An adequate nature of growth, flowering pattern and, as a result, stable yielding of cultivar E-DK-4-PQCIP make it applicable for growing under Polish conditions (Gęsiński 2006a). A comparison of the characters analyzed in American and European cultivars shows that the stock material both for breeding and growing should be European group cultivars.

Evaluation of quinoa growth and development in Poland suggests that basic habitat conditions are favourable; it concerns both climatic and soil conditions. Light soils, which are most abundant, are adequate for quinoa development (Gęsiński and Kwiatkowska 1999a, b). As for the weather conditions, temperature, sun-exposure and even such a low level of rainfall as reported in 1999 do not constitute a factor eliminating the development of that species. The only problem is the length of the vegetation period. The vegetation period of quinoa is long, which concerns mostly American cultivars, represented by 'Kancolla'. Their development under Polish conditions ends at the flowering stage or at the beginning of seed setting, under favourable conditions – the milk stage. That character eliminates that breeding group from growing under Polish conditions. In that respect, European cultivars, represented by E-DK-4-PQCIP, are favourable; their vegetation period is about 150 days long, which guarantees reaching the dough stage of seeds. However, there is still another problem connected with the development physiology of that species. Despite reaching the dough stage by seeds, the plant still contains high weight of green leaves, which is a problem connected with the harvest of that material. In the case of two-stage harvest, being more labour-consuming, the problem is solved. The seeds persist well in the inflorescence and its dislocation does not cause bigger losses. Unfortunately, in the case of bigger-scale production, the only solution is a fast chemical plant drying, especially because the harvest coincides with the end of September – beginning of October, the period which is already rather cold and moist. This suggests that the best solution would be to breed a Polish cultivar of an even shorter period of vegetation than the current European cultivars and so, obviously, the primary genotype should originate from that breeding group.

Interesting research were reported based on the analysis of selected 24 American and European cultivars of quinoa under Polish conditions (the Kuyavia and Pomerania Province), carried out as part of the Quinoa Test (Gęsiński 2008b). As reported by Dębski and Gralak (2001), the number of cultivars of that species is about two thousand, which differ not only in the plant height (from about 70 to 250 cm), resistance to drought, productivity, the seed colour. The question arises whether all the American cultivars available are inapplicable to cultivation under Polish conditions. A high variation in American cultivars was found; five of them produced seeds under the conditions analyzed. The most favourable characters and, at the same time, the best adjustment to climatic-soil conditions of the Kuyavia and Pomerania Province were found in English, Danish, and Dutch as well as Chilean (Baer-II-UAP) and Brazilian cultivars (02-Embrapa; Gęsiński 2008b). The plants of those cultivars showed a well-developed compact inflorescence filled with seeds, demonstrating an inconsiderable growth as compared with strongly-growing American cultivars which, at the same time, demonstrate fast emergence, short period of vegetative phase, flowering, and, as a result, short vegetation period. Those observations coincide with the earlier presented linear relationship of the length of the vegetation period on the plant height for quinoa under Poland's latitude (Gęsiński 2006b).

The above analysis also confirms the observations reported by Grochowski (2000) who noted that Chilean cultivars show favourable characters under European conditions. It shows that that group can also include cultivars from Brazil. Therefore selecting the genetic material of quinoa for growing in Poland (no Polish cultivar has existed so far), one shall make use of the selection of cultivars not only English, Danish, and Dutch but also Chilean and Brazilian. A rich experience in breeding that species in Chile guarantees a good genetic material, which is confirmed by one of the new Chilean cultivars, 'Faro', the seed yield of which under European conditions exceeds the so-far-existing European cultivars (Gęsiński 2000).

Interestingly, a decisive factor while selecting quinoa cultivar to be grown in Poland is the length of the vegetation period, besides the yielding potential under those environment conditions. However, as suggested by Mastebroek and van Loo (2000), the shortening of the growth and development period in that species, by breeding own cultivar, best adjusted to Polish conditions, seems to be the best solution, especially that the length of the vegetation period even of currently available European cultivars requires the September harvest. However, having a rich base in a form of good stable-yielding-under-our-latitude American genotypes (cultivars from Chile and Brazil) as well as good European cultivars, launching quinoa for cultivation in Poland does not pose any limitations.

Saponins elimination

Basic problems with introducing and using new alternative crops is most often connected with two aspects; the first one concerns the acclimatization and adjustment of agrotechnical practises to specific soil and climate conditions, while the second one is related to the new machine park. Those problems are especially difficult to solve due to high costs as well as due to the call for completely new technical solutions. Thus, introducing such species identifies problems which, at the beginning, often appear to be greater that the advantages defined. For that reason the adjustment of the existing machinery to the requirements of new species seems to be the simplest solution.

Quinoa seeds contain saponins in the outer layer of the fruit-seed coat (Variano--Marston and DeFrancisco 1984; Chauhan et al. 1992; Kozioł 1992). They are considered to be antinutritional substances (unwanted components of foods) giving a bitter taste (Johnson and Ward 1993; Dini et al. 2004). Therefore, the seeds of quinoa must undergo pre-processing. To use the existing devices, cylinder threshers were suggested for mechanical scarification of quinoa seeds to limit saponins. A question arises: what is the effectiveness of that device? There was investigated an effect of the intensiveness of abrasion on decreasing the content of saponins in seeds. A significant effect of mechanical scarification on the content of saponins in quinoa seeds after the application of the cylinder thresher was found. The suggested procedure makes it possible to reduce 93.6% of the content of saponins in quinoa seeds (Gęsiński and Gozdecka 2009). It shows a high effectiveness of the saponins reduction, considering the fact that limiting the saponins content to 0.1% eliminates bitter taste and makes it possible to use the seeds (Kozioł 1991). It was found that the saponins content depends on the times of scarification, which makes the adjustment of that process possible, whereas seed threshing only using the cylinder thresher limits the saponins content by 19.9%, which predisposes the application of that device as superior to the standard thresher for quinoa.

Another device applied to remove saponins from quinoa seeds was drum scarifier. Aan effect of the intensity of abrasion and the operation time on a decrease in the content of saponins in seeds was investigated. The present research involved two types of scarifying drums with the round and hexagonal exterior and three types of abrasive (120, 180, 220). The principle of operation of scarifier involves the rubbing of seeds through abrasive during the pouring and cascade movement of seeds. The content of saponins was determined with the foam test. It was found that the type of abrasive and the operation time considerably decreases the saponins level. The highest degree of reduction in the content of saponins in quinoa seeds was recorded by applying, irrespective of the drum shape, abrasive 220 and the number of drum rotations of 1000 (Gozdecka et al. 2008). One can claim that mechanical scarifying after an adequate selection of process parameters can well be applied to remove saponins from the seeds of quinoa. Besides, the present research can facilitate the development of constructional assumptions of the production device.

Chemical properties of soil after cultivation

A big question mark concerning the soil reaction to the plant are alien crop species, currently being introduced to Europe, also to Poland, including *Cupea, Spida*, *Miscanthus*, *Spartina*, *Amaranthus*, *C. quinoa*, *Polygonum sachalinense*, *P. cuspidatum* (Nalborczyk 1999) and others, which means also crop species not grown so far and currently introduced into arable fields. With that in mind, caring for the plant stand, facing the tendency of production simplifications and an increasing proportion of cereals in crop rotation, defining the soil properties, the stand left by new species promoted as a group of alternative crops seems very important, especially that most of them is proposed not only in organic farming systems (where caring for the value of the stand left is most crucial for an adequate operation), but also integrated, and in the case of some of them – even intensive. For that reason research has been taken up on the effect of varied nitrogen fertilization (60, 120, 180 $kg \cdot ha^{-1}$) in growing quinoa on selected chemical properties of soil. The content of basic components of soil was analyzed before cultivation and after harvest of quinoa grown for seed where, additionally, manure was applied and when grown for green matter – without manure. It was found that after quinoa cultivation, the values of most chemical soil components were higher, which points to positive trends in the changes of chemical properties of soil after growing quinoa. The application of nitrogen at the doses (60-180 $kg \cdot ha^{-1}$) with manure in quinoa growing stimulates similar chemical soil properties. The greatest similarity of the chemical properties of soil in the cultivation without manure were found after the application of the dose of 60 and 120 $kg \cdot ha^{-1}$ of nitrogen; they also stimulate positive tendencies of changes. The applied dose of 180 $kg \cdot ha^{-1}$ of nitrogen without manure in growing quinoa decreases the value of most chemical components (Gęsiński 2008a). One shall note that growing quinoa without its intensification is environment-friendly; it does not deteriorate chemical properties of soil and so it does not impose a heavy human interference. The species also shows the easiness of adapting to varied soil conditions. Quinoa has low soil requirements, thanks to which it can be grown in the regions of low level of agrotechnical practices (Mujica 1997). Due to a growing problem of monoculture, it can be used as a crop rotation plant (Grochowski 1996) and due to a positive tendency of changes in the chemical properties of soil following the application of organic fertilisation, growing quinoa in organic systems is also justifiable.

Quinoa under European conditions

Interesting results were obtained based on the comparative analysis of the growing potential of quinoa in Poland as compared with Europe and South America. The research was performed as part of the international Quinoa Test, in which not only European countries participated but also the countries from America, Asia, and Australia (Mujica et al. 2001). For the purpose of this paper European research centres were selected, representing Copenhagen (Denmark), Larissa (Greece), Bydgoszcz (Poland), Uppsala (Sweden) and Valdichiani (Italy) as well as South America: Buenos Aires (Argentine), La Paz (Bolivia), Brasilia (Brazil), Cajon (Chile), Cusco and Puno (Peru). Only those quinoa cultivars which demonstrated full development cycle were analyzed (Gęsiński 2006b). The analysis was performed based on the following publications: Mujica et al. (2001); Gęsiński (2000, 2001, 2006b); Iliadis and Karyotis (2000); Ohlsson and Dahlstedt (2000). It was found that high values of the sun exposure and moderate rainfall increases quinoa yield, while excessive rainfall has a negative effect.

Great differences in the growth and yielding between respective cultivars of quinoa in the clusters analyzed which were the effect of weather conditions were observed. Quinoa goes into the generative phase earlier at higher temperature values and sun exposure (Iliadis and Karyotis 2000), and thus under conditions similar to subtropical, Mediterranean and equatorial climate. Under the conditions of moderate climate with considerably lower mean temperature, the vegetation period gets much longer. Even though the quinoa has not been classified as a short-day species and it is photoperiod-neutral (Bertero et al. 1999), the day length has a significant effect on the length of respective development stages (Bertero et al. 1999). Christiansen and Jacobsen (2006) found that the length of the flowering and fruit-bearing period under short day conditions gets much shorter. The highest seed yield was found under the conditions of short vegetation period and high value of sun-exposure (8.4 h daily). Grochowski (2000), evaluating the morphotype from Chile, found that water excess for quinoa is more unfavourable than water deficit. Evaluating that reaction in white goosefoot, Sage et al. (1990) observed a simultaneous decrease in air temperature, photosynthesis parameters, transpiration and water use efficiency, despite an increase in conductivity. The biggest biomass was reported for quinoa cultivars under the conditions of Bolivia, Denmark, and Poland due to the longest vegetation period in those countries, which made abundant green matter production by the plant possible. This was confirmed by Risi and Galwey (1989) who claim, based on the characteristics of Bolivian cultivars, that quinoa under European conditions shows a more luxuriant vegetative growth and a longer vegetation period. Despite that, the conditions found in Europe are favourable to the cultivation of quinoa. The species demonstrates an average length of the vegetation period in Poland as compared with Europe. The highest seed yield in Europe was recorded in Greece. The conditions in Bydgoszcz (Poland) are very favourable for the cultivation for green matter and the seed yield (Gęsiński 2008c, d).

Nutritive value

Quinoa offers high nutritive value which exceeds the commonly grown species. The seeds demonstrate higher nutritive value, as regards all the nutrients, than wheat or maize (Table 1). The content of nutrients in green matter is similar to most legume plants and is even superior to some of them, e.g. red clover at the flowering phase. The analysis of the content of nutrients in seeds and green matter of 24 quinoa species researched showed their high contents (Gęsiński 2006b). What is noteworthy, a high content of nutrients both in seeds and in green weight, especially protein as well as crude ash and carbohydrates and basic macroelements. What seems interesting is a higher proportion of protein in green matter of quinoa (21.5%) than in seeds (17.6%) as well as crude ash (12.7% of dry matter) in green forage and in seeds (5.82%). However, undoubtedly, both the seeds and green matter of that plant are rich in nutrients. One shall also note a high content of fat which has a direct effect on the energy value, which additionally enhances the nutritive qualities of seeds of quinoa (Gozdecka and Gęsiński 2009).

Quinoa can be used both for nutrition purposes (animal feed) and as human food. Seeds and green parts of plants (leaves, stems) are useful. Its main advantage, however, are seeds. They demonstrate a very good chemical composition (Johnson and Ward 1993; Malewska 1995; Gęsiński 2000).

Table 1. Chemical composition of seeds and green matter of quinoa, corn, and wheat [%]

Nutrients	Seeds			Green matter	
	Quinoa	Corn	Wheat	Quinoa	Wheat
Protein	17.60	10.2	14.2	21.50	16.1
Ash	5.82	1.7	2.2	12.70	9.0
Fat	4.83	4.7	2.3	3.30	2.9
Fibre	5.28	2.3	2.8	25.60	26.4
N-free extracts	69.80	81.0	78.4	37.00	45.6
P	1.13	0.4	0.4	1.27	0.2
K	1.40	0.5	0.5	5.39	2.2
Ca	0.21	0.1	0.1	2.21	1.5
Mg	0.20	0.2	0.1	0.32	0.4

Application

The seeds of quinoa used in baking industry can be used as an additive for bread in different forms, e.g. entire seeds: roasted, soaked, soaked and roasted, and mostly flour produced from them. An additive of quinoa seeds to bread dough provides some advantages, e.g. enriching the bakery products with high-value nutrients, e.g. protein rich in amino acids, especially lysine and accelerated the dough fermentation process. One can also note an enhancement of physical features of dough, including an especially significant enhancement of its volume, prolonged freshness and thus the applicability for consumption. The seeds of can also be a good grit raw material; such groats are similar to groats made of millet (Haber et al. 1992).

Yet another advantage of quinoa seeds is the fact that they do not contain gluten; hence high potential for low- and gluten-free media and dishes for babies, small children and adults suffering from celiac disease.

Quinoa flakes with milk provide a very nutritious meal. Grain is also used for producing alcoholic beverage called *chicha*. It is a national drink of Andean Indians, while young plants can be consumed in a form of salads just like spinach (Grochowski 1996).

Quinoa seeds can provide precious animal feed. Similarly, the entire plant in a form of green forage or hay can be used in nutrition of ruminants and pigs (Carlsson et al. 1982; Carlsson 1989).

Saponins can be used for the production of pharmaceutical steroids, beer, fire agents, soaps, detergents, shampoo, cosmetics, and in photography.

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THE PLANE TREE (*Platanus* sp.) AND ITS PLACE IN THE URBAN LANDSCAPE OF BYDGOSZCZ

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Origin, morphological features and utilization of trees of the genus *Platanus*

The family *Platanaceae* includes only one genus – *Platanus*. It is estimated to include 10 species of trees and one interspecific hybrid. Of the separate species, five occur in Central America (*Platanus chiapensis* Standl., *P. lindeniana* S. Watson, *P. mexicana* Torr., *P. oaxacana* Standl., *P. rzedowskii* Nixon & L. M. Poole), three originate from north America (*P. occidentalis* L., *P. wrightii* S. Watson, and *P. racemosa* Nutt.), one species with the native range extending from the east coasts of the Mediterranean to Iran (*P. orientalis* L.) and one from Vietnam (*P. kerii* Gagnep.). Currently, only two of the above mentioned species are of large economic significance: the North American *P. occidentalis* (American sycamore) and its hybrid with the Oriental plane (*P. orientalis*), with the botanical name *P.* × *hispanica* Mill. ex Münchh (syn. *P.* × *acerifolia* (Aiton)Willd.).

The family *Platanaceae* belongs to the oldest taxa of angiospermous plants; they originate from the upper Cretaceous. In Tertiary deposits (dated to the period from Eocene to Miocene), in different regions of North America and on the south-east coasts of the Mediterranean, fossil remains of representatives of several extinct plane species are found, with the species which are common on both continents, *P. aceroides* (Ball Fossils Collection, Texas; Seneta and Dolatowski 2002; Kvacek et al. 2003). This proves the fact that *Platanaceae* still occurred commonly in the area of all Laurasia before separation of continents, at least 60 million years ago. As was mentioned above, none of the modern plane species origins from Europe, while they occur in America and Asia. This is a result of the Arctic-Tertiary disjunction which divided ranges of the original occurrence of this old genus, and spatial isolation of Europe in the postglacial period prevented planes from returning to this continent in natural way. Remigration of the plane tree to Europe took place only thanks to man's activity (Kornaś and Medwecka-Kornaś 2002; Podbielkowski 2002).

All the trees of the genus *Platanus* can reach very large sizes and are relatively long-lived: under natural conditions they live over 300 years (Szczepanowska 2001), although we find reports that specimens of Oriental planes can be found in Iran that reach an age of 1,000 years (Heywood 1993).

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Planes are characterized by light bark peeling off, they form palmate leaves similar to maple leaves but (unlike maple) with spiral leaf pattern on a shoot. These are monoaecious trees with flower heads. The fruits are nuts formed in ball-shaped aggregations which remain on trees for winter and open only in spring, releasing fruits covered with down, which is an adaptation to dispersal by the wind.

Both fossil species of planes and their modern substitute species show considerable morphological similarities. Presumably, that is why an easy, spontaneous crossbreeding happened of the American sycamore and Oriental plane specimens, planted closely in Oxford gardens at the beginning of the 17th c. The appearance of fertile hybrids of those species was documented as early as in the second half of the 17th c. It is worth mentioning that doubts were thrown on this spontaneous hybridization for many years (Heywood 1993; Seneta and Dolatowski 2002). Nevertheless, on the grounds of research on DNA structure, the genetic difference of the hybrid and its initial forms has been confirmed recently (Grimm and Denk 2008). It should be stressed, however, that specimens of *P.* × *hispanica* show large variation and forms similar in habit to both initial ones can be found among them. The feature that enables the relatively easiest distinction of *P. occidentalis* from *P. orientalis* and *P.* × *hispanica* is the number of fruit aggregations formed on one petiole: in the case of the American sycamore they are single, whereas at least two of them occur in the others.

It was noticed early that the interspecific hybrid of planes has valuable functional properties – it combines resistance to drought and air dust pollution, inherited from the Oriental plane, with the beautiful, massive habit and good tolerance towards winter conditions, typical of the American sycamore. It endures forming cutting well, and has relatively small soil requirements. In a short time the hybrid gained the reputation of a perfect tree for urban and roadside plantings. This is proved by its common names: London plane, French plane or Spain plane. Planes provide very precious wood which finds wide application in furniture industry, building woodwork production etc. The wood is pale pink with delicate outline, hard and quite elastic (Heywood 1993).

In Europe, the hybrid *P.* × *hispanica*, which was also recently introduced successfully into South Africa, has been grown almost exclusively for 200 years; but in North America, native planes (of different species) called there sycamores remain the favourite trees. The Oriental plane has certain economic significance mainly in West Asia, on the Balkans and in the south of the Italian Peninsula and Sicily, and the occurrence of *P. kerii* is limited only to the tropical zone (Poyton 1992). Geographical range of planes is limited by rather high heat requirements; especially young plants may be not frost-resistant enough. For that reason, several-year-old trees are planted, obtained from nurseries situated in the areas of a milder climate. Although it increases the costs of growing those valuable trees, yet it considerably reduces losses resulting from the risk of their freezing, and in addition, it is well tolerated by trees, which endures replanting even at older age (Szczepanowska 2001; Seneta and Dolatowski 2002).

Planes are attacked by a series of pathogens, the most dangerous of which are diseases caused by fungi of the subclass Ascomycetes (*Ascomycotina*): spot blight of plane leaves (caused by *Gnomonia platani* Kleb.) and canker-stain of plane tree (caused by *Ceratocystis fimbriata* Ellis et Halsted f. sp. *platani* Walter). The former disease is recorded in the whole Europe including Poland; it results in preharvest drop of leaves, leading to a considerable weakening of trees but not killing them (Tello et al. 2000; Lesisz 2005); whereas canker-stain of plane is an extremely dangerous disease, leading to the complete dying out of trees. Growing intensity of its occurrence is being observed in France and Italy (Vigouroux 1986). Among pests feeding on plane leaves, spotted tentiform leafmine (*Phyllonorycter blancaldela* Fabr.) which lives, apart from plane, on many species of trees (Kadłubowski and Wilkaniec 1982) is mentioned as predominant.

Technical abilities of protection against diseases and pests of trees planted in cities are very small, and their vitality is considerably lower than of those growing in natural habitats (Szczepanowska 2001). All the more valuable are long-lived specimens, which have managed to survive in the artificial environment of the city and sometimes reach imposing sizes. In Poland many of them are under protection on the strength of the Act of 16th April 2004 On protection of nature. Dz. U. No. 92, item 880, granting them nature monument status.

The planes in Bydgoszcz

Planes are trees which are relatively rarely planted in Poland. They can be found most frequently in the west and south-west regions. The majority of them are old trees. Undoubtedly, promotion of planting those plants, exotic for our land, is related to the activity of German gardeners (in the territory of the former Prussian annexation). In Bydgoszcz, until the period after World War II, the leading gardeners were citizens of German origin (Biskup 1991; Kutta 2004).

The genus *Platanus* is scarcely represented in the flora of Bydgoszcz. We can meet representatives of two species – American sycamore and London plane. The exact date of planting American sycamores is known; in 1926 a double avenue of planes was established in Revd Ryszard Markwart Street on the south side and a single avenue on the north side (Kuczma 1995). Bearing in mind that plane specimens between ten and twenty years old are used for plantings, presently those trees may already be about 100 years old. A number of the trees have already been cut down, and those which are growing now are very big and present the state from very good to quite good (after removing a part of limbs).

The other old planes – hybrids – are growing in a line along the part of Powstańców Wielkopolskich Street, and also alone and in a small group in other places of the city. As far as those trees are concerned, it was not settled when they were planted, although there are some premises which can allow us to approximate their age. The former ones, impressive as they are, do not particularly stand out from the surroundings. Presumably, they were planted at the end of the 1930s, when the buildings in a part of the street where they grow were arranged (Modra 1996; Badtke 2007). Although they did not reach as huge sizes as those growing in Revd Ryszard Markwart Street, they might not be much younger. Other worthy of note specimens of the London plane can be found in the oldest part of the city. In 1991 nine of them were entered in the Regional Register of Nature Monuments of the City of Bydgoszcz (RR 1991; Kaja 1995).

London planes – nature monuments in Bydgoszcz

Over 2005-2007, a study of the physical state and the state of habitats of trees, Bydgoszcz nature monuments, was conducted in the Department of Botany and Ecology of the Faculty of Agriculture UTP (Jendrzejczak et al. 2006), including eight out of nine monumental planes. The ninth specimen (no. 905 in RR 1991) is growing at the Military Aircraft Factory on Szubińska Street. Due to the lack of direct access, it has not been analyzed. In 1991 its diameter at breast height was assessed at 280 cm (RR 1991; Kaja 1995).

The measurements of the full height of trees, crown height, trunk circumference at a height of 1.30 m and at the ground as well as the crown spread (crown radius measured in eight directions) were made in order to characterize tree sizes according to the binding dendrometric methodology (Bruchwald 1999).

The shape of tree crowns was described in words, according to the nomenclature used in dendrometry, and by the coefficient of regularity of crown projection shape (w_k), calculated from the equation:

$$w_k = \frac{\sum_{i=1}^{8}(r_p + r_i)}{8r_{\max}}$$

where:

r_i – length of individual crown radii, $i = 8$,
r_{max} – length of the longest crown radius of the eight measured,
r_p – trunk radius at ground, calculated based on trunk circumference measurement.

According to this equation, the coefficient equal to 1.0 indicates trees with the crown evenly developed in all directions. A chart illustrating the horizontal projection of the crown was made for all the specimens examined.

All the monumental specimens of the London plane are characterized by a good or very good state of health, probably resulting from the inborn resistance of this species to living in urban conditions. This is the case in spite of the fact that they usually grow in the neighbourhood of buildings, intensively used traffic routes, including (in one case) the immediate vicinity of a platform of the railway station!

Table 1. Biometric data of monumental specimens of London planes in Bydgoszcz

Type of measurement	Number of a tree							
	I	II	III	IV	V	VI	VII	VIII
Tree height [m]	29.50	29.00	33.00	29.00	19.00	26.00	28.00	21.00
Crown base height [m]	4.50	7.00	6.00	6.50	6.50	2.50	3.50	6.00
Crown height [m]	25.00	22.00	27.00	22.50	12.50	23.50	24.50	15.00
Trunk circumference at height 1.30 m [m]	4.00	4.56	4.52	3.58	2.84	3.62	3.42	3.26
Trunk circumference at ground [m]	6.25	7.32	6.37	4.80	4.13	5.70	5.35	4.52
Crown spread [m]								
N – S	20.00	22.40	24.50	15.00	19.80	22.80	19.70	20.90
E – W	25.50	30.80	29.00	29.50	20.30	23.30	17.30	20.90
Crown projection area [m^2]	488.64	498.48	528.63	365.83	310.06	351.21	246.46	328.37
Coefficient of crown projection shape	0.73	0.85	0.86	0.68	0.83	0.86	0.84	0.85

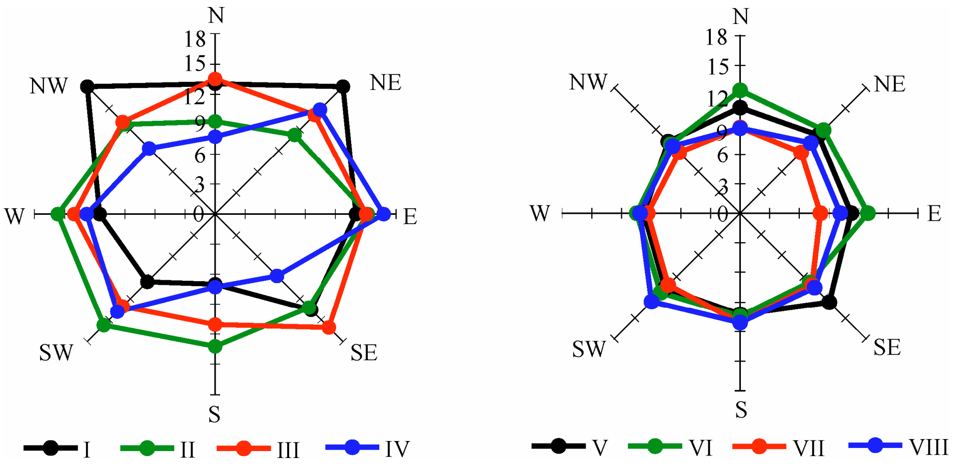

Fig. 1. Crown projections of specimens of eight monumental London planes in Bydgoszcz; maximal range of limbs [m]

A group of four planes growing in a row at the back of a house belonging to the Polish State Railways at 63 Dworcowa Street (no. 772 in RR 1991; in Table 1 marked as the planes I-IV) deserves special attention. The are growing on the Brda bank, at a site which is particularly favourable for specimens of this species. They reached the most considerable sizes of all the monumental planes. This refers particularly to their imposing height and very thick trunks. The third of the planes from the east is the highest of the monumental trees and, presumably, one of the largest trees in Bydgoszcz. Due to the closeness of a building from the north side, those beautiful specimens have deformed crowns, growing in east-west direction (Fig. 1); the trees clearly lean back from the building towards the river.

This imposing group of trees at the stage of leaf formation almost covers the huge building standing in the background. The edifice was put to use in 1889 as the seat of East Railway Direction and surrounded by a beautifully designed square (Kuczma 1995). It may be assumed that at that time the planes were planted at the back of the square.

The sizes of the discussed planes are gigantic for the conditions of Bydgoszcz. However, it is difficult to notice them through the surrounding buildings. The best view of them opens from the Queen Hedwig bridge.

In the vicinity of those trees, also in the territory administered by the Polish Railways, another (V) monumental specimen of the London plane is situated (no. 1202 in RR 1991). It can be found right next to platform 1 of the Bydgoszcz Główna railway station, in Zygmunt August Street. Such location of a huge tree may seem strange, to put it mildly, its living conditions are very difficult, and yet it has reached a height of 21 m at the crown spread close to 21 meters. What is more, the crown is very well formed and developed evenly in all directions (Table 1, Fig. 1). Presumably, the tree was planted after the construction of the front building of the railway station had been finished (in 1914). It was surrounded by a square planted with trees (Biskup 1991; Kuczma 1995).

The age of the other three monumental planes is probably similar to the latter, and the time of their planting is relatively easier to determine and can be dated to 1905-1909, so they must be more than 100 years old.

The first of them, marked here as specimen VI, (no. 94 in RR 1991) is growing at the Theater Square at the corner of Karmelicka Street. In 1909, a green was established at this place on the grounds after the closed down Carmelite monastery, surrounding a new theatre building, planted with many trees (Biskup 1991; Modra 1996). There must have been the planes among them which grow in this square today, including the monumental specimen. The tree crown is slightly irregular, better developed from the east, towards Mostowa Street. However, it is very wide-stretching, thick and low-set (Table 1, Fig. 1).

The next (VII) beautiful plane tree (no. 95 in RR 1991) is growing at the edge of the Casimir the Great's City Park. It is a part of the green strip surrounding St Apostles Peter and Paul's church. This huge tree with a height of 28 m and a wide-stretching, very regular crown (Table 1, Fig. 1) dominated a considerable part of a lane running along the south side of the Liberty Square. Reports exist that the arrangement of green on this square coincided with organizing the surrounding of the mentioned church after finishing its building at the turn of the 19th and 20th centuries (Kutta 2004). It may be supposed that also the tree was planted at that time.

At the same time, the construction of an impressive building at the junction of the present Gdańska and Juliusz Słowacki streets was finished, where now the broadcasting station of the Polish Radio of Pomerania and Kuyavia is situated. As in the case of all the tenements which were then put to use, also at the rear of that house a garden was established which still exists now (Biskup 1991). Next to the building, the last (VIII) of the monumental planes described is growing (no. 97 of the regional register). It is lower than others, but almost equal in respect of other dimensions (Table 1). Presumably, this specimen was also planted in the first years of the 20th c.

Comparing the sizes of all the mentioned trees and projections of their crowns indicates that long-standing living in urban conditions have not influenced unfavourably their growth and development. The closeness of a large building and actions correcting the crowns changed the habit of the planes I and III to a large extent, but the others are quite regularly developed (their w_k coefficients are close to 0.9).

Conclusions

All the planes mentioned in the study were already magnificent trees at the end of the interwar period. They were mentioned in the register of the major city trees made out in 1938 (Kuczma 1995). They have been in a very good state up to the present day, especially the specimens of London planes. Both those on which the status of nature monuments has been conferred and the others distinguish themselves in the rich flora of the city. They belong to the most magnificent trees in the city, reached impressive sizes and need a special care to be preserved in such a good condition as they are now. The fact that the trees have been in a good state of health so far should be particularly stressed. It means that they find a favourable environment in conditions of Bydgoszcz. Therefore, it would be worthwhile enriching the city flora with next plantings of this precious species. Sites near the Brda river in its reaches through the city centre, especially on the south bank without buildings, can be a suitable place for them.

Setting about planting with planes, a growing threat of injuries caused by fungal diseases and pests must be taken into account. Reports from different regions of Poland indicate that the health of the old planes is deteriorating (Lesisz 2005). This, however, does not take on the proportions of damages observed in the countries of West Europe (Vigouroux 1986; Tello et al. 2000). Methods for protection of planes against the most dangerous fungal pathogens have already been worked out. Their effectiveness is first of all determined by utilization of seedlings from licensed nurseries. Apart from applying proper seedling material, it is necessary to carry out the chemical protection of young trees, which determines their appropriate acclimatization at new places (Lesisz 2005).

In conclusion it is worthy of note that the only information available in the literature concerning the sizes of the monumental trees described refer to the value of their breath height and are lowered in relation to the actual state. The inventory of their state which was made updated and increased our knowledge about those beautiful specimens of nature.

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CLAY MINERALS IN DIFFERENT SOIL TYPES FROM THE KUYAVIAN-POMERANIAN PROVINCE

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In the polydispersive arrangement of soil elements such as: soil solution, humic substance, iron and aluminium oxides, and clay minerals, a series of processes that determine the course of soil-forming processes takes place. As a result of their influence, soils of various types were generated, differing in the morphological structure, physical and chemical properties, and mineralogical composition (Johnson and Watson-Stegner 1987).

Intensity of the secondary transformations of clay minerals in the soil decreases with the depth, thus demonstrating characteristic zonality and profile diversification (Allen et al. 2004). These processes occur the most intensely in the surface horizon, which is related to the chemical weathering and uneven distribution of organic substance and mineral elements in the soil profile (Smeck and Novak 1994).

First studies on the properties of the soils of Kuyavia region were done in the 1960s by Cieśla (1961; 1968). His results became the point of reference for the present studies concerning the evaluation of changes in the physico-chemical properties and mineralogical composition of the clay fraction of soils from Kuyavian-Pomeranian Province.

Present mineralogical studies are not limited to the soils of the Inowrocław Plain but also include the soils of the Krajeńskie Lake District, the Lower Vistula Valley, the Chodzieskie Lake District, the Chełmińskie Lake District, the Dobrzyńskie Lake District, and the Toruń Valley. These soils are diversified in regard to the typology and the origin of their parent material. They were derived from glacial till, fluvioglacial formations, and alluvial, limnic and eolian sediments (Dąbkowska-Naskręt 1990; Długosz 1994b; Jaworska 1994a; Kobierski 2001; Długosz and Malczyk 2003; Bartkowiak 2008). The aim of the present study was the determination of the effect of soil-forming processes on the mineralogical composition of clay fractions. Undoubtedly, primary soil material undergoes strong diversification under the influence of these processes. However, there is no basis for claiming that pedogenesis changes completely the mineralogical composition of the fraction by ø < 0.002 mm. Therefore, a specific set of secondary minerals cannot be unambiguously assigned to a given soil type. This results from the qualitative and quantitative diversification of the products of

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parent material weathering, which is one of the most important factors that determine soil properties.

Local conditions related to the diversified geomorphology of the mesoregions and specific morphological structure of soil profiles are the reason why few researchers use X-ray diffractometry (XRD) method for mineralogical assessment of arable soils in their studies. Works describing arable soils of Kuyavian-Pomeranian Province are few (Dąbkowska-Naskręt 1990; Długosz 1994b; Jaworska 1994a; Kobierski 2001; Bartkowiak 2008). Complex studies of the soils clay minerals impose the choice of analytic methods and determine the interpretation and methods of results elaboration. In the studies, the procedures valid in the analyses of soil samples were used (Cieśla 1965a; Gonet and Cieśla 1988). According to these premises, selected parameters of bulk soil samples and clay fraction in soil profiles were determined.

Soils of the studied region

Soil cover of Kuyavian-Pomeranian Province is very diversified in regard to the origin and type of the soil parent material, among which glacial till of the Vistula glaciation is dominant. In addition, fluvioglacial formations also occur in the form of outwash plain, kame and esker sands. Ten percent of the surface is covered by Holocene formations, such as peat, alluvial, delluvial, and limnic sediments (Kondracki 2002). Type of parent material is one of the factors that affect the spatial variability of the soil cover, which is its natural property related to the diversification in soil factors and overlapping soil-forming processes (Bockheim et al. 2005). Climatic conditions had a significant influence on the course of the soil-forming processes and their directions. Course of these processes also depends on natural drainage conditions, relief, and also on the amount of precipitation (Gerrard 1981). Average annual precipitation in the region is one of the lowest in Poland (Peszek 1996).

Some of the most characteristic and at the same time the most fertile arable soils in the region are Kuyavian Phaeozems, previously known as haplic Chernozems, which were described in detail by Cieśla (1961; 1962; 1965b; 1968) and Cieśla and Dąbkowska-Naskręt (1983). It was found that they developed under the influence of several environmental factors, from which the hydrological factor was of the greatest significance. On the surface of carbonate glacial till, included in the gleyic process, organic matter humification processes took place, which led to the creation of a genetic horizon with a significant humus content. According to the Word Reference Base for Soil Resources (WRB 1998), the surface horizon (Ap) of Kuyavian Phaeozems meets the criteria of the *mollic* diagnostic horizon. In addition, diagnostic horizons such as: *cambic*, *calcic* were found in Kuyavian Phaeozems and, as a result of clay fraction translocation into the soil profile, *argic* diagnostic horizon – illuvial horizon (Bt; all symbols of the horizons according to the Polish soils systematics 1989) may be formed.

In Kuyavian-Pomeranian Province, a characteristic type of plain landscape and moraine elevations with ranges of terraces and dunes intersected by accumulative valleys can be found (Gilewska 1999). In the local depressions, the so-called histic Phaeozems were formed. However, the latest studies show that these soils undergo transformation in the following direction: gleyic Phaeozems → mollic Phaeozems → dystric Phaeozems → cambic Phaeozems → Phaeozems with the *argic* horizon (Kobierski 2001). This process starts from local elevations and gradually extends to lower locations (Marcinek and Komisarek 1991; Marcinek 1998). As a result, a slow decrease in the acreage of Phaeozems occurs, which evaluates towards soils that are their analogues – Cambisols with *mollic* horizon (Marcinek et al. 1995; Prusinkiewicz and Bednarek 1999).

After melioration, changes in the air-water properties of the soils were noted in the region. The latest observation shows the weakening of the gleyic process, as a result of natural lowering of the level of ground water (years of smaller precipitation), as well as the applied drainage. In the gleic Phaeozem subtype, the gleyic process traits are still visible, often including the whole soil profile. It is worth noting that Cambisols and Luvisols present in the Inowrocław Plain area do not show any gleyic process traits (Kobierski and Dąbkowska-Naskręt 2003).

Second most frequent soil type of Kuyavian-Pomeranian Province is Luvisols usually derived from glacial till. Basis for their classification is the presence of *argic* diagnostic horizon (Bt horizon) in their soil profiles. Many of the Luvisols in the region, due to their morphological structure (lack of visible *luvic* – eluvial (Eet) horizon), were classified as Cambisols. Proofs that they are not Cambisols were given by Kobierski's research conducted within project KBN 0700/P06/2003/25, which explicitly showed the presence of Bt horizon in their soil profiles. Questions concerning the classification of arable Cambisols occurring in the young glacial area are still valid (Szrejder 1998; Prusinkiewicz and Bednarek 2001; Marcinek and Komisarek 2004; Bednarek et al. 2004), especially since, on the basis of the research results, an urgent need for a verification of soil-agricultural maps of the region has been stated.

In the river valleys and floodplains of Kuyavian-Pomeranian Province, Fluvisols of diversified granulometric composition (even within the profile) can be found, which is a result of their lithogenesis (Dąbkowska-Naskręt 1990). In addition, hydrogenic and organic-mineral soils formed from limnic sediments can be found in the region (Kordowski 2003), as well as Arenosols formed from eolian sand near Bydgoszcz (Długosz and Malczyk 2003).

Mineralogical composition of the clay fraction of soils from the region

Clay minerals that are part of clay fraction, in addition to humus, belong to the active components that decide about many important soil properties. Some of the properties are cation exchange capacity, reaction, and buffer properties.

Main clay minerals of arable soils in Poland are illites, smectites, and chlorites. More rarely vermiculites and kaolinites occur (Stankowska 1976; Kaczyński and Grabowska-Olszewska 1997). In addition to homogeneous minerals (known as pure minerals), also mixed-layer minerals appear, such as illite/smectite (I-S) and smectite/chlorite (S-CH). Clay fraction of the arable soils of Kuyavia and Pomerania region is mostly illitic because illites and their interstratified forms with smectites play a dominant role in soils derived from glacial till, alluvial and fluvioglacial deposits, and water-originating silt (Cieśla and Dąbkowska-Naskręt 1983; Długosz 1994a; Jaworska 1994a, b; Dąbkowska-Naskręt and Długosz 1996; Dąbkowska-Naskręt et al. 1996a, b; 1998a, b; Długosz et al. 1997; Kobierski 2001; Długosz 2002; Kobierski and Dąbkowska-Naskręt 2003; 2005; Długosz et al. 2004; 2005). Diffractometric analysis of the clay fraction of soils derived from the eolian sands of inland dunes from the surroundings of Bydgoszcz showed, however, the presence of very poorly crystallized illites (Długosz and Malczyk 2003).

Arable soils of the studied mesoregions derived from the glacial till of ground moraine of various ages are characterized by a regional specification of the chemical composition of clay fraction, which may result from various participation of illites (Figs. 1-6). The highest participation of these minerals was found in the surface horizons of all soil types. This is shown in the diffractograms, in which very clear peaks can be seen of the d-spacing: d = 1.00 nm; 0.500 nm; and 0.333 nm (Środoń and Gaweł 1988).

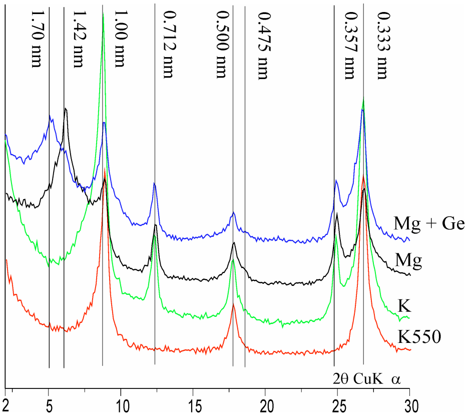

Fig. 1. Diffractograms of clay fraction from the Cca horizon of the Krajenskie Lake District

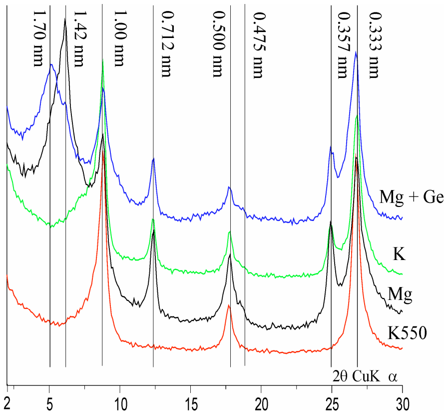

Fig. 2. Diffractograms of clay fraction from the Cca horizons of the Chodzieskie Lake District

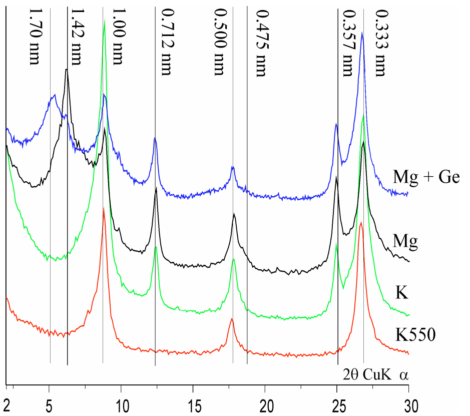

Fig. 3. Diffractograms of clay fraction from the Ccagg horizon of the Dobrzynskie Lake District

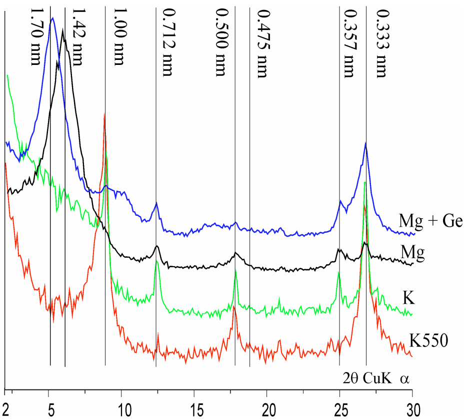

Fig. 4. Diffractograms of clay fraction from the II Cgyigg horizon of the Unislaw Basin

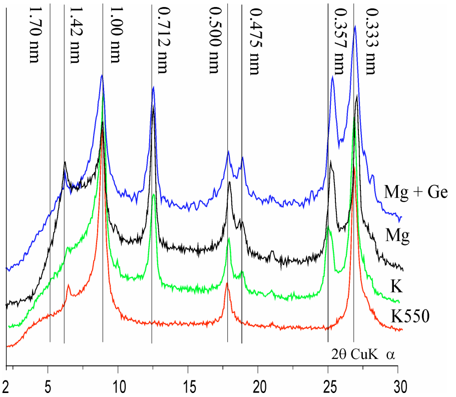

Fig. 5. Diffractograms of clay fraction from the Gca horizon of the Inowroclaw Plain

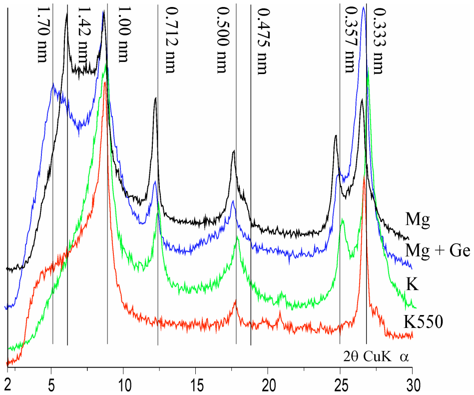

Fig. 6. Diffractograms of clay fraction from the C horizon of the Krajenskie Lake District

Relatively high K_2O content in the soils bulk samples and clay fraction <0.002 mm indicates a domination of illites in arable soils from the investigated region (Cieśla and Dąbkowska-Naskręt 1983, Kobierski and Dąbkowska-Naskręt 2003, 2005).

Illitic minerals dominated in the clay fraction of the surface (Ap) and eluvial (Et) horizons of Luvisols (Figs. 7, 8).

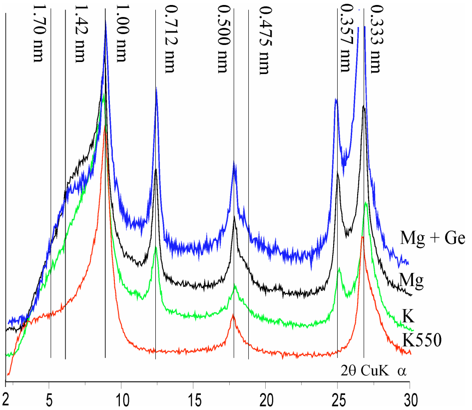

Fig. 7. Diffractograms of clay fraction from the Ap horizon of the Phaeozem

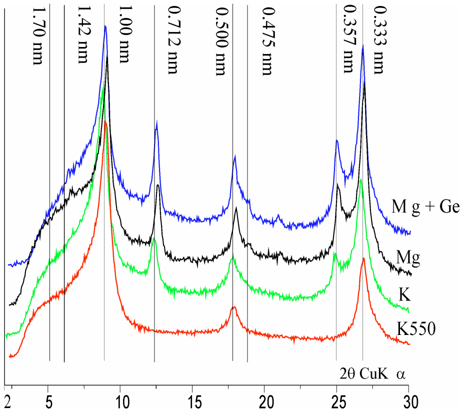

Fig. 8. Diffractograms of clay fraction from the Eet horizon of the Luvisol

Direction of mineral transformation, known as illitization, was earlier diagnosed most often in the Ap horizon of the soils (Filon 1994), in which fertilisation with high doses of potassium caused lasting bonding of this element in the structures of illitic minerals (Długosz 1994b; Długosz et al. 1997; Kobierski and Dąbkowska-Naskręt 2003, 2005).

During the analysis of the soils texture, clear enrichment in the fraction <0.002 mm of illuvial (Bt) horizon of Luvisols was observed. The sand (soil fraction) dominates in the majority of the surface horizons of all soil types. Smectite group minearals dominate in fine clay fraction (<0.2 µm), which is translocated as the first one from the upper horizons of the soils (Chodak et al. 1990; Jaworska 1994a; Dąbkowska-

-Naskręt and Długosz 1996; Dąbkowska-Naskręt et al. 1996b; Reid et al. 1996; Długosz 1997; Dąbkowska-Naskręt et al. 1998b; Jaworska and Dąbkowska-Naskręt 1999; Wilson 1999). Distribution of clay fraction in the soil profiles in the analysed region points to the lessivage process as the dominant soil-forming process, which also appeared in Kuyavian Phaeozems and the Fluvisols of the Lower Vistula Valley (Dąbkowska-Naskręt and Długosz 1996; Kobierski and Dąbkowska-Naskręt 2003).

Illites content in the soils of the region points to a certain regularity directly related to pedogenesis and processes modifying the soil parent material. A similar connection was noted also in the Fluvisols of the Lower Vistula Valley, in which the content of smectites and illite/smectite minerals increased with the depth, indicating a pedogenic character of their enrichment (Dąbkowska-Naskręt and Długosz 1996).

In the cambic – illuvial Bbr(t,fe) horizon of Phaeozems and Cambisols of the region, the influence of the lessivage process on their mineralogical composition was found. In the clay fraction of Bbr(t,fe) horizons, an increase in smectite content and a higher percentage participation of smectite layers in illite/smectite and smectite/chlorite minerals was noted (Kobierski and Dąbkowska-Naskręt 2003).

Mobility of clay fraction in the soil profile first depends on the dominant soil-forming process and then on the mineral composition. In the upper part of the parent material of Kuyavian Phaeozems, the Bca calcic horizon was found, characterized by accumulation of smectite minerals. This confirms the hypothesis about the presence of both accumulation of calcium carbonate and oriented clay in the same horizon, which implies a complex history of carbonate leaching, deposition of pedogenic calcite, and clay illuviation (Gunal and Ransom 2006). The depth of $CaCO_3$ leaching and the extent of calcium carbonate precipitation in the profile are function of the original carbonate content, water chemistry (pH) and cumulative quantity of infiltrating water. This process was also observed in the Btca horizon (illuvial horizon, clay fraction and carbonate enriched) of eroded Luvisols (Figs. 9, 10).

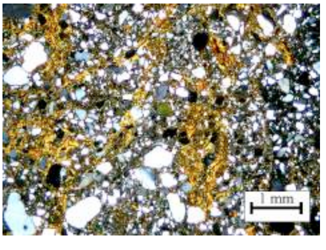

Fig. 9. Micromorphology of the Bt horizon of the eroded Luvisol. Crossed nicols

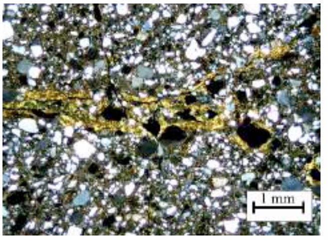

Fig. 10. Micromorphology of the Btca horizon of the eroded Luvisol. Crossed nicols

The lowest content of illite minerals was found in the clay fraction of the Bt horizons of Luvisols, the upper part of parent material of illuvial horizon was enriched in $CaCO_3$ (Bca) of Phaeozems, and Bbr(t,fe) horizons of Cambisols. The presence of a clear correlation between the percentage content of fine clay fraction and the illite content in them was observed. This dependency is inversely proportional, describing higher amounts of illite minerals in genetic horizons with a lower content of fine clay fraction. The highest content of smectites and illite/smectite minerals in which a high participation of smectite layers was stated was observed by Kobierski and Dąbkowska-

-Naskręt (2003) in the Bt horizon of Luvisols, Bca of Phaeozems, Bbr(t,fe) of Phaeozems and Cambisols from the region (Figs. 11, 12).

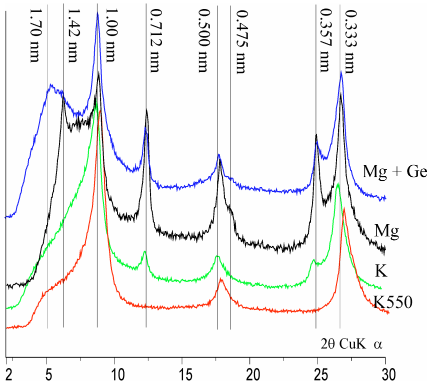

Fig. 11. Diffractograms of clay fraction from the Bt horizon of the Luvisol

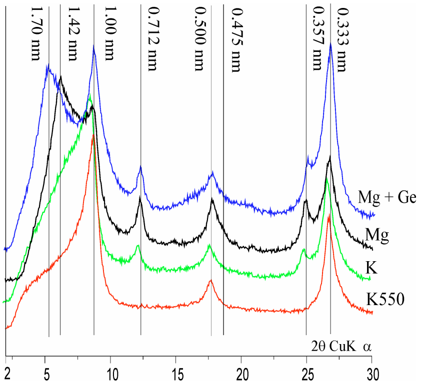

Fig. 12. Diffractograms of clay fraction from the Ccagg horizon of the Phaeozem

Inseparably from illite and smectite minerals, mixed-layer minerals of the illite/smectite (I-S) type occur (Eberl et al. 1993). These minerals of the majority of soil types from Kuyavian-Pomeranian Province were characterized by a diversified smectite (S) layers content (Fig. 6). Clay fraction of the surface horizons of the soils from the Inowrocław Plain contained 15-65% smectite layers (Długosz 1994a; Długosz 1997; Dąbkowska-Naskręt et al. 1998b; Kobierski and Dąbkowska-Naskręt 2003, 2005). Very low content of smectite layers (15% S) was characteristic for the I-S minerals of Luvisols in the Dobrzyńskie Lake District. These were minerals of the illite/smectite type with the ordered structure of the ISII type (Dąbkowska-Naskręt et al. 1996b). Presence of these minerals confirms the described in literature smectite aggradation process (Eberl et al. 1986). During the analysis of the diffractograms of the clay fraction of illuvial horizons and parent material with $CaCO_3$ (Cca) and parent material with gleyic processe (Ccagg) of the soils of the region, an increase of smectite layers in illite/smectite minerals was observed (Środoń 1981; 1984), among which minerals with an entirely random structure dominated (Kobierski 2001). In the Fluvisols of the Lower Vistula Valley, the presence of smectite layers (S) in illite/smectite minerals oscillated between 38% and 79%.

In the soils included in the gleyic process, interactions between physico-chemical properties and the direction of clay minerals transformation were stated. Large content and mobility of iron and magnesium cations in variable soil humidity may be an indicator of the chloritisation and smectitisation processes of clay minerals that take place in it (Kobierski and Dąbkowska-Naskręt 2003).

The primary chlorites are commonly trioctahedral, with the octahedral layer and polymerized hydroxyl interlayer dominated by Mg^{2+} and Fe^{2+} and other divalet metal cations. Trioctahedral chlorites are typically found in soils where only slight weathering has occurred (weathering of biotite). Secondary chlorites are alternation products of primary minerals but pedogenic chlorites, created through the process of chloritization, are products of smectite or vermiculite weathering (Righi et al. 1993). On the the X-ray patterns of K^+ saturated clay fraction, a weak 1.42 nm peak of chlorites which collapses after heating up to 550°C (K550). It can be stated that chlorites of pedogenic origin dominated in the clay fraction of most arable soils in the region (Długosz 1994b, 1997; Dąbkowska-Naskręt et al. 1998a; Kobierski and Dąbkowska-Naskręt 2003). These were for the most part chlorites with a diversified content of iron and magnesium (Dąbkowska-Naskręt 1990). In the horizons Ap and Eet of stratified Luvisols from the Dobrzyńskie Lake District, an accumulation of these minerals was found (Figs. 13, 14).

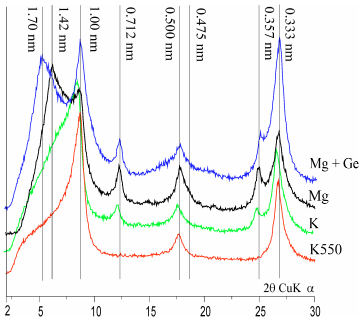

Fig. 13. Diffractograms of clay fraction from the Ap horizon of the stratified Luvisol

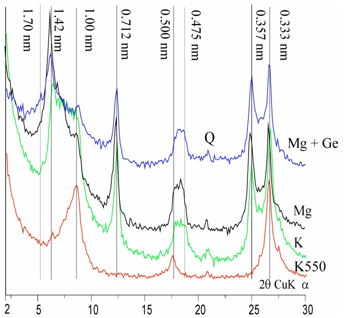

Fig. 14. Diffractograms of clay fraction from the Cca horizon of the stratified Luvisol

Pedogenic chlorites are characterized by a labile structure, which is proven by a large amount of peaks within d = 0.467-0.476 nm and the loss of the line peak (001) after the thermal treatment of K^+ saturated clay fraction (Barnhisel and Bartsch 1989). Chlorite transformation direction was observed the most clearly in the gleyic horizon of Phaeozems (Fig. 5). Even texture of these soil profiles is conducive to a free flow of water together with elements dissolved in it (Kobierski and Dąbkowska-Naskręt 2003). Chemical analyses show that in the horizons included in the gleyic process, the highest iron and magnesium content was stated, both in the bulk soil samples and clay fraction. Groun water, gleyic process, neutral soil pH, and a high $CaCO_3$ content influence the course of clay minerals transformation. This leads to slowdown, especially in soil environment with low chemical reactivity (Środoń 1980; Eberl et al. 1986, 1993; Józefaciuk 1998). Relatively high content of free iron (Fed) and exchangeable magnesium cations in the soil solution was conducive to the chloritisation process in the soils of the Inowrocław Plain (Kobierski and Dąbkowska-Naskręt 2003). Small participation of chlorites in clay fraction was found in Luvisols and Cambisols in which there is a lack of hydromorphic traits that evidence gleyic process.

In the clay fraction of the soils of Kuyavian-Pomeranian Province, a significant content of smectite/chlorite minerals was found (Figs. 6, 11), (Dąbkowska et al. 1996; Długosz et al. 1997; Kobierski and Dąbkowska-Naskręt 2005).

A small group of secondary minerals was constituted by the mixed-layer minerals of the illite/chlorite (I-CH) type. In the majority of cases, the presence of illite layers exceeded 60%, taking on higher values in parent material horizons.

Specific minerals whose presence was found in the soils of the region are vermiculites and mixed-layer minerals containing vermiculite layers (Figs. 15, 16). The presence of these minerals is proven by peaks with d-spacing; d ≥ 1.42 nm, visible in the diffractograms of Mg^{2+} saturated clay fraction (Stoch et al. 1983).

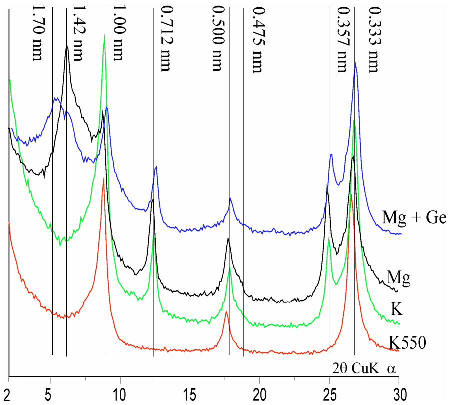

Fig. 15. Diffractograms of clay fraction from the Ap horizon of the eroded Luvisol

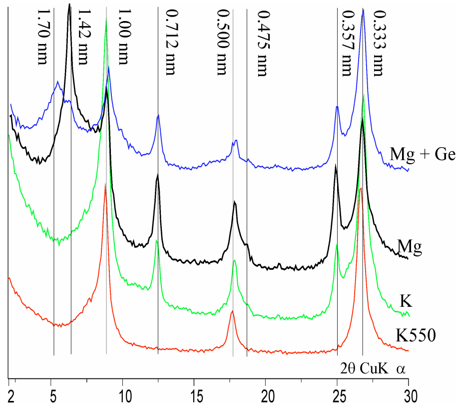

Fig. 16. Diffractograms of clay fraction from the Bt horizon of the eroded Luvisol

Minerals smectite/vermiculite (S-V) contain in their structure a predominant amount of smectite layers. The position of the peaks from interlayered minerals is related to the peaks from their components. The diffraction peaks from a randomly interstratified mineral will be intermediate between the two nearest peaks of its component. Smectites having d = 1.69-1.72 nm peaks were observed with Mg^{2+} glycol-saturated (Mg + Ge) of clay fractions (Borchardt 1989). In all the studied pedons the amount of smectite in the clay fraction increased with depth and reached maximum in the Bt and Cca horizons of soils. The results of XRD analysis showed that heating up to 550°C (K550) did cause a collapse of the d = 1.42 nm peak to d = 1.00 nm. The disappearance of the d = 1.42 peak upon K^+ saturation of clay fraction indicates that vermiculite is present and chlorite is absent. The d-spacing of vermiculite is 1.42 nm when Mg^{2+} is saturated, spacing that cannot be expanded further by glycolaction (ethylene glycol). In illuvial and parent material horizons rich in exchangeable magnesium and calcium cations, the isomorphic substitution of K^+ in the illite structure may occur. Then, transformation of illite into smectite or vermiculite through mixed-layer structures occurs. Characteristic d ≈ 1.20 nm and d ≈ 1.10 nm peaks of clay minerals collapse to d = 1.00 nm after heating in 550°C. The complete collapse upon the heating of the peaks from the K^+ saturated of clay fraction indicated the presence of pure vermiculites (Pawel and Uziak 1977), (Figs. 13, 14). Presence of these minerals was found in the illuvial and parent material horizons of eroded Luvisols in the Krajeńskie Lake District, the Chodzieskie Lake District, and the Chełmińskie Lake District (project KBN 0700/PO6/2003/25), (Figs. 1-3). Vermiculites and interstratified minerals with vermiculite layers were also found in the stratified Luvisols from the Dobrzyńskie Lake District (Fig. 14). These soils, on the basis of texture analysis, were classified as silt loam, with loam present in the parent material. Micromorphological analysis confirmed the bisegmentality of these soils. In the top layer, water-originating silt with well and moderately rounded quartz grain and few, weathered potassium feldspar grains was found (Figs. 17, 18).

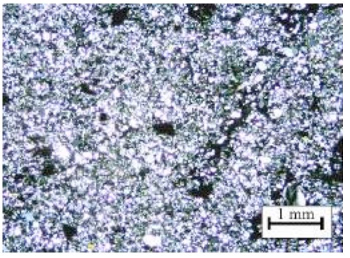

Fig. 17. Micromorphology of the Eet horizon from stratified Luvisol. Crossed nicols

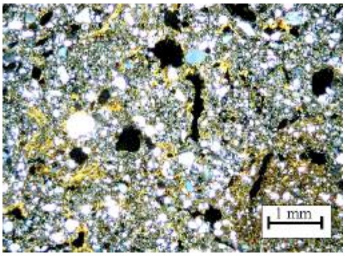

Fig. 18. Micromorphology of the Bt horizon from stratified Luvisol. Crossed nicols

Under the layer including Ap and Eet horizons lies loam that contains moderately rounded quartz grain, few feldspars and plagioclases with no clear weatering signs, as well as pyroxenes and amphiboles. In horizons Bt, illuvial clay components (skelsepic and lattisepic plasma) infilling (Figs. 17, 18) vughs and local clay enrichments of a laminated structure containing crystal iron oxides are visible (project KBN 0700/PO6/2003/25).

Surface erosion and intensive agricultural cultivation of Luvisols in the mesoregions of the Krajeńskie Lake District, the Chodzieskie Lake District, and the Chełmińskie Lake District caused irreversible changes in their morphological features. The transformations consisted in the inclusion of the shallow eluvial horizon Eet in the Ap horizon. The thus formed sequence of genetic horizons in the soil profile resembles in its morfology Cambisols, and this is why in the past these soils were classified as typic Cambisols. Issues concerning Cambisols classification were taken up by Marcinek (1994) in his studies, who pointed out the need for the verification of taxonomy premises and introduction of a new subtype of eroded Luvisols. In these soils, under the Ap horizon, the Bt horizon with characteristic eluvial clay plasma and an accumulation of the clay fraction of laminated structure rich in iron oxides occurs.

Based on the characteristic micromorphological properties it is shown that the clay components are visible between grains (*lattisepic*), in places in the forms of sheaths around the grains (*skelsepic*; Figs. 9,10). Clay fraction of the surface horizons of eroded Luvisols contained more smectite minerals than the clay fraction of the typic Luvisols of the analysed region (Fig. 16).

As accessory minerals in the clay fraction of all analyzed pedons of Kuyavian -Pomeranian Province were kaolinites. Their presence was stated on the d = 0.712 nm; d = 0.357 nm peaks (Środoń and Gaweł 1988; Dixon 1989). Disappearance of these peaks upon K^+ saturation and heating (550^{o}C) indicates the presence of kaolinite.

Small area of Kuyavian-Pomeranian Province is occupied by soils developed from allochtonous sediments (the Unisław Basin). These are soils of diversified morphological structure. Presence of the gyttja of various types in the bedrock points to the changing conditions of their aggradation (water level) and confirms the diversity of the aggraded sediments. These processes were of no influence on the mineralogical composition of clay fraction, in spite of the diversified content of calcium carbonate, iron oxides, and organic carbon in the soil profile. In these soils, clay fraction contained mostly smectite and interstratified minerals of the illite/smectite (I-S) type with a significant amount of smectite layers (Fig. 4). Clay fraction in these soils probably derived from the glacial colloidal components from the Vistulian glaciation (Bartkowiak 2008).

Summary

The nature of clay minerals in arable soils is easily afectted by soil forming processes and anthropogenic activity. Although the soils were mapped in the same soil series, the geomorphic position of the pedons and nature of the parent material affected the properties and clay minerals composition. In the horizons of the parent material, which is characterized by genetic homogeneity, great similarity in the mineralogical composition of clay fraction was observed. Mineralogical analysis shows the predominance of illites and illite-interstratified minerals in the clay fraction. Moreover, in the parent material with gleyic spots, the presence of chlorite group minerals was detected. The dominance of smectite increased in the Bt and Cca horizons. The high content of vermiculite in the surface horizons of eroded Luvisols was caused by physical properties of soils, especially in particle size distribution and pedogenic processes. Clay illuviation is also one of the most important pedogenic processes for Kuyavian-Pomeranian Province. Arable soils with an argillic horizons cover most of the cropland area of the analyzed region. Knowledge of clay movement and the relationship of clay mineralogy to soil properties is important to understand the performance of soils from the analyzed region. Such information is very much needed for the current classification of the soils.

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SWAMP ANGELICA *Ostericum palustre* Besser. IN GRASSLAND COMPLEXES OF THE NOTEĆ RIVER VALLEY AND THE BYDGOSZCZ CANAL

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Conditions of occurrence of *Ostericum palustre*

The majority of grasslands was established and has remained thanks to their use for agriculture purposes. For a long time farmers have undertaken various attempts in order to increase yield of grassland as well as to improve the use value of meadow sward for feed production. Vegetation of most current grassland has been changed. Only few meadows in Poland have retained their natural character. The most frequent cultivation measures applied on meadows include seeding of meadow sward with forage grass mixtures. This results in the biggest changes in meadow flora, reflected in withdrawal of rare stenotopic species, which have small competitive abilities and are sensitive to changes in habitat, in favour of nitrophylic species. The phenomenon of a depletion of many plant species was intensified by land amendment works carried out mostly in the 1960s and 1970s, which most often aimed at land drainage. This phenomenon was observed by many authors throughout the country (Brzeg and Wojterska 1996; Grynia and Kryszak 1997; Kucharski 1999; Ratyńska 2003; Chmiel 2006; Krasicka-Korczyńska 2007a;). Harvesting of meadow sward for hay-silage, applied currently in agriculture, also limits and sometimes even prevents meadow plant seeds from forming and shedding, which also can eliminate many species of meadow plants (Krasicka-Korczyńska 2007b; 2008a). The destruction of meadow sward by herbicides is also observed (Łyszczarz and Łuniewski 2006) before the application of sward seeding, which will probably even deepen the changes in meadow flora which are unfavourable for biodiversity protection. In spite of this, some rare species have remained in the Noteć River Valley and the Bydgoszcz Canal, and among them swamp angelica *Ostericum palustre* – a priority species (Krasicka-Korczyńska 2008b).

Species biology

O. palustre belongs to the family umbellifers *Apiaceae*. It is a perennial plant with a short rhizome, cylindrical or thick spindle-shaped. The stem is inflated, matt green, coloured reddish at the bottom, strongly grooved with a height of 40-180 cm. Lower

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leaves are long-petioled, with segments of primary petioles bending down. Leaf blade is 2-3 pinnately compound, pinnae are unevenly serrate, triangular-ovate or cordate-ovate (Fig. 1).

Fig. 1. Lower leaves of *Ostericum palustre*. Phot. E. Krasicka-Korczyńska

Upper leaves are considerably less; they embrace the stem with dilated sheaths. The inflorescence is an umbel made up of 8-30 umbellets. Angelica blooms from June to September. Flowers are monoecious, with distinct sepals and wide, white petals cut at the top. Fruits, diachene type, are 4-6 mm long and 2.5-4 mm wide, ellipsoidal or egg-shaped, winged on ribs. Due to the similar habit and occurrence habitat it is often confused with wild angelica *Angelica sylves*tris and ground elder *Aegopodium podagraria*, which are common species in Poland's flora.

Geographical distribution

Swamp angelica belongs to the group of species with the Euro-Asia-continental range (Oberdorfer 1990). Its natural range stretches from the regions of Central Europe and farther in a quite narrow strip through East Europe, to West and Central Asia (Meusel et al. 1965; Hulten and Fries 1986; Fig. 2).

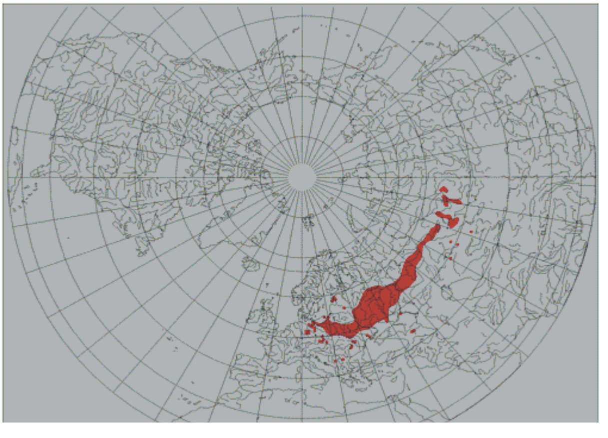

Fig. 2. Range of *Ostericum palustre* (Hulten and Fries 1986)

In Poland it occurs within a wide strip stretching from the Lublin region, through Podlasie, Mazovia and Kuyavia, to Great Poland. Single sites have been recorded reaching as far north as Kaszuby (Zając and Zając 2001; Fig. 3).

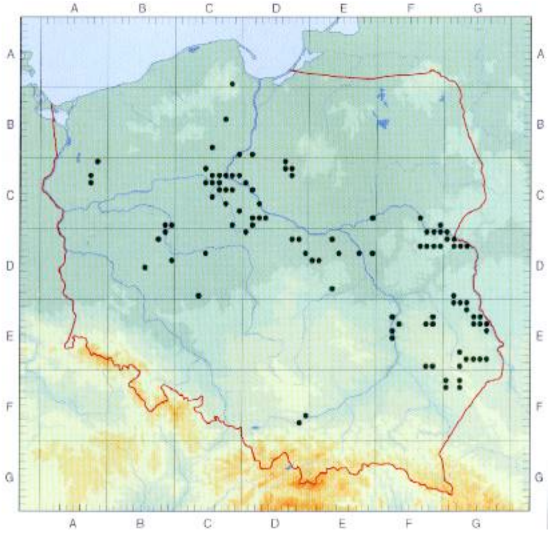

Fig. 3. Distribution of *Ostericum palustre* in Poland (Zając and Zając 2001)

It is a species under strict protection (Regulation of the Ministry of Environment 2004). In the Polish Red Book of Plants it occurs as an endangered species (Kaźmierczakowa and Zarzycki 2001). Due to a small number of sites (only 101) collected in the database ATPOL (Zając and Zając 2001), many of which is of a historical value today, it has been entered on the Red List of Vascular Plants of Poland as an endangered species. It is a priority species of Natura 2000 Areas (Regulation of the Ministry of Environment 2005). In the Kuyavia and Pomerania region *O. palustre* has been classified as a species in danger of extinction (Rutkowski 1997).

As a rare and vanishing species it occurs in the area of West Pomerania and Great Poland (Żukowski and Jackowiak 1995; Krasicka-Korczyńska and Rutkowski 2005; Jackowiak et al. 2007), Gdańsk Pomerania (Markowski and Buliński 2004), Central Poland (Jakubowska-Gabara and Kucharski 1999), West Polesie (Kucharczyk and Szukałowicz 2003), the Lublin Upland, Roztocze, West Wołyń and the Lublin Polesie (Kucharczyk and Wójciak 1995), and also as an extinct species from the former Kraków province (Zając and Zając 1998). It has been found on the Małopolska Upland (Bróż et al. 2002; Nobis and Piwowarczyk 2004; Bróż and Podgórska 2006).

Specimens of *O. palustre* rarely occur individually, they most often form populations of different size occurring in loose clusters, sometimes even ten to twenty individuals per 1 m^2 (Załuski 2004). In Poland these are sites of highly varied population sizes. Sites from north Kuyavia and Great Poland belong to the most abundant (Załuski 1995; Czarna 1999; Czarna and Załuski 2001). Very numerous populations of this species were observed in Dalewo, Dolsk, and Królewiny at the Łąka Pyzdrska (Czarna 1999). Hundreds and possibly even thousands of specimens were observed in the 80s in the vicinity of Inowrocław and Rojewo (Głoćko 1981).

Phytocenotic spectrum

Habitats of swamp angelica occurrence are placed on a list of habitats of priority importance, requiring protection in the form of determing NATURA 2000 areas: 6410 – *Molinia* meadows (*Molinion*), 6510 – lowland and mountain fresh meadows extensively used (*Arrhenatherion elatioris*), 7230 – mountain and lowland alkaline peatbogs of a character of bog-springs, sedge moors and moss moors (Dz.U. No. 94 of 2005).

Communities to which the species is related are meadows of the class *Molinio-Arrhenathereta* (Czarna and Załuski 2001). *O. palustre* occurs in humid, extensively used meadows of the order *Molinietalia* (Matuszkiewicz 2005). It was most frequently recorded in the community *Selino-Molinietum caeruleae* of the alliance *Molinion caeruleae* (Grynia 1962; Załuski and Kępczyński 1991) and in *Angelico-Cirsietum oleracei* of the alliance *Calthion* (Grynia 1962). Angelica was less often observed in the communities of humid meadows *Caricetum caespitosae*, *Epilobio-Juncetum effusi*, *Filipendulo-Geranietum* and in the fresh meadows and grasslands *Lolio-Cynosuretum* and *Potentillo-Festucetum arundinaceae* (Sudnik-Wójcikowska 1981), as well as the sedge moors *Caricetum acutiformis*, *Caricetum ripariae* and *Caricetum appropinquatae* (Fijałkowski and Chojnacka-Fijałkowska 1982) and the light alder carr *Ribeso nigri-Alnetum* of the class *Alnetea glutinosae* (Fijałkowski 1994).

Threats and protection

The main threat to this species is habitat changes caused by draining the areas of river valleys and abandoning the traditional meadow cultivation technologies. During last two years, noticeable losses have been observed in population resources, most probably related to drought periods. Dominance of generative specimens has been observed for several years (Załuski 2004).

List of *O. palustre* sites in meadow complexes of the Noteć River Valley and the Bydgoszcz Canal found in the years 2006-2009 (Fig. 4)

1. Forestry Drogosław, the south-east part of forest area 1-01-67-f-00. Several individuals occur there in a fresh, wet meadow with cabbage thistle *Angelico-Cirsietum olerecei.* The meadow is used for hay.
2. Forestry Jaktórka, the south fragment of forest area 1-03-5A-s. Fresh, wet meadow and riverine bush in the vicinity of drainage ditches. Several specimens occur which bloom and bear fruit. Overgrowing meadow, single young specimens of shrubs occur.
3. Forestry Jaktórka, the south fragment of forest area 1-03-5A-t. Fresh wet meadow and riverine bush in the vicinity of the Gąsawka River. Several specimens occur there which bloom and bear fruit. Hay meadow.
4. Forestry Pszczółczyn, the east part of forest area 1-06-87-a. Several specimens grow at a drainage ditch.
5. Forestry Pszczółczyn, the south-east part of forest area 1-06-87-c. Several specimens grow at a drainage ditch.
6. Forestry Borek, the west and east part of forest area 2-08-39-l. Several specimens of *O. palustre* occupy a narrow strip at a drainage ditch.
7. Forestry Borek, forest area 2-08-50A-d. Several specimens of *O. palustre* occupt a fresh wet meadow.
8. Forestry Laskownica, forest area within the Noteć River Valley 2-11-114A-b. Several specimens in a fresh wet meadow used for hay.

9. Forestry Laskownica, forest area within the Noteć River Valley 2-11-119-a. Several specimens occur in a moss meadow, partly used for hay.
10. Forestry Laskownica, forest area within the Noteć River Valley 2-11-119-c. Several specimens in a fresh wet meadow used for hay.
11. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-82A-i. Wet, fresh meadow not mown, several specimens.
12. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-82A-j. Wet, fresh meadow, not mown, several specimens.
13. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-84-i. Wet, fresh meadow, not mown, several specimens.
14. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-84-l. Wet, fresh meadow, not mown, several specimens.
15. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-91-d. Wet, fresh meadow, not mown, several specimens.
16. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-91-f. Wet, fresh meadow, not mown, several specimens.
17. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-91-h. Wet, fresh meadow, not mown, several specimens.
18. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-c. Wet, fresh meadow, not mown, several specimens.
19. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-d. Wet, fresh meadow, not mown, several specimens.
20. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-f. Wet, fresh meadow, not mown, several specimens.
21. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-g. Wet, fresh meadow, not mown, several specimens.
22. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-h. Wet, fresh meadow, not mown, several speicmens.
23. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-i. Wet, fresh meadow, not mown, several specimens.
24. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-j. Wet, fresh meadow, not mown, several specimens.
25. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-272-k. Wet, fresh meadow, not mown, several specimens.
26. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-274-a. Wet, fresh meadow, not mown, several specimens.
27. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-274-b.Wet, fresh meadow,k not mown, several specimens.
28. Forestry Nakło n. Notecią, forest area within the Noteć River Valley 2-12-273-c. Wet, fresh meadow, not mown, several specimens.
29. Forestry Tur, forest area within the Noteć River Valley 3-17-188C-d. Wet, fresh meadow, not mown, several specimens.
30. Anieliny – the Noteć River Valley – *O. palustre* occurs numerously in most area of fresh, wet meadows used for hay. It also occupies the edges of local drainage ditches.
31. Chobielin Młyn – the Noteć River Valley – occurs numerously in most areas of fresh, wet meadows used for hay.
32. Gostusza – the Noteć River Valley – occurs very numerously in fresh, wet meadows used for hay.
33. Jadwiżyn – the Noteć River Valley – occurs numerously in fresh, wet meadows used for hay.
34. Jeziornica – several specimens occur in fresh, wet meadows used for hay.
35. Ludwikowo – the Noteć River Valley – several specimens occur in fresh, wet meadows used for hay.

36. Łabiszyn – the Noteć River Valley – several dozen specimens occur in fresh, wet meadows used for hay.
37. Łodzia – the Noteć River Valley – occurs commonly very numerously.
38. Małe Rudy – the Noteć River Valley – numerously along the Noteć Canal. Apart from that, along drainage ditches.
39. Nakło on Noteć – the Noteć River Valley – numerously in fresh meadows used for hay and in drainage ditches, less frequently in rushes.
40. Oporowo – the Noteć River Valley – quite numerously in meadows, along the Noteć River Valley.
41. Paterek – the Noteć River Valley – numerously.
42. Paulina – the Noteć River Valley – numerously in fresh, wet meadows, less frequently in *Molinia* meadows.
43. Polichno – the Noteć River Valley – numerously in fresh, wet meadows, less frequently in *Molinia* meadows.
44. Pszczółczyn – the Noteć River Valley – rarely in moss meadows.
45. Pturek – the Noteć River Valley – numerously.
46. Rzywno – the Noteć River Valley – several dozen specimens.
47. Samostrzel – the Noteć River Valley – numerously in fresh, wet meadows, less frequently in *Molinia* meadows.
48. Weronika – the Noteć River Valley – numerously in fresh, wet meadows, less frequently in *Molinia* meadows.
49. Bnin – the Notec River Valley – numerously in fresh, wet meadows, less frequently in *Molinia* meadows.
50. Władysławowo – the Noteć River Valley – several dozen specimens along the drainage ditches.
51. Zamość – the Noteć River Valley – numerously in the area of the Noteć Canal, individually in the Noteć River Valley.
52. Zielonczyn – the Bydgoszcz Canal Valley – numerously.
53. Gorzeń – the Bydgoszcz Canal Valley – occurs very numerously in fresh, wet meadows used for hay.
54. Kruszyn Krajeński – the Bydgoszcz Canal Valley – quite numerously in fresh, wet meadows used for hay.
55. Lisi Ogon – the Bydgoszcz Canal Valley – quite numerously in fresh, wet meadows used for hay and individually in sedge moors.
56. Minikowo – the Bydgoszcz Canal Valley – very numerously.
57. Łochowo – the Bydgoszcz Canal Valley – numerously.
58. Ślesin – the Bydgoszcz Canal Valley – very numerously.
59. Trzeciewnica – the Bydgoszcz Canal Valley – very numerously.
60. Załachowo – the Bydgoszcz Canal Valley – numerously.
61. Folusz near Szubin – the Gąsawka River valley – occurs in patches in *Molinia* meadow complexes and quite numerously in fresh, wet meadows. Most often in meadows used for hay.
62. Rynarzewo – the Gąsawka River valley and Noteć River Valley – several specimens.
63. Wojsławiec – the Gąsawka River valley – several specimens.
64. Sipiory – occurs numerously in fresh, wet meadows used for hay.
65. Studzienki – occurs numerously in fresh, wet meadows used for hay.
66. Lisi Kąt – occurs numerously in fresh, wet meadows used for hay.
67. Wielki Sosnowiec – numerously in wet, fresh meadows.
68. Białe Błota – numerously in *Molinia* meadows.
69. Szaradowo – the Biała Struga River valley – numerously in *Molinia* meadows, salinited.

(Explanations: very numerously – coverage may reach 65%; numerously – coverage to 25%)

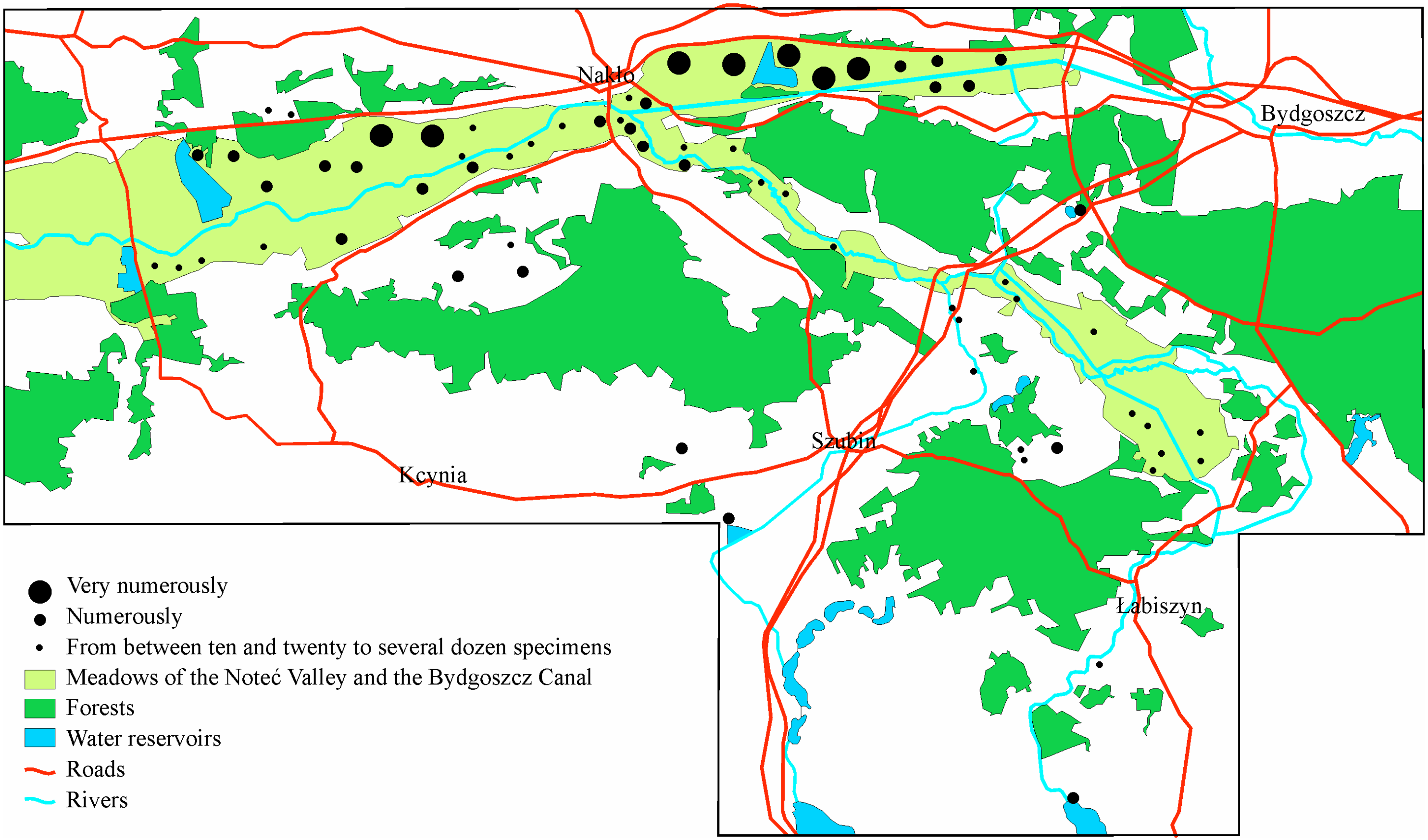

Fig. 4. Swamp angelica *Ostericum palustre* Besser. in grassland complexes of the Noteć River Valley and the Bydgoszcz Canal

O. palustre frequently occurs in the Noteć Valley (at the fragment from Barcin, to the west boundaries of the Kuyavia and Pomerania Province to Jadwiżyn) and throughout the Bydgoszcz Canal. It occurs also in the valley of the Gąsawka River and in the Noteć Canal Valley at the section from Zamość to Łabiszyn). Additionally, it can be observed it in small meadow complexes within the wide Szubińsko-Łabiszyńska Plain (Kondracki 2000). It usually occupies wet meadows with a large proportion of sedges. On utilized meadows it remains more intensively only by ditches and in depressions. It happens to reach a coverage of 30% on one meadow, and may be completely absent on an adjacent meadow, which is undoubtedly affected by the method of cultivation technology and meadow management. In total, 69 sites have been observed. It occurs most numerously in patches of phytocenoses of *Caricetum caespitosae*, in the assemblage of *Poa pratensis-Festuca rubra* and *Epilobio-Juncetum effuse*, and less frequently in *Caricetum gracilis*, *Caricetum acutiformis*, *Caricetum distichae*, *Angelico-Cirsietum oleracei* and *Potentillo-Festucetum arundinaceae*. It occurs sporadically in patches of *Junco-Molinietum*, and individually in phytocenoses *Phalaridetum arundinaceae* and in communities with *Deschampsia ceaspitosa*.

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PERMANENT GRASSLAND BY THE BYDGOSZCZ CANAL: PAST – PRESENT – PROSPECTS

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The Bydgoszcz Canal is an artificial waterway of about 26 km connecting the Brda and the Noteć, and through them, water catchments of West and East Europe. The author of the project of 1766, commissioned by King Stanislaw August Poniatowski, was the geographer captain Ćśaky. However, the building costs appeared to be too high for the capabilities of the Crown's treasury at that time. The task was completed after taking over of these lands by Prussia and on the orders of King Fridrich II, the canal was build hurriedly over 1773-74. Local people and workers brought mostly from Germany were used for work at its construction. Because of the tremendous pace of work and killing working conditions, nearly one fourth of about 20 thousand workers died of exhaustion and diseases. The canal was opened on 14th June 1774 (www.kanalbydgoski.bydgoszcz.pl). Geographically, this structure is a part of the old channel of the ancient Vistula river, through which, in the period of a glacier stop in Pomerania Lake District, waters flowed to the west. At present, it consists of:

1) outlet into the Brda: N 53°8'24,64", E 17°58'24,72",
2) branching of the Old and New Canals: N 53°7'59,46", E 17°56'58,73",
3) end of the Old Canal: N 53°7'33,79", E 17°59'2,96",
4) outlet into the Noteć: N 53°7'44,08", E 17°36'42,83" (Fig. 1) (www.geoportal.gov.pl).

Fig. 1. Situational plan of lands located on the Bydgoszcz Canal

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In its over 200-year history, the Canal has been repaired, depened and restructured many times. The Bydgoszcz Canal together with adjacent lands is located in four communes: Bydgoszcz, Białe Błota (Bydgoszcz district) as well as Sicienko and Nakło (Nakło district), in the separated area Natura 2000 of the Central Noteć Valley and the Bydgoszcz Canal in the Bydgoszcz region PL02 (www.geoportal.gov.pl).

Materials and methods

The study is related to the history, characteristic and agricultural utilization of lands situated in the Bydgoszcz Canal valley. Studies carried out in this area in the past, as well as those currently conducted in the Department of Grassland Management, serve as the source material. Agricultural importance and transformations of these mostly meadow grounds were discussed on the example of a meadow complex of about 260 ha in Experimental Station Minikowo owned by University of Technology and Life Sciences (UTLS) in Bydgoszcz. According to Roguski (1961) and the authors of this study, those meadows are representative for sodden grounds lying in the Bydgoszcz Canal valley (Fig. 1).

The weather conditions were described on the basis of a synthetic study by Roguski et al. (1996) and the readings of the meteorological point Kuyavian--Pomeranian Agricultural Advisory Center (KPODR) in Minikowo. The ground water dynamics was estimated in 15 wells situated perpendicularly to the Bydgoszcz Canal. The specialist firm of geodetic services DeBIT from Nakło made two measurements of land altitude above the sea level across the valley:

- at the boundaries of the village Zawada-Minikowo – they served to compare with the heights of 1913 and 1963, reported in studies by Roguski (1961) and by Gapiński and Miatkowski (1998; Fig. 3),
- at the sites where wells for ground water level measurements were located (about 1.5 km of the village limits towards Nakło).

Groundwater states were measured systematically at 21 dates at intervals of 7-10 days from April to October 2006 and 2007.

Botanical composition was estimated with the valuation method in the first regrowths in 2005 and 2006 (Filipek 1983). First cuts were gathered at two considerably different dates; in plots located from the railway track to the Prussian Ditch, in the second week of June, whereas behind the Prussian Ditch, after 1st July. This date was related to the requirements of the farm and environment program realized by experimental station within the package "Seminatural two-cut meadows (P01b – (Journal of Laws RP, Warsaw, 9 August 2004, No. 174, 1809 Regulation of the Council of Ministers of 20 July 2004)". Second regrowths were cut after 7-9 weeks from the harvesting of the first cut, and yields were determined by collecting samples from harvests cut from an area of 20.48 m^2. Chemical analyses of the plant material were made by the Pomeranian Agricultural Advisory Center Laboratory in Stare Pole. Energy value was given in the German Agricultural Society system (Zarudzki et al. 1999). Soil studies in the 70s, 80s and 90s were carried out at the District Chemical and Agricultural Station in Bydgoszcz, and in 2008 in the Centre for Research and Development H. Cegielski Ltd. in Poznań.

Results and discussion

Thermal and rainfall conditions

From the characteristic of the weather conditions it follows that the average total precipitation in Bydgoszcz during 1861-1994 amounted to 513 mm (from 269 to 809 mm) and during the growing season, 320.1 mm (from 113 to 651 mm; Table 1; Roguski et al. 1996). This region is characterized by great changes of air temperatures by the year (from 5.4 to 10.5^{o}C), and the average air temperature from the long-term period 1945-1994 was higher by 0.7^{o}C as compared with the period 1848-1913. January is the coldest month in the region, with a long-term average of -2,2^{o}C (from -11.3 to 4.3^{o}C), and July is the warmest, with 18.6^{o}C (from 14.5 to 22.9^{o}C). Index evapotranspiration according to Penman in the growing season over 1945-1994 amounted to 550 mm, and climatic precipitation deficiencies in Bydgoszcz were on average 226 mm. The above-mentioned authors state that in the Noteć valley, encompassing also the Bydgoszcz Canal, climatic precipitation deficiencies are less by ca 20% due to a lower temperature and higher air humidity.

Table 1. Weather conditions in Bydgoszcz and Minikowo

Month	Mean temperature [^{o}C]			Precipitation [mm]		Water needs acc. to Klatt*** [mm]
	Bydgoszcz*		Minikowo**	Bydgoszcz*	Minikowo**	
	1848-1913	1945-1994	1949-2006	1861-1990	1949-2006	
Jan	-2.6	-1.7	-3.7	30.3	29.3	–
Feb	-1.4	-1.2	-0.2	25.0	29.3	–
Mar	1.6	2.5	-0.1	29.5	19.0	–
Apr	7.0	8.0	8.4	34.7	57.5	50
May	12.5	13.6	13.3	49.5	72.4	65
Jun	16.9	17.2	15.8	58.7	28.9	80
Jul	18.5	18.7	19.3	72.0	58.4	90
Aug	17.3	17.9	16.6	62.0	81.4	80
Sep	13.2	13.7	15.8	43.1	33.7	55
Oct	8.0	8.6	9.9	38.1	9.1	–
Nov	2.4	3.7	5.1	36.8	50.1	–
Dec	-1.0	0.3	3.6	34.9	37.5	–
Jan-Dec	7.7	8.4	8.7	514.9	506.7	–
Apr-Sep	14.2	14.8	14.9	320.1	332.3	420

* Roguski et al. (1996)
** according to readings of Meteorological Point in KPODR Minikowo
*** Grabarczyk (1983)

Mean annual temperatures and total precipitations in the second half of the 20th century in Minikowo and Bydgoszcz were similar (Table 1). However, they were differently distributed. April and May in Minikowo were definitely more humid than in Bydgoszcz. Higher average amounts of rainfall favoured plant biomass production on permanent grasslands in 1st regrowth, and water needs of meadow plants calculated according to Klatt (Grabarczyk 1983) were satisfied. Evidently drier June, with only 28.9 mm of rainfall, was suitable for hay-making. Nevertheless, together with the dry and hot July, it hampered forming of the 2nd regrowth. August (harvest time) was the most abundant in rainfall, followed by dry September and October with a very poor precipitation.

Habitat conditions

The secondary aim of the Bydgoszcz Canal construction was to increase the economic importance of grounds lying in its valley through their meadow and pasture utilization. In the past, they provided bulk feeds for intensively developing cattle, sheep and horse breeding, including those kept in the Bydgoszcz garrison. Presently, after a considerable decrease in the livestock population, these grounds are mostly utilized as extensive two-cut meadows (Łyszczarz and Dembek 2006; Łyszczarz et al. 2006).

The Bydgoszcz Canal valley is a flat area 1.5 to 3 km in width, mostly with soils formed from carbonate peats of a thicknes from 2.5 to 9 m (Roguski 1961; Gapiński and Miatkowski 1998). From the north it is enclosed by the edge of a ground moraine cut through with erosional side valleys. Their outlet is closed by the railway embankment of the Bydgoszcz-Nakło line (Fig. 2).

Modernizations of the Bydgoszcz Canal involved also drainage work conducted over 1911-1915, during World War II and in the years 1977-1978. Their scope and appropriateness is proved by the change in arrangement of open drainage ditches from parallel (Fig. 2) to longitudinal (Fig. 1), in connection with the underground drainage of the area. At present, many drainage devices such as gates, passes, and even midfield bridges have been destroyed, and the efficiency of the drainage appliances is small.

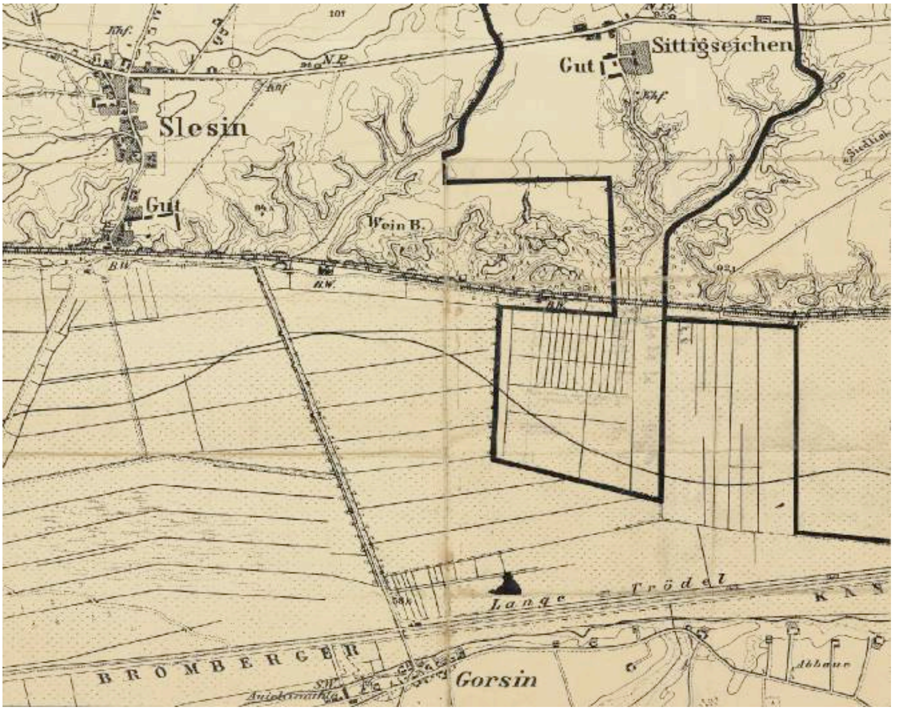

Fig. 2. Archival map with a parallel arrangement of drainage ditches (courtesy of doc. Z. Miatkowski, the Institute for Land Reclamation and Grassland Farming in Bydgoszcz)

From the measurements of ground water level taken in 1951 it follows that its level in drained areas was from about 90 to 60 cm, and in those poorly drained, from several to 65 mm (Roguski 1961). Klapp (1962) reports, however, that in wet years it should equal from 31 to 60 cm in peat soils and from 10 to 31 cm in dry soils. Average current water ground level in the meadows in Minikowo (of 315 measurements in the period from April to October) was 50.1 cm – in 2006 and 38.3 cm – in 2007 (Table 2). It was evidently connected with precipitation. Its shortage in June and July 2006 resulted in a lowering of water level, on average at the whole facility from 43 cm in June to 81 cm in July. Intensive rainfalls in August caused an increase in the level by 20 cm. In 2007, with a higher amount of precipitation, particularly in May, June, and July (in total 276.2 mm) ground water level was definitely more stable and ranged from 32 cm in May to 47 cm in October (Table 2). From the above comparison it can be deduced that in the evidently drier 2006, the average ground water state was too low in relation to the optimal (Table 1).

Table 2. States of ground water level, precipitations and air temperatures; WG – ground water level

Month	2006			2007		
	WG [cm]	Precipitation [mm]	Temperature [°C]	WG [cm]	Precipitation [mm]	Temperature [°C]
Jan-March		49.3	-4.2		163.0	3.1
Apr	26	77.0	7.1	37	18.7	8.7
May	27	59.9	12.5	32	70.4	14.0
Jun	43	21.8	16.8	41	99.8	17.9
Jul	81	24.2	22.4	34	106.0	17.5
Aug	61	129.0	16.6	36	45.5	17.9
Sep	53	40.6	15.2	41	31.0	13.0
Oct	60	12.1	9.6	47	18.5	7.7
Mean Jan-Oct	50.1	423.0	12.2	38.3	553.0	12.5

The analysis of the water level in all the wells, including average water states of 21 measurement dates, shows their great variety (Table 3). Only in the first well located about 80 m of the edge of the plateau they were almost identical at different amounts of rainfall in both years, 46.3 in 2006 and 48.5 cm in 2007. This proves a significant supply of this part with seepage waters (Roguski 1961; Program for development… 1969). However, in the second well already their effect was considerably less, since in the drier 2006, a lower ground water level, on average by ten to twenty centimeters, was recorded. This is explained away by the fact that waters in peat soils exhibit hardly any horizontal movement, whereas they easily permeate in the vertical direction (Roguski 1961). Also in the other wells, the water level was on average from several to 20 cm lower in the drier year. Water dynamics including all the measurement dates was still more differentiated, i.e. from several to almost 115 cm in 2006 and from several to about 70 cm in 2007. The evident influence of precipitation on ground water state is confirmed by its level of August 3, 2006 and August 5, 2007. In the dry 2006, the average state of ground water in the whole valley amounted to 96.9 cm, whereas during the rainy 2007, it only amounted to 30 cm.

Table 3. Location of wells and ground water level (ASL – Altitude Sea Level)

No.	Name of measuring point	Altitude ASL [m]	Distance [m]	Ground water level [cm]	
				2006	2007
1	Head of railway rail	67.42	0.0	–	–
2	Area at bench-mark	60.55	52.5	–	–
3	Bench-mark bolt	60.88	52.6	–	–
4	Well 1	60.09	79.8	46.3	48.5
6	Well 2	58.82	110.1	52.6	39.5
8	Well 3	58.88	160.8	68.4	41.9
11	Well 4	58.20	255.6	61.1	57.1
14	Well 5	57.99	374.2	53.3	48.0
20	Well 6	57.85	575.3	60.4	46.8
23	Well 7	57.86	633.1	61.4	45.3
27	Well 8	57.55	780.4	48.3	28.5
31	Well 9	57.42	930.4	42.0	22.0
35	Well 10	57.36	1081.6	31.9	18.8
36	Bank of Prussian Ditch	57.38	1096.7	–	–
37	Water table in Prussian Ditch	56.92	1098.5	45.0	50.0
39	Well 11	57.27	1143.5	37.2	36.2
43	Well 12	57.26	1293.5	42.8	28.9
47	Well 13	57.25	1443.5	41.3	29.8
51	Well 14	57.28	1593.4	46.4	30.4
56	Well 15	57.42	1793.4	54.4	39.8
63	Bank of Bydgoszcz Canal	58.75	2093.5	–	–
64	Water table in Bydgoszcz Canal	58.32	2189.2	58.15	58.32

The valley, artificially formed and changed for over 230 years, is also supplied by the south waters of the Canal. After its construction, however, it definitely had a draining character. With years, after reconstructions and first of all, after drainages, it was stated that the water level in the Canal was above the adjoining meadow grounds (Fig. 3, Table 3) and was nearly identical with that in 1950s, when it amounted to 58.46 (Roguski 1961). The land depression of that time, however, was definitely less than at present. Currently, in Minikowo it covers about 1.5 km of valley's width (between well 4 and 15). Water from the depression part is drained through the Prussian Ditch (the Ślesin Canal, the Ślesin Ditch), dug after 1882, going into the Cardinal Pond in Ślesin (Fig. 1). Thus, the Prussian Ditch currently plays the major role in the Canal valley moisture regulation, since it contains the outlets of main and collecting open drainage ditches from nearly all valley.

Subsoil settling is an effect of a considerable importance for this region, related to drainage works and their agricultural utilization. This is proven by measurements of the Altitude Sea Level (ASL) taken in the years 1916-1963-2006 along the boundary of the village Zawada-Minikowo. They indicate that in the 90-year period the valley 'settled' in different points from several dozen to over 200 cm (Fig. 3); the least at the north edge by the railway rails, the most at the Prussian Ditch. Reduction of the elevation resulted from mineralization of surface layer of soil and its thickening deep in the profile (Roguski 1971).

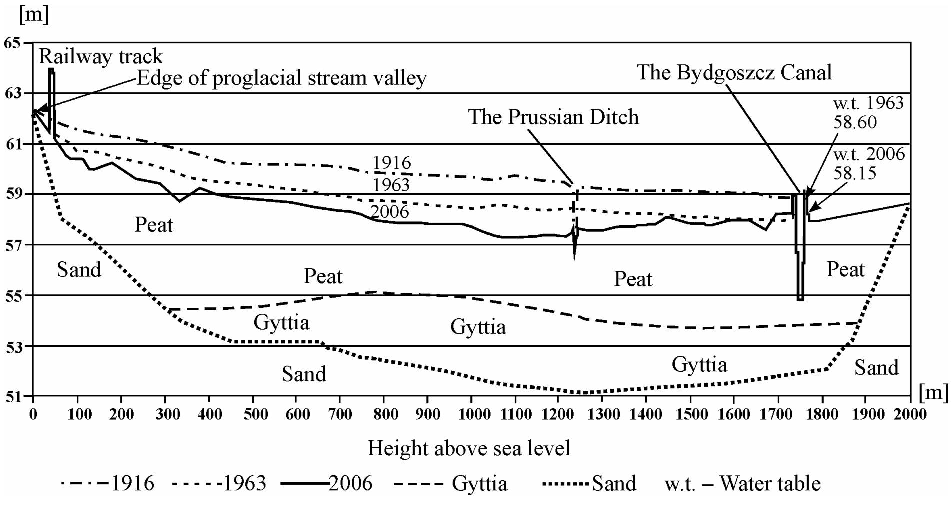

Fig. 3. Cross section through proglacial stream valley of the Bydgoszcz Canal over 1916-2006

Due to the carbonate character of peatmoor, the soil pH in meadows in Minikowo in the last 30 years has been the most stable element of their physico-chemical properties (Table 4). In the top 30-cm layer pH in 1 n KCl ranged from 6.7 to 7.8. Slightly lower pH, i.e. from 6.7 to 7.3, was recorded in 1988. This could have resulted from more intensive fertilization applied in Minikowo in the 80s. This was confirmed also by an increase in potassium and magnesium in soil (Table 4). Abandoning meadow fertilization at the end of the 20th century could contribute to an increase in pH and then to its stabilization. This is proved by completely comparable results of analyses from 1997 and 2008. Also the average content of organic matter in meadow soils in Minikowo in studies by Gapiński and Miatkowski (1998) as well as by the present authors (Łyszczarz et al. 2006) was similar and amounted to 45.9% in 1997 and 43.5% in 2008. However, a very high variety was indicated in different points of the valley ranging from 21.2 to 73.4%, as well as in carbonate content, from about 9 to over 52 $g \cdot kg^{-1}$ $CaCO_3$ in 1 kg soil (Łyszczarz et al. 2006).

Habitat abundance in „soluble” forms of phosphorus was high (Gorlach and Mazur 2001), the average from all the research periods being 98.9 mg P_2O_5 per 100 g soil, and ranged from 41 to 209.5 mg P_2O_5 (Table 4). Changes in the content of this component as well as of the others could have resulted also from varied fertilization in the past. At more intensive fertilization in 1978, the amount of phosphorus in soil exceeded the highest boundary value determined – above 100 mg P_2O_5 in 100 g soil. In unfertilized grounds, which were taken over by the farm in the 70s (data from 1979), the content of this element was on average 71.2 mg P_2O_5 per 100 g soil, ranging from 41 to 89 mg P_2O_5. Farming in the 80s involved the intensive, 3-crop production of bulky feeds and high fertilization including slurry. This could result in the fact that in the analyses from 1988 as much as 63.5% of meadow area in Experimental Station Minikowo was in the medium class of abundance in phosphorus (Table 5). The other grounds were characterized by its high (35.5%) and very high (1%) content. Reducing abundance in this element can be explained by increasing its availability for plants, under conditions of lower pH. Abandonment of intensive production in the 90s lead on average to over 12% growth in phosphorus content in soil during 1997-2008 (Table 4).

Table 4. Physico-chemical properties of meadow soils in valley in Experimental Station Minikowo

Year	pH in KCl		Organic matter content [%]	Available form content [mg·100 g^{-1} soil]		
				P_2O_5	K_2O	Mg
1978*	mean	7.4	–	<100	60	29.6
	range	7.2-7.6	–	<100	35-125	15.5-52.8
1979**	mean	7.6	–	71.2	47	28.3
	range	7.5-7.7	–	41-89	27-70	14-40
1988***	mean	7.1	–	–	–	–
	range	6.7-7.3	–	–	–	–
1997****	mean	7.5	45.9	105.7	18.4	–
	range	7.3-7.7	21.7-68.5	52.7-184.2	12.4-31.3	–
2008*****	mean	7.5	43.5	118.8	14.7	24.2
	range	7.3-7.8	21.2-73.4	67.7-209.5	8.8-24.8	15.6-35.9
Mean	7.4		44.7	98.6	35	27.4

* Sapalski (1978)
** Kuczyńska (1979)
*** Source material ZR Minikowo
**** Gapiński and Miatkowski (1998)
***** Present study

Table 5. Results of study of soil abundance from permanent grassland for Experimental Station Minikowo of 1988

Component	% of grassland area in class of abundance				
	very high	high	medium	low	very low
Phosphorus	1	35.5	63.5	0	0
Potassium	1.3	28.5	17.4	35.9	16.9
Magnesium	14.2	85.8	0	0	0

In 1979, the average content of available forms of potassium in the outer part of the valley was 60 mg K_2O per 100 g soil (from 35 to 125 mg K_2O per 100 g soil). Thus, it was the top limit of the low class of abundance in this component. The amount of potassium in 1979 in the grounds annexed to Experimental Station Minikowo was even lower – on average 47 mg K_2O per 100 g soil. Also analyses from 1988 indicate a high habitat differentiation concerning this component. They showed that 35.9% of meadow area was in the low class of abundance, 16.9% – in the very low class, 17.4% – in the medium class and 28.5% – in the high class. A very high concentration of available forms of potassium was found in 1.3% of the total area. Considerable variation of abundance and bordering of sections with very low and low abundance and sections with high abundance (soil maps), may indicate different fertilization levels, including slurry applied in the past. Meadow soils of Experimental Station Minikowo are characterized by low average magnesium content. This referred to studies from the 70s and the current data (Table 4). In the 70s, no difference was found in this respect between the areas with varied degrees of utilization. However, the high magnesium content determined in soil study of 1988 is difficult to interpret, all the more so because later studies from 1997 and 2008 do not confirmed the results.

Botanical composition of meadow sward

Botanical composition of meadows in Minikowo was greatly diversified. In the first place, it indicated an evident relation to their stability, lack of fertilization, ground water level, and to the location and state of drainage ditches. A total of 82 species of vascular plants were determined in the botanical composition of the first growths of 2005 and 2006: 12 cultivated and 6 non-cultivated grasses, 7 legumes, 14 of sedges and rushes, and 43 of other botanical families. Also many Polish and foreign authors stated that in varied habitat conditions, at the long-term lack of meadow fertilization, meadows are characterized by a considerable biodiversity (Tillman and Dovning 1994; Trąba 1997; Verkaar et al. 1997; Leconte et al. 1998).

Cultivated grasses, which were most numerous in a strip of 600 m from the railway line to well 6, accounted for 33 to 54%, and non-cultivated 4-32%. Low grasses such as red fescue and meadow bluegrass were predominant; together, in some plots they account for even up to 48% sward. Both species, and particularly meadow bluegrass, are considered the characteristic species of ageing peat-muck habitats, hindering meadow renovation (Baryła 2004). In addition, red fescue is an indicator of habitats poor in nutrients, particularly in potassium (Łyszczarz 1994). Thus, its considerable proportion in sward confirms potassium deficiency shown in soil analyses. Cultivated high grasses, significantly determining the production potential of meadow communities, occurred in small amounts and very irregularly. Red canary grass was found in all the plots, and creeping bent grass in many of them, from scanty amount to several per cent. Tall fescue and meadow foxtail grass occurred in an amount of about 1% and, occasionally, orchard grass, meadow fescue and timothy grass. Tall oat-grass and smooth bromegrass occurred only along paved midfield roads and collecting drainage ditches. Among grasses of limited fodder usefulness, there were most of meadow soft grass, which accounts for several per cent in sward, whereas much less of marsh bent grass, quack grass, water manna-grass, floating manna-grass, and meadow bluegrass. Of grasses which are undesirable in larger amounts, coarse hairgrass occurred (on average 4%, ranging from 1 to 8%).

Species of the genus Carex were observed in all the plots: acute sedge, blue sedge, marsh sedge, vernal sedge, blister sedge, common sedge and hairy sedge, as well as fox sedge and yellow sedge. Interior hollows were settled by common spike-rush and, occasionally, wood bulrush. Sedges occurred in places, occupying the areas of several dozen to several thousand square metres. Those places had an extremely simplified botanical composition, where only one of the above-mentioned species was evidently predominant. Only hairy sedge did not form assemblages and most often occurred in company with meadow bluegrass and red fescue. The family Juncaceae was most frequently represented by joined rush, toad rush and, occasionally, European meadow rush.

Of the total scarce amount of legumes, the most of marsh birdsfoot trefoil occurred in the strip of land between the Bydgoszcz and Prussian Canals and considerably less – of common birdsfoot trefoil (mostly in the north part of the valley). Marsh birdsfoot trefoil formed assemblages of several dozen metres in company with slowly growing high sedges and marsh meadowsweet. It also occurred in the similar company in a study by Szoszkiewicz et al. (2003). White clover appeared sporadically, but also in strips of several metres along the mid-meadow road. Other dicots, however, accounted for a considerable proportion. This was a group of plants with numerous species, and in terms of quantity, in some plots it even exceeded the proportion of cultivated grasses from 33 to 54% (Table 6). In this group predominantly occurred: common dandelion, hogweed, edible thistle, common dock, curled dock, bitter crowfoot and creeping crowfoot, wood chervil, common milfoil, and marsh meadowsweet, and in damaged sward: meadow cress, goose potentil, ivy-like nepeta, common chickweed, marsh stitchwort, common stinging nettle, true bedstraw and hedge bedstraw. Considerable amounts of bog horsetail, and also of the protected species *Ostericum palustre* Besser. and early marsh-orchid, were noted on constantly water-logged sites. Also Sosnowski hogweed, imported to Minikowo in the 70s, occurs in growing amounts in the meadow communities of the valley, currently predominant in one of many-hectare buffer zones and spreading along drainage ditches.

Sodding, in spite of the occurrence of considerable amounts of creeping and loosely tufted grasses and sedges, was greatly varied and ranged from 50 to 95%, most often at a level of 80%. Sod layer is mainly damaged with agricultural appliances and wild boars. This favours infestation with dicotyledonous plants, particularly with common chickweed and marsh stitchwort and species of the genus Ranunculus, not only lowering the fodder value of communities, but also decreasing sward resistance to further injuries.

Table 6. Botanical composition of meadow sward – groups of plants [%]

Plant groups	Cultivated grasses	Other grasses	Legumes	Sedges and rushes	Other*	Sodding
Range	33-54	4-32	0-2	2-22	16-44	64-88
Mean	42.4	16.1	0.1	9.4	32.0	75.4
Species number	12	6	7	9	40	–

* dicotyledonous herbs and weeds

Meadow use value in Experimental Station Minikowo calculated on the basis of botanical composition by means of the use value numbers worked out by Filipek (1973) was determined as poor to average. Areas most distant from the Bydgoszcz Canal, with higher amounts of meadow bluegrass and red fescue, were more valuable, and those situated near the Prussian Canal, were the worst. Moreover, Trąba (1997) stated that under conditions of large biodiversity, the actual use value of meadows is small.

Yielding and nutritional value of meadow sward in Experimental Station Minikowo

Lack of fertilization for several years allowed the estimation of the natural production potential of meadows in Minikowo. In 2005 total yields from both cuts were on average in all the treatment 1.93 t, and in 2006 2.65 t dry mass per ha (Table 7). Great variety in the range 1.01 to 3.18 t DM per 1 ha was shown, as in botanical composition. Thus, the yields lay in the lowest limits reported for grass communities (Peeters and Kopeć 1996), and their amount is now just the same as average yields from grassland obtained in Poland in the 1950s (Sołczewski 1960). Also considerable differences in amounts of total protein and crude fibre was found in sward. Protein content was 91.9-248.6 g, whereas fibre content amounted to 157.7-298.2 $g \cdot kg^{-1}$ DM

(Table 7). Substantial differences in amounts of those components in multispecies, unfertilized sward with a considerable proportion of meadow bluegrass were indicated by Delaby (2000). Small content of fibre could result from a considerable proportion of dicotyledonous plants. The content of calcium was high, and that of phosphorus sufficient and good, and in the majority of analyses it satisfied cattle nutritional requirements. This needs the concentration 8-10 g Ca and 4-5 g P in kg^{-1} DM (INRA, Alimentation des ruminants… 1987). Hubert and Thélier-Huché (1992) state that the multispecies character of sward, and particularly the high proportion of dicotyledonous species, always increase Ca and Mg concentration. Apart from that, considerable amounts of Ca in sward may also result from a high carbonate content in the sod layer and from a substantial proportion of sedges in the sward. Babnik et al. (1996) found that in multispecies sward, sedges contained the most calcium as compared with other plant groups, that is over 11 $g \cdot kg^{-1}$ DM.

Table 7. Yielding and chemical composition of meadow sward [$g \cdot kg^{-1}$ DM]

Year	Yield [t $DM \cdot ha^{-1}$]	Total protein	Crude fibre	NEL [MJ kg^{-1} DM]	Ca	P
2005	1.93	91.9-248.6	151.3-234.8	5.82-6.06	12.6-21.9	3.39-4.62
2006	2.65	78.7-233.8	168.2-298.2	4.99-5.78	11.6-17.6	2.98-4.12

Perspectives

Meadow grounds situated in the Bydgoszcz Canal valley has been subjected to a constant transformation of varied intensity in different periods of its history. Currently, it is one of the largest (about 3950 ha) and most compact meadow complexes in Kuyavian-Pomeranian Province, located in the grounds included into the program Natura 2000. The basic doctrine of this program is to act in favour of retaining the natural heritage of Europe, pursuant to the uniform law aiming to optimize the costs and to enhance favourable environmental effects. Uniform law should facilitate cooperation of many institutions dealing with nature protection constantly and those for whom it is a marginal activity. A task and aim of European significance should more easily gain the common social acceptation, all the more so because particular member states are obliged to maintain protected values within the areas composing the network Natura 2000 in not worsened state, which does not have to exclude their economic utilization (http://pl.wikipedia.org/wiki/Natura_2000).

Given the above requirements, and the long-term need for the agricultural utilization of these grounds, according to the needs of Experimental Station in Minikowo, research work was started in the Department of Grassland Management UTLS in Bydgoszcz in 2004, concerning the agricultural and ecological valuation of these grounds. The results of the previous studies allowed the separation of areas which are suitable for increasing of agricultural usefulness. The usefulness of different renovation methods was assessed and the method for renovation of part of the most northward area described in the study was developed. A constant monitoring of this area is assumed in respect of the study of soil, humidity, botany as well as the effect of farm and environment programs and sustainable agriculture on feed yielding and value. In the near future decisions should be taken concerning the elimination of Sosnowski hogweed and drainage system modernization. Those grounds have been and will be a perfect place for arranging classes and field trips for the students of the Faculty of Agriculture and the Faculty of Animal Breeding and Biology, Research Center for Cultivar Testing workers and representatives of seed companies from our region as well as farmers having meadows of similar habitat conditions.

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PROBLEM OF EUTROPHICATION OF ASTATIC WATER ECOSYSTEMS OF THE ŚWIECIE UPLAND

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Causes of eutrophication

Eutrophication of surface waters is a natural process which involves the enrichment of waters with mineral biogenic nutrients. In the 20th century it was mainly connected with the human activity, especially an increased production of organic wastewater, increased consumption of inorganic fertilisers in agriculture and the runoff of nutrients to waters due to soil erosion. The main nutrients which intensify the eutrophication processes is phosphorus (Vollenweider 1968; Canfield and Bachman 1981) and organic nitrogen (Kawecka and Elloranta 1994). In the water reservoirs of high trophy, besides the supply of nutrients from the catchment area, also the internal enrichment occurs, which involves freeing phosphorus from bottom sediments under anaerobic conditions (Kajak 1979). Eutrophication is identified by an excessive increase in primary production and, as a result, mass algal blooms, decreased water transparency, increased organic matter load, which can lead to oxygen deficits at the bottom. It is a process which is definitely unfavourable, deteriorating the water quality, limiting its applicability for household purposes, especially in the aspect of some Cyanobacteria blooms which can, potentially, produce toxins dangerous for other organisms, mainly hepato- and neurotoxins (Mankiewicz et al. 2003).

In the area of cyclonic Poland the most numerous type of reservoirs are small astatic water ecosystems: midfield and midwood water gardens, swamps and flushes. As far as the phycology is concerned, such reservoirs are very poorly defined. Scarce research into algae of such reservoirs in Greater Poland point to their strong eutrophic character (Jurkowska 1987; Chmielewski 1992). The trophy of such ecosystems is definitely affected by local geological, climatic, biotic (plant cover) conditions and the effect of anthropogenic impact.

Eutrophication of astatic water reservoirs of the Świecie Upland

In the south-eastern edge of the Świecie Upland over 1996-2002 there were carried out stocktaking and phycological studies of small natural midfield and midwood water reservoirs (Paczuska and Paczuski 1996; 2007; Paczuska et al. 2002; Paczuska 2007).

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The water ecosystems of such type demonstrate a low water weight the table of which undergoes very considerable fluctuations, accompanied by extreme changes in physicochemical conditions, including water drying off. The dynamics of changes in algal communities which occur in the water gardens researched is fast, in general adjusted to the current conditions. Defining trophy in these reservoirs is difficult due to the dynamic environmental changes, which must have been a result of strong fluctuations in water levels caused by different factors, it is difficult to apply the trophy classification typical for lakes where the scope of environmental changes is smaller and not that dynamic. Algal communities of astatic water ecosystems of the Świecie Upland vary a lot. Each reservoir has its set of species unique in time and random (Fig. 1). The recurrence of respective species throughout the year and two years of research is inconsiderable. Depending on the environmental conditions over a dozen or so days there can occur a total reservoir reconstruction, which points to a high biodiversity of these ecosystems.

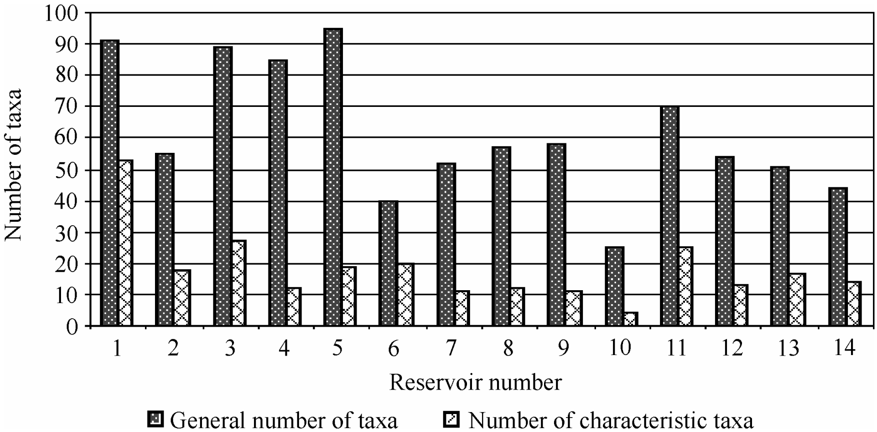

Fig. 1. General number of taxa and the number of characteristic taxa (which occur only in a given reservoir) in the astatic ecosystems of the Świecie Upland researched over 1996-1997 and 2001-2002)

Most algal taxa which occur in the reservoirs researched are ubiquistic, eurytopic species which occur in different habitats, most frequently cosmopolitan, showing a high tolerance to the environment changes. The ecosystems of this type seem to be very susceptible to eutrophication caused by anthropogenic impact. However, the regular studies demonstrate that the processes connected with the trophy of these reservoirs are much more complex than expected. In the first place, the trophic classification of these reservoirs was difficult because, depending on the local climatic conditions of precipitation, evaporation, water table level fluctuations in each month of studies, and changes in algal communities, especially over 2001-2002, fast physicochemical changes in water-garden waters were observed. Algal blooms, being a symptom of eutrophication, both in phycological studies in 1996-1997 and in 2001-2002 were sporadic (Table 1).

There was only one of the total of 15 midfield reservoirs in which a strong Cyanobacteria dominance (comm. 1 2001-2002) in summer when exposed to a high water state after intensive precipitation, the total biomass of Cyanobacteria in July 2001 was 93.6 mg·dm^{-3} was observed. The extreme Cyanobacteria dominance in this reservoir can be due to the fact that the reservoir is located in the intensively-cultivated field, with no natural barriers in a form of plantings and macrophytes; as exposed to an elevated level of water table due to precipitation, an increased surface runoff of biogenes from the field must occur. Facing low water states in the reservoirs, at other dates, no blooms were identified.

Table 1. Algal blooms in astatic water reservoirs of the Świecie Upland over 1996-1997 and 2001-2002

Taxon	Reservoir no	Date	Biomass [mg·m^{-3}]	Concentration of ammonium ions [mg·dm^{-3}]	Concentration of nitrate ions [mg·dm^{-3}]	Concentration of phosphate ions [mg·dm^{-3}]	pH
Trachelomonas volvocina Euglenophyta	3	08.96	3.2	0.22	0.05	0.1	6.0
Volvox aureus Ehr. Chlorophyta	6 1	07.96 08.97	4.8 2.8	0.07 0.03	0.23 0.01	0.38 0.03	7.3 7.0
Snowella lacustris Cyanopocaryota	1	07.01	52.2	0.64	0.04	0.004	6.5
Microcystis aeruginosa Cyanoprocaryota	1	08.01 08.02	8.6 5.8	0.24 0.13	0.059 0.073	0.15 0.28	7.0

Sporadic character of strong algal dominance in the reservoirs researched of the Świecie Upland can demonstrate that the trophy of waters of these ecosystems undergoes changes depending on the environmental conditions, however, following different rules than those observed in bigger reservoirs. It appears that the factor which determines the trophy of this type of reservoirs in the area researched is a short- and long-term precipitation balance and not the specificity of the surrounding agricultural space.

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CAUSES AND EFFECTS OF QUALITATIVE CHANGES OCCURRING IN PRODUCTS OF PLANT ORIGIN

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Factors modifying qualitative features of products

Quality requirements for plant raw materials mainly refer to contaminations with crop protection preparations, heavy metals, excessive nitrogen fertilization, and infection with pathogens. An essential condition of a producer's (grower's) remaining on the market is not only the proper quality of the food product, but also its constant improving. Market monitoring indicates that improving the product appearance is coming to fore. Also taste and functional value are of great importance in product promotion.

Raw plant materials and their products represent the most numerous group of foodstuffs. Most agricultural yields have some biological (physiological) properties making possible and facilitating the prolongation of their durability on the one hand, and consequent qualitative changes on the other. Therefore, the criteria for learning the causes and effects of changes are of basic, elementary importance.

In order to carry out the general assessment of products of plant origin one cannot ignore the influence of factors which often have negative, contrary to expectations, effect on the quality features:

- Food products must be characterized by a better quality and have a higher „Image" in comparison with feeds.
- Content of harmful substances and other undesirable compounds does not generally pose any problem due to very strictly set boundary values. Nevertheless, one cannot completely omit additive and often complex changes resulting from the radioactive contamination of the product.
- It is essential to prevent the growth of mycotoxins (particularly at their increase in cereals recorded in recent years), whose even low amount measured in p.p.m. in relation to their effect on the human organism remains a great unknown to this day.
- Both fresh and stored products usually satisfy functional and processing requirements; however, particularly as a result of their longer storage with the additional application of preservatives, quality requirements grow, and consequently, their tightened control.

Emotional reaction of consumers to so called 'chemicalization' of food is expressed in looking for so called healthy food, also referred to as 'biological', 'ecological',

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'organic', 'integrated' etc. For producers, this opens great opportunities for the use of social emotions for marketing purposes, but causes huge legislative troubles for legislators not only in Poland but throughout the world. The problem is that it has not been defined clearly what the above concepts mean and the practical market control of such products is not possible.

Thus, what is the real meaning of the term 'quality'. Quality of foodstuffs is the mirror reflection of their functional value, which is determined by many parameters. First of all, action between objective, i.e. rational, and subjective, i.e. emotional, criteria should be taken into account (Table 1; Rogozińska 1999).

Table 1. Criteria determining the quality of food products (Rogozińska 1999)

Objective criteria	1. Features of nutrition physiology: food raw materials: composition and availability, biological value, value of fillers, harmful raw materials, durable healthy (nutritional) additives, digestibility, energy value, accordance with standard 2. Certification value: processing properties 3. Food value: organoleptic properties 4. Production conditions: technology, process parameters, environmental conditions
Subjective criteria	1. Psychological features: expectations, requirements, ideal features 2. Ecological features: cropping system, farm animal raising, energy input, losses as a result of improving 3. Social aspects: status, tradition, culture 4. Political aspects

The factors influencing quality, affecting effects and consequences as a result of processes occurring in plant material are: genetic predisposition, place of cultivation, soil and climatic conditions, fertilization, maturity stage, as well as the time of harvesting (water content) and conditions after harvesting (dry matter content and storage methods). Some of the above-mentioned factors, after a long period of time, can result in changing the acquired characters (Table 2).

Table 2. Factors influencing quality changes of products of plant origin (Rogozińska 1999)

Factors closely linked with production	Factors closely linked with storage
Cultivar	Activity of water environment
Environmental conditions (soil type, climatic conditions, fertilization)	Temperature
Application of pesticides	Concentration of oxygen and CO_2 content in the atmosphere
	Concentration of component content (mainly fats and fatty acids)
	Radioactive and microbiological contamination
	Contamination with animal feces

Mineral fertilization has an effect directly modifying quality features of food products of plant origin. Applying mineral and organic fertilization in order to meet the plant need for food, its effect on physiological nutritive value and certification usefulness of agricultural products for a given species should be taken into consideration.

Nutritional raw materials added to plants may contribute to considerable changes in quality features:

- Content of major nutrients (such as proteins, vitamins, minerals, starch, sucrose).
- Components valuable for nutrition physiology (e.g. ballast substances, availability of raw material content).
- Organoleptic properties (colour, palatability, flesh structure, consistency).
- Resistance properties (e.g. damages, diseases, environmental stresses).
- Preserving of characters after harvesting (storage properties).
- Functional and processing properties (e.g. properties of crushing – grinding, baking, cooking).

The effect on particular features depending on the form of fertilization applied is illustrated in Figures 1 and 2.

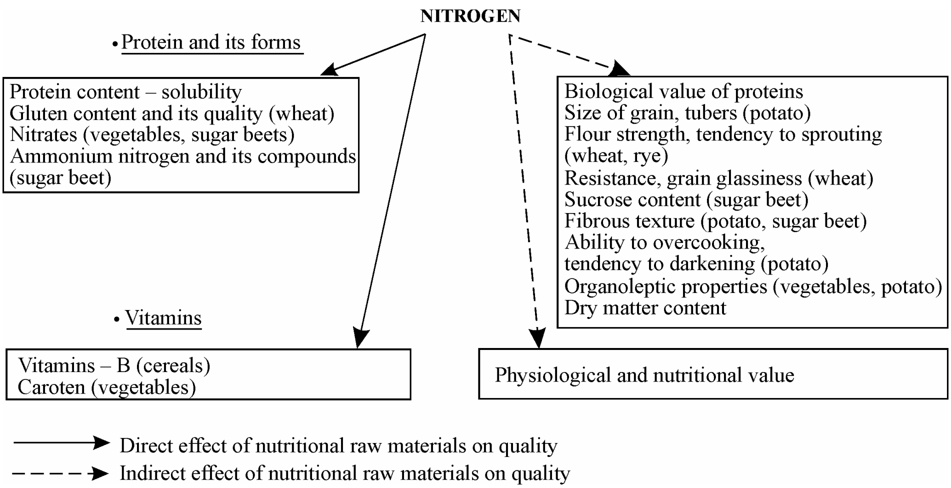

Fig. 1. Effect of nitrogen on features of products of plant origin (Rogozińska 1999)

What is and what means quality is precisely assessed by the market and the consumer, but the producer is a farm ('Institution'), whose product is open and visible for everybody, fit for processing in terms of quality – taking into account the environmental effect.

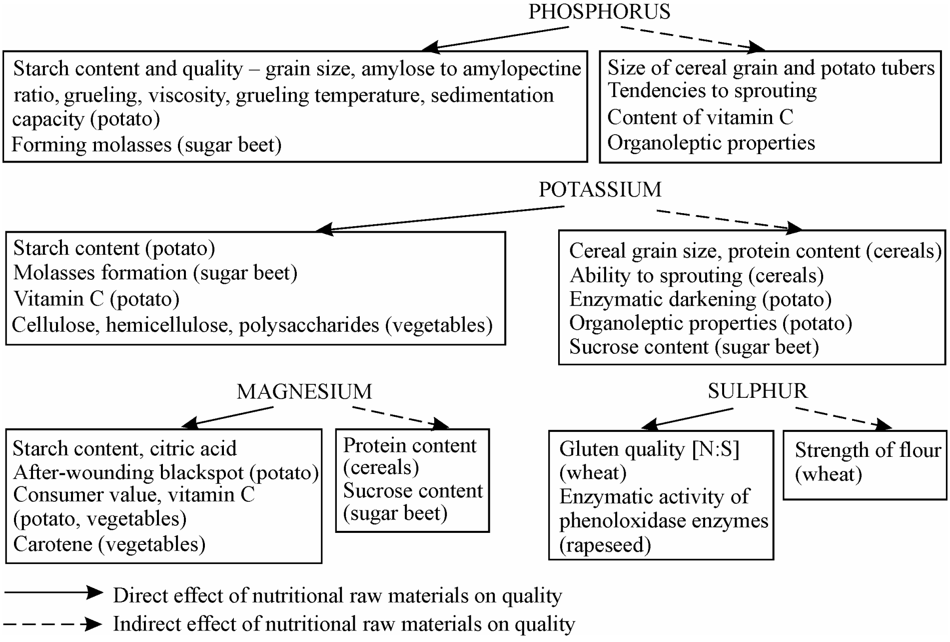

Fig. 2. Effect of P, K, Mg and S on the components of plant raw materials that modify their functional value (Rogozińska 1999)

Methods for food product quality assessment

From the point of view of the producer, food products are assessed by means of subjective and objective methods (Rogozińska 2000a). The group of subjective methods involves sensory (organoleptic) tests, and that of objective methods, laboratory tests (chemical, microbiological and physical).

The task of sensory assessment as a control tool is to state the accordance with the standard of quality class. Quality standards must have constructive and progressive character, i.e. they must motivate to improve the current state and at the same time, take into account the real possibilities of the actual technical and technological state of production.

Research on establishing the standard is carried out by means of the multiple comparisons method using the comparative standard or the scaling method, involving the assessment of some significant quality discriminants.

Organoleptic assessment is loaded with great responsibility both for not certifying positively a product which is defective or of a definitely low quality and not disqualifying a good product.

Quality assessed with the visual-organoleptic method

Organoleptic method is the quality assessment made by means of senses. The word organoleptic derives from two words from Old Greek: ‘organo’, which means an organ, instrument and the Old Greek verb ‘lambano’ – catch, feel; the participle of this word always refers to the same subject, like in this particular case, ‘leptos’ – what act on senses. Thus, to assess organoleptically means to catch (capture, feel) with senses. Estimating the quality of a raw material, a product, by means of organoleptic methods includes focusing on one or several quality elements and assessing in a symbolic way. Organoleptic test includes detecting qualitative differences or determining the total or partial quality with the help of sense organs, possibly with eliminating of likes and opinions of people making the analysis – thus, it is a purely physiological measurement – in which our senses are the measuring apparatus. Good understanding of the basis the sensory perception is essential in proper methodological approach in the sensory analysis.

Organoleptic (sensory) assessment can be discussed as a four-stage process (Fig. 3). A physical or chemical stimulus, coming into contact with receptors, stimulates one or more senses, then a signal is transmitted to the cerebral cortex, causing the activation of some parts of it. Perceived sensory impression is the effect of stimulating the sensory system. Providing the perceived impression with a given information code as a result produces a given impression of recognition. This is a coded sensory impression.

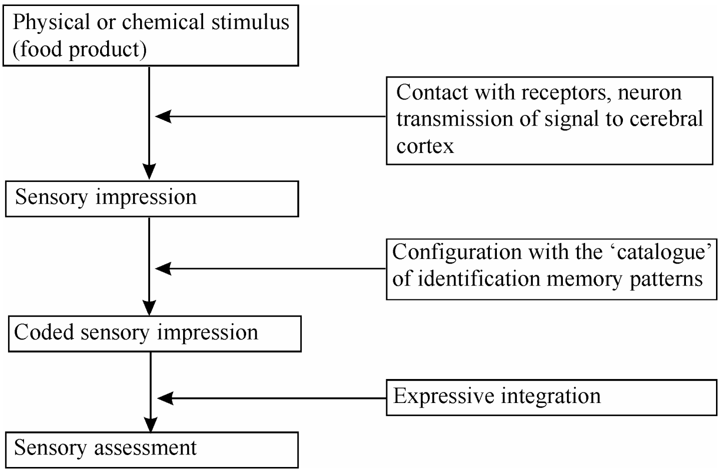

Fig. 3. Scheme of cognitive process in assessment (Rogozińska 2000a)

Physical phenomena are stimuli triggering sensual responses such as taste or smell of food. An important feature of the sensual apparatus is that it always makes a comparative assessment which is called subjective. Therefore, it requires high skills and concentration of assessing people.

Physiological and psychological determinants of food sensory analysis

Stimuli inducing sensual reactions are objective physical phenomena or non-volatile substances soluble in water, volatile substances in the air and others. Visible effects of stimulation by one or several sensory stimuli are determined by perception.

Instrumental research apply many specialized analytical methods, but the results obtained with them do not give direct information about quality features, which constitute the essential aspect for the consumer, i.e. the direct impression of quality and attractiveness of food. Impression is the simplest psychological process, which is formed as the effect of objects or phenomena on sense organs, and involves reflecting particular features of these objects in cerebral cortex. The mere physiological statement that a product is sweet, salty, acid or bitter is an objective statement of a real fact. However, defining whether this state makes a pleasant or unpleasant impression on us, whether we like or do not like these impressions – involves the psychological side of sensual impressions and has a subjective force of feelings.

Identification of the quality of an impression and determining its intensity and estimating to what extent the impression is desirable or undesirable is presented as the three-dimensional characteristic of sensory impressions.

Methodological standards

In order to standardize methods and procedures in sensory analysis, methodological standards were introduced. Poland was one of few countries that began (in the middle of the 60s) to work on standardization of sensory analysis methods. However, with time and under the influence of organoleptic (sensory) analysis development they became out of date.

In 1994, the Problem Standardization Committee No 235 on Sensory Analysis was appointed in the Polish Standardization Committee. The committee began to work on establishing ISO standards, concerning the methods of sensory analysis as the Polish Standards (PN). Standards PN ISO, according to the rules adopted, have already been set or are in the course of working out.

ISO standards (adapted as PN) constitute the grounds for methodological progress and standardization in this domain. Detailed standards, whose aim is sensory assessment of particular groups of products, are often inconsistent, and even contrary to new standards PN ISO. Therefore, the harmonization of the Polish standardization law in this domain will require a tremendous effort and then active introduction into practice.

Currently the sensory analysis needs guided, formal preparation. An analyst must know how to design an experiment, choose the proper procedure of preparing samples, decide what method to apply, and then be able to analyse the results (Rogozińska 1999, 2000a).

Application of sensory analysis in quality control of plant raw materials – organoleptic analysis of table potato tubers

The quality of table potato tubers is determined by three basic elements: nutritive value, consumption features and functional characteristics. As far as potatoes are concerned, the concept of quality is rather difficult to precise, due to their different purposes, introducing new cultivars and storage methods. Organoleptic assessment is the basic quality index determining their value (Ciećko et al. 2005).

Characterized variations in sensory characters of tested potato tubers depending on applied doses and forms of potassium fertilization (KCl, K_2SO_4) are presented in Tables 3 and 4 (Rogozińska 2000b, 2002). The variability of quality standard as a result of application of differentiated doses of magnesium with two nitrogen doses is presented in Table 5. Mineral fertilization applied in the form of KCl did not influence changing features qualifying the tested product to a given functional type (Table 3), in contrast to the other forms of mineral fertilization (Tables 4 and 5).

Table 3. Consumption and usefulness of potato tubers of cv. 'Mila' depending on fertilization with KCl (mean of 9 years); 1 – taste (5 – very good; 1 – fodder); 2 – smell (1 – neutral); 3 – colour (6 – dark yellow; 1 – white); 4 – consistency (1 – concise, hard; 4 – soft); 5 – tendency to overcooking (1 – unchanged, 4 – overboiled); 6 – flesh structure (1 – gentle, 4 – rough); 7 – flouriness (1 – no floury, 4 – very floury); 8 – moisture (1 – moist, 4 – dry); 9 – type (A – salad, B – general-purpose, C – floury, D – very floury, AB, BC, CD – mixed)

Dose [kg KCl·ha^{-1}]	Qualitative features of tubers								
	1	2	3	4	5	6	7	8	9
0	3.0	2.0	4.5	2.0	1.5	2.0	2.0	2.0	B
80	3.5	1.5	5.0	2.0	1.5	2.0	1.5	2.0	B
160	3.5	1.5	4.5	2.5	2.0	2.0	2.0	2.0	B
240	3.0	2.5	4.0	2.0	1.5	2.0	2.0	2.0	B
240 + 80 MgO	3.0	2.0	4.0	2.0	1.5	2.0	1.5	1.5	B

Table 4. Consumer and functional value of potato tubers of cv. 'Mila' depending on fertilization with K_2SO_4 (mean of 9 years). For explanations, see Table 3

Dose [kg K_2SO_4·ha^{-1}]	Quality features of tubers								
	1	2	3	4	5	6	7	8	9
0	3.0	2.0	4.5	2.0	1.5	2.0	2.0	2.0	B
80	3.5	2.5	4.5	2.5	2.0	2.5	2.5	2.5	B/C
160	3.0	2.0	4.5	2.0	1.5	2.5	2.0	2.0	B
240	3.5	1.5	4.5	2.0	2.0	2.0	2.0	2.0	B
240 + 80 MgO	2.5	1.5	5.0	2.0	1.5	2.0	2.0	2.5	B/C

Table 5. Consumer and functional value of potato tubers of cv. 'Mila' depending on fertilization with MgO (mean of 9 years). For explanations, see Table 3

Quality features of tubers	Dose N [kg·ha^{-1}]	MgO kg·ha^{-1} to soil				
		0	35		70	
			MgO kg·ha^{-1} on leaves			
			0	15	0	15
Taste	N_{80}	3.0	3.3	3.4	3.0	3.0
Smell		1.5	1.2	2.7	1.7	1.7
Colour		3.3	3.7	3.7	3.7	3.9
Type		B	B	A/B	A/B	A/B
Taste	N_{160}	3.0	3.0	3.2	3.1	3.2
Smell		1.5	1.3	1.3	1.5	1.8
Colour		3.9	3.5	3.5	3.4	3.2
Type		A/B	B	B	A/B	A/B

The assessments of tested consumer features such as taste, smell and colour of cooked tuber flesh (shown in Tables 3-5) were subjected to standardization in order to obtain information concerning relationships between the results obtained. The values of tested features higher than $\bar{x}$ standardization = 0, thus higher than average are illustrated in Figures 4, 5, 6, 7, 8 (Rogozińska and Jendrzejczak 2004).

Each of tested consumer features responded to the basic experimental factors. Applied potassium fertilization (a dose of 80 kg $K_2O \cdot ha^{-1}$) had a considerably favourable effect on the palatability of tested samples of potato tubers, in contrast to mineral magnesium, applied additionally to potassium (Fig. 4). Although the smell was more favourable in tubers fertilized with a dose of 80 kg$K_2SO_4 \cdot ha^{-1}$, under the influence of potassium in the form of chloride, this feature had a positive effect after the application of a higher dose (240 kg $KCl \cdot ha^{-1}$). Additional magnesium fertilization in a dose of 50 kg $MgO \cdot ha^{-1}$ with 80 kg $N \cdot ha^{-1}$ significantly affected the improvement of consumer values of potato tubers. The application of a higher dose more than 160 kg $N \cdot ha^{-1}$, moved a positive effect of magnesium on tuber taste and smell up to a dose of 85 kg $MgO \cdot ha^{-1}$ (Fig. 8).

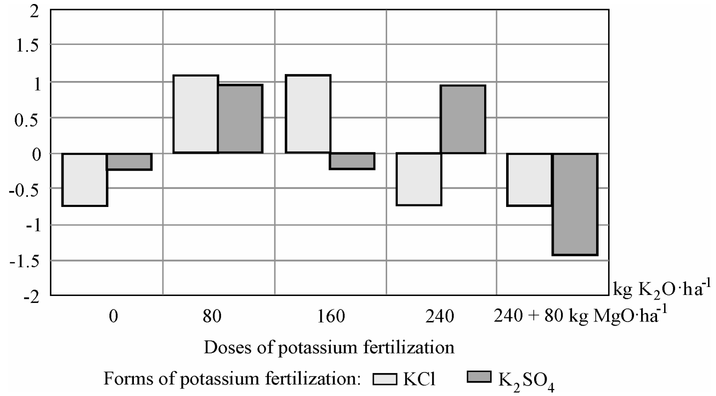

Fig. 4. Taste of potato tubers depending on doses and form of potassium fertilization (last variant with addition of magnesium)

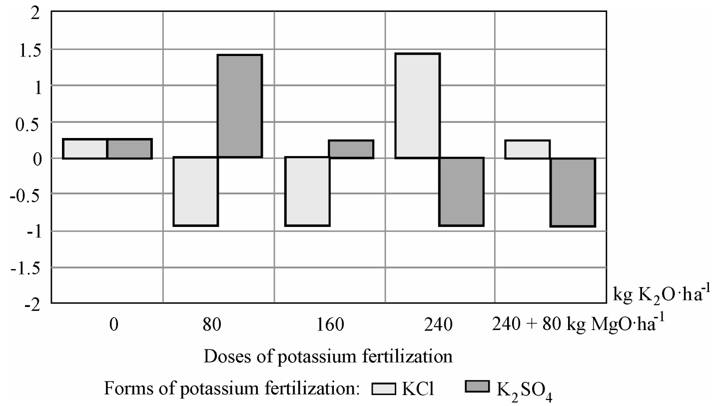

Fig. 5. Smell of potato tubers depending on doses and form of potassium fertilization (last variant with addition of magnesium)

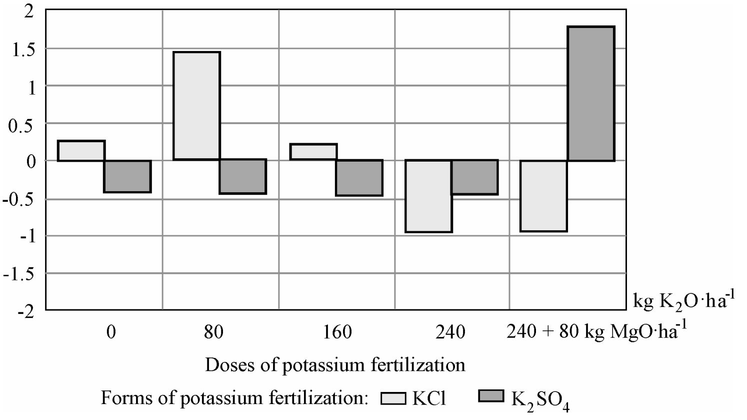

Fig. 6. Colour of potato tuber flesh depending on doses and form of potassium fertilization (last variant with addition of magnesium)

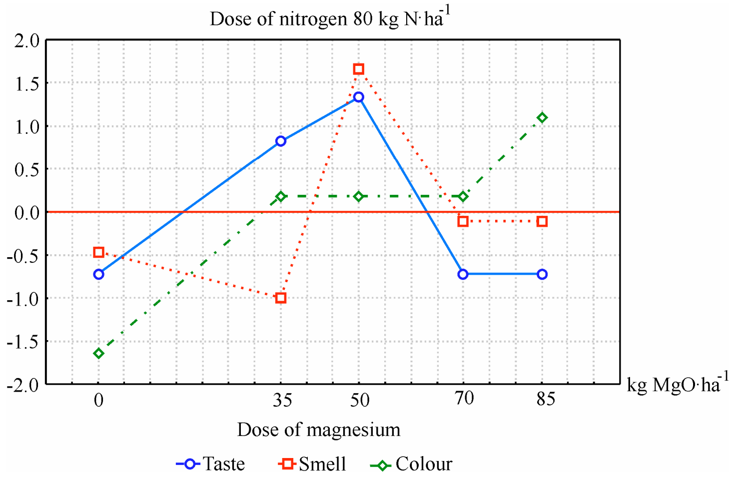

Fig. 7. Organoleptic assessment of potato tubers depending on magnesium fertilization doses at a constant dose of 80 kg $N \cdot ha^{-1}$

An important quality feature of potato tubers – making a considerable drawback – is a tendency to flesh darkening, which can be the reason for the total disqualification of the raw material for processing (Delgado et al. 2001). Darkening of cooked tubers involves connecting chlorogenic acid with Fe to dark-coloured complexes of ferri-dichlorogenic acid. This process is stopped in the presence of iron chelating compounds, such as phosphates and mostly citric acid. In practice, darkening depends on the ratio of citric acid to chlorogenic acid, and this, in turn, on the N:K ratio in tubers. At the wide N:K ratio, the amount of free organic acids, including citric acid, decreases and cooked tubers show a larger tendency to darkening. The sensitivity of tubers to black spot of flesh, which is a form of non-enzymatic darkening, decreases at a good potassium supply of plants. On the basis of the results of organoleptic assessment (9-year-study), it can be stated explicitly that tendencies to darkening (dark blue-grey-black spot) of potato tuber flesh decrease or even do not occur at their good potassium supply (Fig. 9).

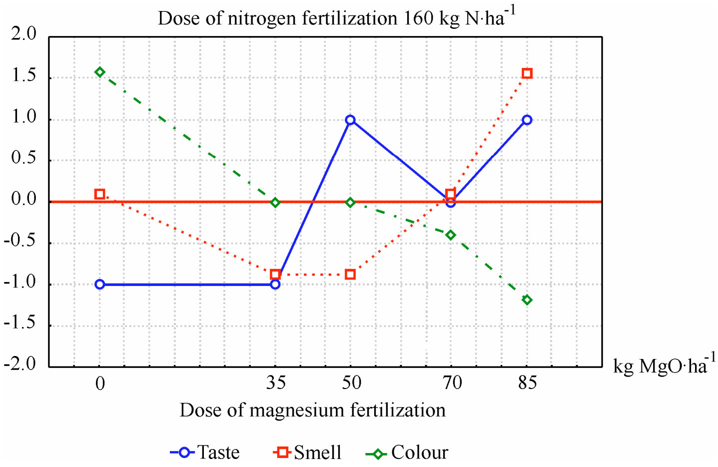

Fig. 8. Organoleptic assessment of potato tubers depending on doses of magnesium fertilization at a constant dose of 160 kg N·ha^{-1}

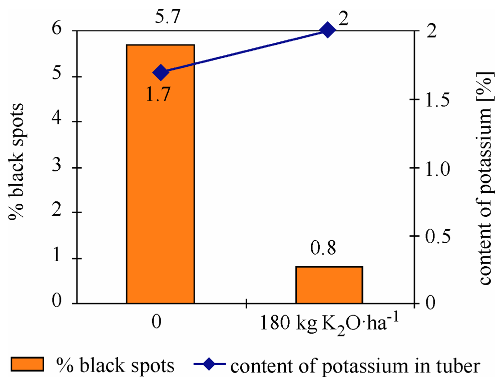

Fig. 9. Effect of potassium fertilization on tendencies to darkening of potato tubers (mean of 9 years of study)

After application of potassium fertilization (in the form of Cl^- – a dose of 160 kg·ha^{-1}) potatoes show not only a larger amount of valuable elements, but also better taste, which is supported by tests carried out concerning the sensory analysis (Rogozińska et al. 2008).

As a result of the sensory analysis of cooked potato tubers it is possible to determine their consumer and functional values, and also to estimate the doses of mineral fertilizers which could positively modify their quality features, making them satisfying both consumers and producers.

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INFLUENCE OF CHOSEN AMELIORATION PRACTICES ON THE SEEDLING GROWTH OF SELECTED FOREST TREE SPECIES AND SOIL MITES (ACARI)

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Water in forest-tree nurseries is best regulated through carefully designed irrigation systems and practices (McDonald 1984). Irrigation is one of the most important cultural practices in forest nurseries. The main objective of nursery irrigation is to avoid unwanted seedling moisture stress and its negative consequences for seedlings (McDonald 1984). The use of irrigation enables a systematic supply of water to young plants, which also ensures adequate moisture for edaphon. This is very important for humification and mineralization as well as for nutrient uptake. Irrigation is conducted mostly with the use of sprinklers. In recent years, water-saving irrigation systems have been tested to improve water management in forest nurseries (Jeznach and Pierzgalski 1996).

The organic matter component of soils is a decisive factor when evaluating their suitability for seedling production at forest nurseries (Niski 1992). High soil productivity in forest nurseries is determined by the supply of organic fertilizers, such as compost. In this trial, compost produced from sewage sludge was used. The natural use of sewage sludge is justified from the ecological point of view (Siuta and Wasiak 2001).

The cap humus of forest soils is inhabited by an abundant number of micro-arthropods. One of the most abundant group of mesofauna are mites, which play a number of important roles in forest ecosystem. Most of them, as saprophages, take roles in decomposition of organic matter which influences the growth of trees.

The aim of the study was to determine the effect of microirrigation (micro-jet sprinkling and drip irrigation) and organic fertilization on the vitality of Scots pine (*Pinus sylvestris* L.) and white birch (*Betula pendula* Roth) seedlings as well as the occurrence of soil mites (Acari) after edaphon inoculation.

One-year-old seedlings of these species are usually produced in forest nurseries. On the other hand, in some cases, the production of older and larger seedlings is also justified. Such seedlings are destined for afforestation under especially difficult conditions, e.g. on post-arable grounds characterized by the strong weeding (Marx 1980).

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Materials and methods

Four nursery experiments were carried out in the years 2003-2005 at Forest Nursery in Białe Błota, Forest District in Bydgoszcz. The first trials were conducted in 2003-2004 (two one-year production cycles for Scots pine and white birch; Fig. 1), and the second two – in 2003-2005 (two two-years production cycles for Scots pine and white birch; Fig. 2).

Fig. 1. Experiments on one-year-old seedlings of Scots pine and white birch

Fig. 2. Experiments on two-year-old seedlings of white birch and Scots pine

These experiments were run on a brown podzolic soil formed from loose sandy soil, in a split-plot system with four replications. Two different factors were compared. The first-order factor – irrigation, was used in the following three treatments (main plots): without irrigation (control), drip irrigation, micro-jet sprinkling. The second-order factor – fertilization, was used in the two variants (subplots): mineral fertilization (standard applied in forest nurseries), organic fertilization (compost).

Seed origin and seeding density were similar to standard nursery practices (Niski and Kłoskowska 1992). Scots pine and white birch seeds were obtained from the seed stands of Forest District in Bydgoszcz. The plot area was 4 m^2 and contained four rows (4 m length) of Scots pine or white birch seedlings. Total number of plots in one experiment was 24 (3 x 2 x 4). Organic fertilizer was produced from sewage sludge (80%) and highmoor peat (20%). This fertilizer was spread in the spring (dose 100 $t \cdot ha^{-1}$) and mixed with the topsoil (10 cm deep) before establishing the field experiments. Introduction of edaphon consisted of mixing topsoil (2 cm deep) with organic matter obtained from the surface of partial cutting in habitat of fresh coniferous forest. This substrate contained the living soil mesofauna which was very abundant. This measure was conducted directly before sowing every year. Mineral fertilization applied in the standard nursery treatment (Niski 1992) was as follows: 70 kg $N \cdot ha^{-1}$, 70 kg $P \cdot ha^{-1}$, 80 kg $K \cdot ha^{-1}$, and 4 kg $Mg \cdot ha^{-1}$.

Drip irrigation was applied using “T-Tape” drip lines (in-line emitters spaced 20 cm apart). Micro-jet irrigation was done with the use of micro-jets “Hadar”. Terms of irrigation and water rates were established according to directives for irrigation of forest nurseries on open areas (Pierzgalski et al. 2002).

To investigate the occurrence of mites, soil samples were taken twice a year (in May and October) in successive years. Samples of 17 cm^2 and 3 cm deep were taken from all plots in 3 replications (this means 3 sample per plot). Mites were extracted from the material in high gradient Tullgren funnels. On average, 7,387 mites (Acari) were identified to order, according to Hammen's systematics (Hammen 1972).

The experimental data was statistically processed by analysis of variance (ANOVA). Fisher-Snedecor test was used to determine a significance of influence of experimental factors and Tukey’s test was used to define significant differences between the combinations. The data of mites were ln-transformed (x + 1) prior to the analyses.

Results and discussion

Climatic conditions and irrigation

Mean air temperature during the vegetation period (April-September) in the years of the study was 14.2°C, ranging from 13.4 to 14.9°C, in 2004 and 2003, respectively (Table 1). Mean monthly values of air temperature in 2003-2005 varied from 7.1°C in April to 18.3°C in July.

Total rainfall from April 1 to September 30, on average for 2003-2005, amounted to 208.3 mm, ranging from 177.5 to 244.5 mm, in 2003 and 2004, respectively. Among the months of the vegetation period, July was characterized by the highest rainfall amount (56.9 mm), and April by the lowest one (16.4 mm).

Water requirements of the seedling nursery during the growing period (April 1 – September 30), determined as evapotranspiration (Et) according to Drupka’s method

(Pierzgalski et al. 2002) amounted to 497 mm, ranging from 475 to 526 mm, in 2004 and 2003, respectively. Mean monthly amount of water needs varied from 54 mm in April to 120 mm in July.

Water deficits during the growing period (April-September), on average for 2003-2005, amounted to 288.7 mm, ranging from 230.5 to 348.5 mm, in 2004 and 2003, respectively. Water deficits were noted in all the months of the growing period. Among the months, June, July and August were characterized – on average for 2003-2005 – by the highest water deficits (above 50 mm). Average seasonal irrigation rates equaled 240 mm in micro-jet sprinkling and 165 mm in drip irrigation in the case of one-year-old seedlings, as well as 87 mm and 65 mm in the case of two-year-old seedlings, respectively.

Seasonal irrigation rates were dependent on rain-precipitation. The highest amounts of water were applied in the case of the one-year-old seedling plantation in the growing period 2003. This year was characterized by the highest air temperature, the lowest amount of rainfall, and as a result – by the highest water needs and water deficits. Total rates of water in drip irrigation and micro-jet sprinkling were higher in the case of the one-year-old seedlings than those for the two-year-old seedlings. It can be explained by the different water requirements of the seedlings of Scots pine and white birch during their first and second seasons of growing (McDonald 1984; Prevost et al. 1989; Pierzgalski et al. 2002).

Table 1. Air temperature, rainfall, water needs, and water deficits in the growing period of Scots pine and white birch, according to Klimek et al. (2008 and 2009), modified

Year	Months of growing period						Apr-Sep
	Apr	May	Jun	Jul	Aug	Sep	
Air temperatures (t) [°C]							
2003	6.4	14.4	17.6	19.2	18.4	13.6	14.9
2004	7.5	11.3	14.7	16.4	17.9	12.7	13.4
2005	7.4	12.2	14.9	19.4	16.3	14.8	14.2
Mean for 2003-2005	7.1	12.6	15.7	18.3	17.5	13.7	14.2
Rainfall (P) [mm]							
2003	13.3	12.1	34.3	88.8	17.8	11.2	177.5
2004	12.1	44.4	35.8	41.8	85.6	24.8	244.5
2005	23.8	69.5	30.7	40.2	20.9	17.9	203.0
Mean for 2003-2005	16.4	42.0	33.6	56.9	41.4	18.0	208.3
Water needs (Et) of forest nursery in the growing period, according to Drupka's method [mm]							
2003	55	86	100	127	101	57	526
2004	53	76	87	108	96	55	475
2005	54	78	89	124	88	57	490
Mean for 2003-2005	54	80	92	120	95	56	497
Water deficits (N = Et – P) of forest nursery in the growing period [mm]							
2003	41.7	73.9	65.7	38.2	83.2	45.8	348.5
2004	40.9	31.6	51.2	66.2	10.4	30.2	230.5
2005	30.2	8.5	58.3	83.8	67.1	39.1	287.0
Mean for 2003-2005	37.6	38.0	58.4	62.7	53.6	38.4	288.7

Growth of Scots pine seedlings

Growth of seedlings is the first process to be inhibited when sufficient water is lacking. Water in forest-tree nurseries is best regulated through carefully designed irrigation systems and practices (McDonald 1984). Irrigation significantly increased the height of one-year-old Scots pine seedlings from 8.9 cm in control plots to 13.2 and 13.7 cm for micro-jet sprinkling and drip irrigation, respectively (Table 2). In the case of two-year-old seedlings, irrigation significantly increased the height, from 26.4 cm (control seedlings) to 33.6 and 34.8 cm for micro-jet sprinkling and drip irrigation, respectively. There were no significant differences in the height between seedlings irrigated with drip system and micro-jets. However, seedlings grown in drip-irrigated plots were in each year slightly taller than those cultivated under micro-jet sprinklers. These results are in agreement with those of several other studies (Lamhamedi et al. 2001; Stowe et al. 2001), which showed that reducing irrigation improves seedling growth. In an experiment carried out by Hilszczańska (2001), Scots pine seedlings grown in plots irrigated daily were shorter (7.2 cm) than those in plots irrigated once a week (8.3 cm). Results of the experiment conducted by Bergeron et al. (2004) also indicate that nursery managers can reduce the quantity of irrigation water used without significantly affecting the growth or physiology of seedlings. On the other hand, irrigation by jet-type sprinklers contributes to the spatial variability of substrate water content and growth of seedlings grown outdoors and the maximum height growth and seedling biomass is attained when average seasonal substrate water content is approximately 40% (v/v) (Lamhamedi et al. 2006).

Use of organic fertilization (compost produced from sewage sludge and highmoor peat) significantly influenced seedling growth. Scots pine plants grown in plots fertilized with compost were on average by 1.5 cm and by 8.6 cm taller than those cultivated under control conditions (without compost) in their first or second growing season, respectively (Table 2).

A significant interaction of organic fertilization with irrigation was found. Irrigated seedlings grown in plots fertilized with compost (sewage sludge and highmoor peat) were taller than plants cultivated under control conditions (Fig. 3). These results corroborate those of Lamhamedi and Gagnon (2003), who showed that to produce quality seedlings, forest nursery irrigation and fertilization management must be optimized. In an experiment conducted by Heiskanen (1995), Scots pine seedlings growing in light *Sphagnum* peat growth medium were subjected to three irrigation treatments – in the wet irrigation treatment, height growth was lower than that in the other treatments. Rapid growth was obtained by irrigating at -5 to -10 kPa matric potential.

Irrigation significantly increased the Scots pine seedling diameter only during their first growing seasons. There were no significant differences between seedlings irrigated with drip system and those watered with micro-jets but a tendency for increased diameter occurred in the case of seedlings irrigated with drip line. Interaction between irrigation and organic fertilization in the shaping of the seedling diameter occurred. Increased diameters were found in plots fertilized with compost and irrigated with micro-jets (Fig. 4). In an experiment conducted by Fayle and Axelsson (1985), daily irrigation alone increased Scots pine stem growth over the untreated condition but less than in a treatment with fertilization.

Table 2. The Scots pine seedling height and diameter as affected by irrigation and fertilization, according to Klimek et al. (2008), modified

Irrigation (I)	Fertilization (II)	Seedling height [cm]		Seedling diameter [mm]	
		one-year old*	two-year old**	one-year old*	two-year old**
Effect of irrigation (I)					
Control	–	8.9	26.4	2.3	8.2
Drip	–	13.7	34.8	3.0	8.3
Micro-jet	–	13.2	33.6	2.9	8.0
Effect of fertilization (II)					
–	mineral	11.2	27.3	2.7	7.4
–	organic	12.7	35.9	2.8	8.9
$LSD_{0.05}$	I	0.615	2.566	0.319	ns
	II	0.325	1.338	0.167	0.250
	I x II	ns	3.045	0.290	1.099
	II x I	0.733	2.318	0.379	0.433

*, ** mean for 2003-2004 and 2004-2005, respectively
ns – no significant difference

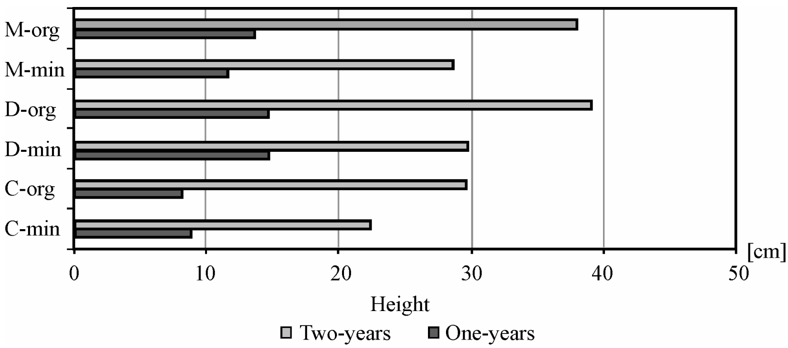

Fig. 3. The Scots pine seedling height as affected by irrigation, fertilization and seedling age, according to Klimek et al. (2008), modified; C, D and M – control (non-irrigated), drip-irrigated and micro-sprinkler-irrigated plots, respectively; min and org – mineral and organic fertilization, respectively; one-year and two-years – one-year old seedling and two-years old seedling, respectively

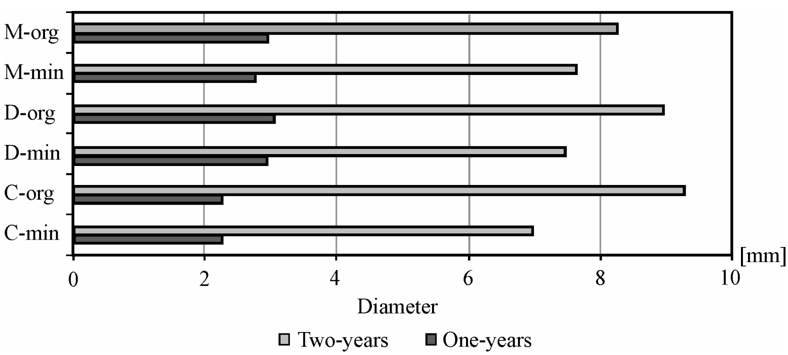

Fig. 4. The Scots pine seedling diameter as affected by irrigation, fertilization and seedling age, according to Klimek et al. (2008), modified. For explanations, see the legend of Fig. 3

Growth of white birch seedlings

High quality seedlings are produced on condition that forest tree nursery irrigation management should be optimized (Lamhamedi and Gagnon 2003). On the other hand, it should be noted that birches use water ineffectively (Perala and Alm 1990). Silver birch seedlings maintain turgor at high soil water potential only by closing stomata, which partially close at about – 15 x 102 kPa.

On the base of statistical analysis, it was found that irrigation significantly increased the height of one-year-old white birch seedlings from 32.6 cm in control plots (without irrigation) to 67.8 and 73.2 cm for drip irrigation and micro-jet sprinkling, respectively (Table 3). In the case of seedlings during their second growing season, irrigation significantly increased the height from 124.1 (control seedlings) to 150.3 and 152.8 cm for drip irrigation and micro-jet sprinkling, respectively. One-year-old seedlings grown under micro-jet sprinkling were significantly higher than those cultivated in drip-irrigated plots but there were no significant differences in the height between seedlings irrigated with drip system and micro-jets during their second growing season, although sprinkled plants were slightly higher (by 2.5 cm) than those under drip irrigation. These results corroborate those of Klimek et al. (2008) concerning the growth of Scots pine seedlings.

Table 3. The white birch seedling height and diameter as affected by irrigation and fertilization, according to Klimek et al. (2009), modified

Irrigation (I)	Fertilization (II)	Seedling height [cm]		Seedling diameter [mm]	
		one-year-old*	two-year old**	one-year old*	two-year old**
Effect of irrigation (I)					
Control	–	32.6	124.1	4.8	11.1
Drip	–	67.8	150.3	7.9	12.8
Micro-jet	–	73.2	152.8	8.6	15.5
Effect of fertilization (II)					
–	mineral	49.5	123.3	6.0	11.9
–	organic	66.4	161.5	8.2	14.4
$LSD_{0.05}$	I	3.617	12.574	0.753	1.725
	II	2.452	6.781	0.485	0.749
	I x II	4.789	15.102	0.973	1.932
	II x I	4.247	11.744	0.839	1.297

*, ** mean for 2003-2004 and 2004-2005, respectively

Irrigation significantly increased a diameter of white birch seedlings both in their first and second growing seasons. Seedlings cultivated under conditions of micro-jet sprinkling were higher than those grown under drip irrigation but the significant difference was detected only for second growing seasons. Organic fertilization (compost produced from sewage sludge and highmoor peat) influenced significantly the growth of white birch seedlings both in the first and second growing seasons. Seedlings fertilized with compost were higher than those grown on the plots fertilized with mineral fertilizers only by 16.9 cm and 38.2 cm (mean for the first and the second growing seasons, respectively).

White birch seedlings cultivated at the treatment with organic fertilization had a significantly increased diameter as compared with those grown at the control conditions (with mineral fertilization only). Differences equaled 1.2 mm and 2.5 mm for one-year-old and two-year-old seedlings, respectively.

Seedlings grown at the treatment with organic fertilization under irrigation were characterized by an increased height and diameter in comparison to those cultivated at this treatment without irrigation (significant interaction between irrigation and organic fertilization; Figs 5 and 6). Similar results were obtained in the experiments on Scots pine seedlings grown under irrigation and organic fertilization (Klimek et al. 2008).

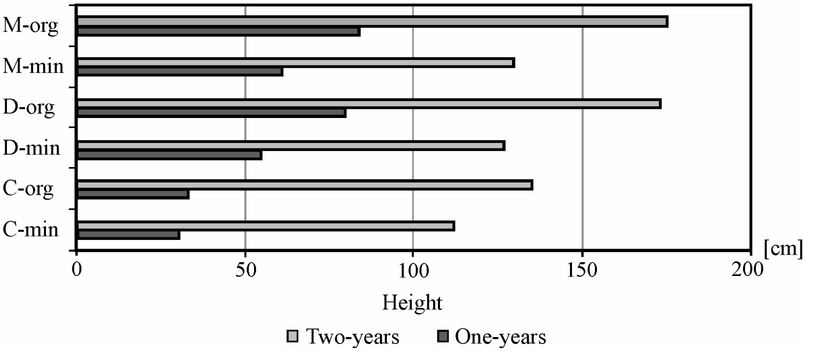

Fig. 5. The white birch seedling height as affected by irrigation, fertilization and seedling age, according to Klimek et al. (2009), modified. For explanations, see the legend of Fig. 3

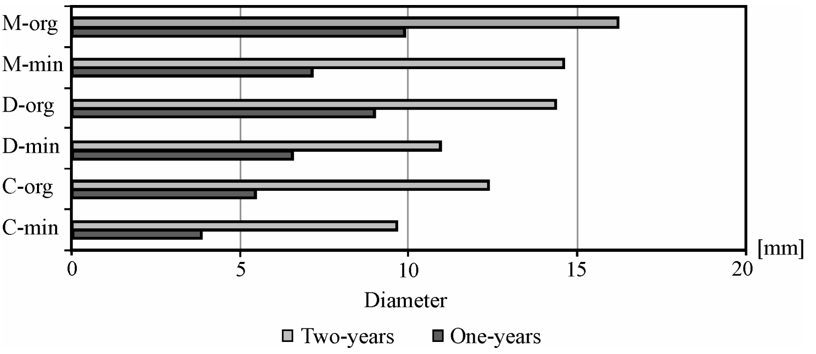

Fig. 6. The white birch seedling diameter as affected by irrigation, fertilization and seedling age, according to Klimek et al. (2009), modified. For explanations, see the legend of Fig. 3

Occurrence of mites in the Scots pine cultivation

The density of mites in soils of pine forests usually reaches several hundred thousand individuals per 1 m^2 of soil area (Klimek 2000). Natural populations of Acari living in the same forest nursery (without the inoculation treatment) were described in our previous paper (Rolbiecki et al. 2005). In the study area of the forest nursery, the density of mites in the plantation of Scots pine seedlings was low (2460 individuals·m^{-2}). In a birch plantation (also without the inoculation treatment), the density of these micro-arthropods was over twice as high (Rolbiecki et al. 2006). In both the cases, natural populations of Actinedida were the predominant type of mites found in forest soils, Oribatida usually are dominant. These saprophages compose about 70% of all mites (Klimek 2000).

In this experiment, after the forest edaphon inoculation of the nursery soil, the average density of oribatid mites ranged from 2090 to 12870 individuals·m^{-2}, depending on the experimental treatment (Table 4). On the basis of the analysis of variance, it was found that the density of mites was significantly affected by irrigation. This influence was visible both in the first and the second year of the study. Organic fertilization did not significantly affect the total density of these arthropods.

Table 4. Abundance (*N* in 10^3 individuals·m^{-2}) of mites under different irrigation and fertilization systems; S – Scots pine cultivation, B – white birch cultivation, I – irrigation effect, F – fertilization effect, min and org – mineral and organic fertilization, respectively

Group of mites	Species of tree	Treatments						I	F
		Control		Drip		Micro-jet			
		min	org	min	org	min	org		
Acaridida	S	0.01	–	0.04	0.04	0.04	–	ns	ns
	B	0.09	0.01	–	0.01	0.03	–	ns	ns
Actinedida	S	1.17	1.23	5.92	2.26	3.45	8.60	$p < 0.001$	ns
	B	1.76	1.28	2.08	2.41	3.30	3.05	$p < 0.001$	ns
Gamasida	S	0.19	0.25	0.38	0.28	0.26	0.40	ns	ns
	B	0.48	0.31	0.40	0.36	0.56	0.50	ns	ns
Oribatida	S	0.93	0.59	3.04	2.63	2.41	3.80	$p < 0.001$	ns
	B	3.00	3.39	5.97	5.00	7.94	7.49	$p < 0.001$	ns
Tarsonemida	S	0.01	0.03	–	0.05	–	0.06	ns	$p = 0.019$
	B	0.06	–	0.11	0.16	0.15	0.36	$p = 0.014$	ns
Acari total	S	2.31	2.09	9.37	5.25	6.16	12.87	$p < 0.001$	ns
	B	5.38	4.99	8.57	7.95	11.98	11.40	$p < 0.001$	ns

ns – no significant difference

A significant increase in the density of Acari in irrigated plots, as compared with those without irrigation (control plots), was noted. The highest density of these arthropods was detected in the case of micro-jet sprinkling and organic fertilization.

In the area studied, Actinedida were usually the predominant order of soil mites – 56.4% of Acari. In the first year of the study their percentage was higher than in the second year (Klimek et al. 2008). An opposite tendency was noted for oribatid mites – their percentage increased from 28 to 43.6% between the first and second year, respectively. Predacious Gamasida were the third most important group, in terms of abundance. Their percentage was on average 6.2% of all mites. In this experiment, mean density of Gamasida ranged from 190 to 400 individuals·m^{-2}. For comparison, soils of pine forests are characterized by a considerably higher density of the mites – 7800-24100 individuals·m^{-2} (Klimek and Seniczak 2002). In the adjacent forest tree nursery, on the Scots pine seedling plantation, an occurrence of Gamasida was not noted (Rolbiecki et al. 2005), and on the birch plantation the density of Gamasida was especially low – 100 individuals·m^{-2} (Rolbiecki et al. 2006). Results indicated that the experimental treatments did not influence the abundance of Gamasida, and during the successive years their density was low. Remaining groups of mites (Acaridida, Tarsonemida) occurred sporadically.

From an ecological point of view, it is interesting that in most plots during the second year of study, a significant increase in the density of saprophage Oribatida was noted (Klimek et al. 2008). This confirms that the edaphon inoculation was well-timed and that the groupings of mites were advantageously reconstructed and conformed to the structure that is characteristic of forest soils in which oribatid mites play a very important role. Literature confirms that these mites can feed on ectomycorrhizal fungi (Schneider et al. 2004; 2005). In addition, soil fauna can influence fungal growth by grazing (Hanlon and Anderson 1979; 1980), which may split the hyphal connections. Soil animals can also directly relocate nutrients by defecation, and transfer microbial propagules into fresh substrates (Lussenhop and Wicklow 1984; Lussenhop 1992).

Statistical analysis indicated that irrigation was the only factor influencing the abundant increase of Oribatida. The increase in abundance of these mites as well as other soil micro-arthropods due to irrigation has been cited in the literature (Lindberg et al. 2002; Tsiafouli et al. 2005).

Occurrence of mites in the white birch cultivation

The density of Acari, on the average for two-years production cycles, was similar to that noted in the Scots pine plantation and ranged from 4,990 to 11,990 individuals·m^{-2} (Table 4).

On the base of the analysis of variance, it was found that the density of mites was significantly influenced by irrigation only. Especially high average density of these arthropods was noted in plots irrigated with micro-jets.

In the white birch cultivation, saprophage oribatid mites were the predominant order of soil mites – 64.7% of all the Acari. In this trial Actinedida ranged from 16% to 53% of Acari, as dependent on the experimental treatment (variant). Predacious Gamasida were less numerous – 6% of Acari. Two other groups of mites, Acaridida and Tarsonemida, occurred sporadically.

The density of oribatid mites in the first year of the study ranged from 1,610 to 6,520 individuals·m^{-2} (Fig. 7), depending on the experimental treatment. In the second year the density distinctly increased. Especially high density was noted in irrigated plots – 7,980-12,010 individuals·m^{-2}. Statistical analysis indicated that irrigation was the factor influencing distinctly the density of these mites. In traditional forest nursery, without edaphon inoculation, the density of oribatid mites in irrigated cultivation of two-year-old birch was scarcely 620 individuals·m^{-2} (Rolbiecki et al. 2006). On the contrary, in the case of two-year-old Scots pine seedling cultivation, after a similar treatment of edaphon inoculation in irrigated plots, the density of Oribatida was distinctly lower (3,290-6,350 individuals·m^{-2}) than that in birch cultivation (Klimek et al. 2008).

The relatively high density of oribatid mites in cultivation of birch, as compared to that of Scots pine, can be a result of the edaphon inoculation treatment as well as ecological conditions of this plantation which are connected with large increases and manifold larger sizes of seedlings. Large seedlings better shadow the soil and counteract the overdrying of the surficial soil layer which can be harmful for soil fauna, and especially for oribatid mites which are sensitive to drought (Lindberg and Bengtsson 2005). In addition, birch seedlings already in the first year of cultivation supply considerable amounts of organic matter (leaf litter) which create advantageous feeding conditions for saprophages.

In the first year of the study, oribatid mites composed on average 53% of all mites. In the second year, after the mentioned increase of their density, they composed on average 71% of gatherings of Acari. This percentage of Oribatida is characteristic of forest soils (Klimek 2000). Soil saprophages are recognized as good bioindicators

(Andrews et al. 1989; Butovsky 1996). Saprophage Oribatida mites are regarded as useful indicators of the degree of decomposition and biological properties of forest humus (Seniczak 1979) as well as different sorts of industrial pollution (Klimek 2000). Therefore, they can be used as bioindicators of the biological condition of soils, and even – the degree of the soil degradation.

Edaphon has a great influence on the soil fertility because soil animals take part in decomposition of organic matter. Lack of soil fauna and also its low density or diversity of species, especially in forest soils, can exert a negative influence on soil-forming processes and functioning of whole ecosystems. It was confirmed in laboratory tests and in bare areas with use of the litterbag method (Huhta 2007).

It is known that the long-lasting and intensive use of forest nurseries can decrease the biodiversity, including ectomycorrhizal fungi (Aleksandrowicz-Trzcińska 2004) as well as it can cause the degradation of soils. On the base of the finished acarological studies it is resulted that after edaphon inoculation treatment, especially in connection with irrigation, the biological condition of soils in the studied nurseries was distinctly improved. It seems that the treatment of edaphon inoculation of nursery soils connected with irrigation, which was described in this trial and in the paper published previously (Klimek et al. 2008), may be regarded as successful, especially in birch cultivation. Establishment of two-years-old birch in forest nurseries can have the positive influence on the biological properties of soils and may be applied in biological regradation of nurseries.

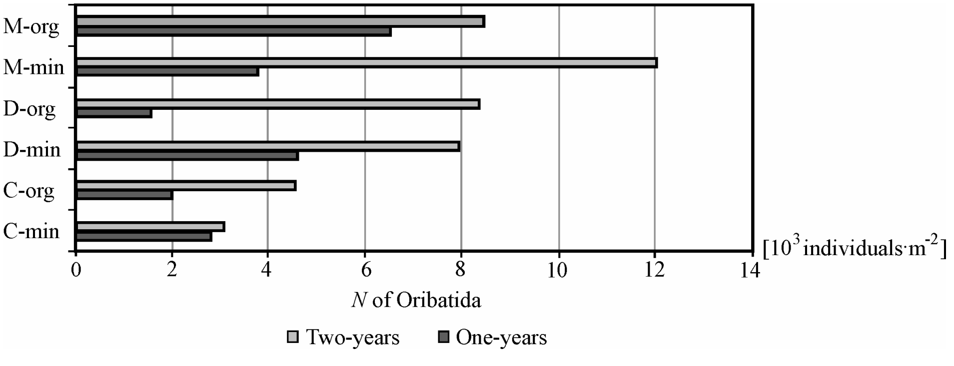

Fig. 7. Abundance (*N* in 10^3 individuals·m^{-2}) of oribatid mites under different irrigation and fertilization system in the one- and two-years white birch cultivation. For explanations, see the legend of Fig. 3

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REGIONALIZATION OF AGRICULTURAL PRODUCTION IN THE KUYAVIAN-POMERANIAN PROVINCE

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Agriculture regionalization in the light of literature

In the process of regional development of the country, regionalization of agriculture, and in regional scale, its division into agricultural areas, is an essential element. The aim of agriculture regionalization is shaping of rural areas and agricultural production towards the effective utilization of regional production factors. This involves a growth of production potential of farms and consequently, an increase in degree of their economic competitiveness.

Agricultural regions are distinguished on the basis of many factors characteristic of agriculture, mainly natural features of agricultural production or socio-economic characters. They were formed in the process of historical development, as consequences of many factors, from emerging of farms, to the legal situation of the state (e.g. annexations), to the social situation of the country (Wawrzyniak and Wojtasik 2000). Consequently, each region is the resultant of many factors, which presently determine the pace of changes in agriculture and rural areas. Thus, each region requires its own way, best utilizing the existing circumstances and possibilities of development. Therefore, development programs concerning agriculture and rural areas should take into consideration the social and economic needs of a given region as well as the character of agriculture and farms.

Niewiadomski (1979) considered regionalization as the primary base for specialist economy, which remains a "reserve link" among other undertakings for agriculture intensification. He claimed that regionalization is specified by a policy of competition determined by skilled combining characteristic features of crops and farm animals with specific of ecosystems and socio-economic relations. Laskowski (1964) understood agricultural regionalization as a process of distinguishing and characterizing of local units and a process of distribution in space and time of economic system, land utilization and production trends. The author determines the region as an area in which a particular economic system prevails. He defines an economic system as such an indicator of agriculture economic structure, which indicates mutual relationships of particular economic branches (plant, animal, and industry) and a degree of intensity of

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agriculture as a whole. This is evaluated by the percentage of branches of finished production expressed in terms of value. A lower classification level is the subregion, determined on the basis of the particular agricultural soil management, structure of agriculturally utilized area and the structure of cropland predominant in the given area. Boundaries of microregions, in turn, are determined by the predominant production trend in the majority of farms situated in the given area.

In the literature, mainly from the second half of the 20th century, one can find different criteria for regional classification and different methodological approaches, hence different classifications. Niewiadomski (1959) distinguishes three groups of methodological criteria: natural, socio-economic and natural-socio-economic. Styk (1964) considers three kinds of classification: natural and agricultural, socio-economic, statistical, and taxonomical. Kopeć (1958) distinguishes four techniques for classification of regions: by points, descriptive, taxonomic, and of sorting basic local units. Niewiadomski and Krzymuski (1959) adopted the descriptive-cartographic method. Łubkowski (1964) separated regional units on the basis of natural differences and then he observed their influence on economic effects. Truszkowska (1969) used natural criteria – she characterized the natural environment on the base of a group of indicators: soil, the lie of the land, water conditions, climate. Góralczyk (1969) adopted the system of agricultural soil management as the criterion for regionalization.

Wawrzyniak and Wojtasik (2000) treat the region as a specific area with a relatively uniform type of farms and the level and structure of production. In particular smaller areas, agricultural microregions may occur, as units of a lower order, with different production trends and varied degree of specialization. This concept, in turn, leads to regionalization of agricultural production, illustrating the spatial diversity of the structure and level of production caused by natural and economic conditions. Niewiadomski and Krzymuski (1959), Dzieżyc (1979) considered regionalization as the primary and fastest factor of progress in agriculture, allowing the increase in agricultural production without additional outlays.

Regionalization is a process of arrangement in space and time of particular crops and their cultivars as well as species and races of animals, and also the distribution of economic and functional soil management systems and production trends (Laskowski 1964). According to Kożuch (1997), regionalization of production should be understood as a spatial differentiation of the structure and level of agricultural production in local units of various levels, resulting from the system of natural conditions and socio-economic factors. Thus, the regionalization of agricultural production means the intentional distribution in space (in administration and regional units) and time of a given plant and animal production. Rudnicki (1999), in turn, defines regionalization as intentional distribution of agricultural production in the given area based on the knowledge of factors exerting the stimulating or limiting effect on the agricultural production in general and particular types of production. Criteria for regionalization are natural factors (components of agricultural habitat) and socio-economic factors (e.g. agricultural structure, village population, markets, agricultural and food industry, contracting, tradition). Regionalization of production is a dynamic process, proceeding in time. Its directions should be determined by a designed target model, the impulses for its realization are organizational and economic activities (e.g. contracting, credit system), whereas social and economic aspects can be limitations (e.g. demand for a given product). The influence of both spurs and limitations of regionalization determines the extent and time of reaching the desired state of the structure of agricultural production (Rudnicki 1999).

According to Kopeć and Szelewicki (1979), regionalization can be expressed in the analytical or planning sense. In the former case, it involves the evaluation of the actual state of production distribution and its determinants in a given area. In the latter, it involves a change in this state. The subject of regionalization in agriculture are mostly branches, production sections, particular crops or bred animals, whereas its aim is to distribute them territorially in such a way, which would guarantee the best production results. This is possible only if this distribution of agricultural production around the area is performed according to the existing system of factors determining production. Therefore, the basis of regionalization is the characteristics of the area in respect of features defining the type and level of occurrence of factors influencing agricultural production. The matter is complicated, however, due to a large diversity of those factors, their variability in time and space, as well as difficulties related to the numerical view of a degree of the effect on production. In practice, a high diversity of production factors can be reduced by choosing the most essential of them. Without the numerical point of view on factors conditioning production, in turn, it is impossible to make an objective evaluation of the environment of production completion. In the analytical regionalization, without such a numerical point of view, it is impossible to understand what they consist in and what are the cause of differences in the efficiency of plant crops between particular areas (Kopeć and Szelewicki 1979).

The level and structure of agricultural production is determined by many different factors. One of the main factors conditioning the regionalization of agricultural plant production and, to a less extent, animal production, is the natural environment. The characteristics of the agricultural production space consists mainly of such environmental factors as soil, climate, the lie of the land, and water relations. All those factors act as a whole and are interrelated, and each of them is important. In separated areas, however, particular elements of the environment may demonstrate different extents of variation and a different degree of agricultural production limitation (Strzemski et al. 1973). Of the natural factors determining the natural conditions of agricultural production in the flatlands of Poland, soil cover shows the higher variability. Thus, that factor becomes the most important element of agricultural production space. Natural value of agricultural production space can be defined as an index expressed in points. It determines the natural potential of the agriculture of the given area with one number, and at the same time, it allows the estimation and comparison of production level in those areas (Kożuch 1997). Second important group of factors influencing the territorial distribution of agricultural production are economic and organizational conditions. However, while the natural conditions of agricultural production are relatively constant, economic and organizational conditions are characterized by a high dynamics of changes.

Classification of administration units in respect of the structure of agricultural production allows the assessment of the effect of particular regionalization factors on land use and production distribution, or examination what arrangement of factors is accompanied by an increase in the cultivation intensity of a given plant of animal breeding.

Kuyavian-Pomeranian Province as a region

Besides other factors, evolving agricultural structure, as a consequence of the process of granting property rights to peasants in the 19th c., had a significant effect on forming the Kuyavian-Pomeranian region. Emerging the settlement network of farms resulted in organization of village life. Then farms came into being as a results of property right process, and around them, village infrastructure, which led to establishing of the given region, as a result of a series of different political and economic events. The Kuyavian-Pomeranian region evolved as a result of blurring post-annexation borders, through including parts of districts from the former Russian annexation to the prewar Pomeranian Province (1938) and attempts to persuade farmers to higher economy standards. Then the next agricultural reforms contributed to forming of the given agricultural structure. The process of forming new farms in the village contributed to creating microregions, which were grouped into village administration units, communes, and these, in turn, composed districts and the province (Wawrzyniak and Wojtasik 2000).

After several changes in the administration division of Poland, at present Kuyavian-Pomeranian Province takes up an area of 17.97 thousand km^2, which accounts for 5.7% of the whole country area and is populated by over 2 million inhabitants (5.4% of people of the country). More than 62% people live in cities, of whom 43% in the biggest five city centres: Bydgoszcz, Toruń, Włocławek, Grudziądz and Inowrocław. In the administration structure of the region there are 23 districts (including 4 municipal and 19 landed), 144 communes, including 17 urban, 34 urban-rural, and 93 rural (USB 2006).

Large production potential of agriculture and farming and food industry, natural values of agricultural production space, the agricultural culture beyond the country standard, make agriculture significant in the economy of the region now and in the future. At the same time, natural conditions of farm management, the ownership and acreage structure of farms, a level of their investment, economic condition, village infrastructure, living standard of urban people, organization of agricultural market, the qualities of nature and rural landscape, are greatly varied around the region. They constitute barriers, and often chances for the development of the province as a whole and of particular nature-agricultural areas (Rudnicki 1999).

Regionalization of plant production

The area of agricultural acreage in 127 rural and urban – rural communes of Kuyavian-Pomeranian Province is 1083 thousand ha, which accounts for 62.4% of the total area of those administration units. Such large proportion of agricultural acreage in the total area indicates the agricultural character of those grounds. However, there is differentiation in this respect between particular communes in the province. Agricultural acreage accounts for from 7.9% of them (Wielka Nieszawka) to 94.8% (Radziejów). Usually agricultural economy has a relatively small proportion in communes with soils of a low agricultural quality, thickly wooded and with considerable areas of open waters.

Arable use of the cropland predominates, thus arable lands account for on average 88.3%, orchards – 0.83%, and permanent grasslands – 10.9% of agricultural acreage. A very large proportion of arable land, exceeding 94%, occurs in 20 communes, particularly such as: Bądkowo (98.4%), Radziejów (97.8%), Papowo Biskupie (97.6%), Dąbrowa (97.1%), and Gostycyn (96.3%). In four communes, in turn (Nowa Wieś Wielka, Skrwilno, Śliwice, and Skępe) they account for less than 70% of agricultural acreage. Distribution of arable land proportion in the structure of agricultural acreage evidently corresponds to the agricultural soil quality. The proportion is high where soils of a good and medium quality prevail, and relatively low in the areas with soils of a low agricultural quality.

Part of arable land is withdrawn from production in the form of fallows. In 2002, 52% of arable land in the province were not sown. The total amount of fallows in the area of arable land is very unevenly distributed around the province. In 11 communes the proportion of unsown arable land exceeds 10%. As a rule, a large proportion of arable lands withdrawn from agricultural production occurs in communes adjacent to big cities and at the same time, having soils of a low agriculture quality (Osielsko, Wielka Nieszawka, Białe Błota, Nowa Wieś Wielka, and Solec Kujawski) or where natural conditions do not favour plant production (Skępe, Bobrowniki, Cekcyn, and Śliwice). In the first group of communes, this is likely to be related with an intention of reclassifying of parts of arable lands for non-agricultural management (industrial plants, service centres, the housing industry). In communes far from big cities with weak soils, fallowing of arable area is determined by low economic effects of management, since in regions with favourable soil conditions withdrawing soils from agricultural production has small sizes and in the commune of Radziejów fallows account for only 0.22% of arable land area.

Permanent grasslands take up on average 10.9% of agriculturally utilized area. This proportion of meadows and pastures in the province is considerably less (by 8.3 pp) than the average in Poland (USB 2006). Only in 10 communes, the percentage of permanent grasslands exceeds 25% of agriculturally utilized area. These are the communes: Białe Błota, Nowa Wieś Wielka, Skrwilno, Śliwice, Skępe, Wielka Nieszawka, Cekcyn, Włocławek, Łabiszyn, and Dragacz. By contrast, in as many as 60 communes this proportion does not exceed 10%, and the least one occurs in the communes: Bądkowo (1.4%), Radziejów (1.7%), Papowo Biskupie (2.3%), Dąbrowa (2.4%), Gostycyn (2.7 %), and Osięciny (3.8%). Evidently, the less favourable soil conditions for field plant production and the more fragmented agriculture, the more proportion of the meadow-pasture management of arable lands. This is confirmed by the negative correlation coefficient ($r = -0{,}62$) between a proportion of permanent grasslands in the structure of agriculturally utilized area and the soil valuation index of arable lands in communes and the negative coefficient ($r = -0{,}30$) with the average area of farms in communes (Table 1).

Fruit culture is strongly regionalized in the province area. Fruit production is relatively well developed (more than 2% agricultural acreage) in 11 communes, especially such as: Choceń, Fabianki, Górzno, where it covers over 3% agricultural acreage (Table 2). By contrast, in 16 communes it is of slight importance (below 0.2%), and in the communes Barcin, Śliwice, Gąsawa, Skrwilno, Kamień Krajeński, and Papowo Biskupie the area of orchards does not exceed 0.1% of agriculturally utilized area. Orchard distribution does not indicate relationship with soil quality in the communes, nor has it a clear regularity in the province, but the intensity of this production is usually higher in communes of smaller farm area (Table 1).

Particular agricultural crops are distinctly regionalized in the province area. Cereal crops have a predominant proportion in the structure of cropland, on average covering

74.7% of sown arable land. However, in as many as 35 communes the proportion of cereals in the structure of cropland exceeds 80%. It is particularly high in the north-west part of the province (area of Tuchola Forests and Wysoczyzna Krajeńska), in the group of four communes surrounding the city of Bydgoszcz (Osielsko, Solec Kujawski, Nowa Wieś Wielka, Białe Błota), three communes adjacent to the city of Toruń (Obrowo, Ciechocin, Lubicz) and few in other parts of the region, particularly along its eastern border. Cereals have a relatively small proportion in agricultural crops in Kuyavia and the districts of Chełmno, Grudziądz, and Nakło. However, only in seven communes (Choceń, Kruszwica, Łasin, Gruta, Osięciny, Włocławek, and Unisław) it does not exceed 65% of cropland area. The total proportion of cereals in the structure of cropland (y) is related to soil quality of arable land measured by the soil valuation index (x_1) and swine livestock per 100 ha of cropland area (x_2) in communes, according to the equation: $y = 101.6 - 32.56x_1 + 0.0236x_2$ ($R = 0.71$). It follows from this that a particularly high proportion of cereals in cropland occurs under conditions of low soil quality and at the same time, a large intensity of swine breeding. Also a growing proportion of cereals in the cropland structure is noticeable from the south towards the north part of the province (Table 1).

Table 1. Linear correlation coefficients between some characters of agricultural production in communes of the Kuyavian-Pomeranian Province; AL – arable land, AA – agricultural acreage, LSU – livestock unit, N – latitude, E – longitude

Type of production	Soil quality AL*	Livestock per 100 ha AA			Size of farms	Geographical situation	
		cattle	swine	LSU		N	E
Total cereals	**-0.58**	-0.16	**0.38**	0.16	-0.17	**0.38**	-0.14
Wheat	**0.74**	**-0.33**	**-0.24**	**-0.34**	**0.29**	-0.03	-0.13
Rye	**-0.86**	0.14	-0.14	-0.11	**-0.32**	-0.05	0.03
Barley	**0.57**	-0.11	0.20	0.16	0.21	-0.09	**-0.35**
Oats	**-0.57**	-0.17	-0.09	**-0.23**	-0.03	0.06	**-0.25**
Triticale	**-0.29**	-0.02	**0.57**	**0.44**	-0.17	**0.40**	-0.05
Mixtures	**-0.51**	**0.33**	**0.33**	**0.42**	**-0.25**	0.19	**0.38**
Maize	0.01	-0.20	**0.24**	0.08	**0.26**	0.11	-0.20
Legumes	**0.28**	**-0.26**	-0.14	**-0.28**	0.06	-0.05	-0.10
Potato	**-0.53**	0.08	-0.17	-0.14	**-0.30**	-0.05	0.13
Sugar beet	**0.58**	0.21	-0.17	0.05	0.06	**-0.57**	0.10
Fodder plants	-0.09	**0.69**	0.00	**0.40**	0.13	-0.03	0.22
Rape and turnip-like rape	**0.59**	**-0.32**	-0.03	-0.14	**0.49**	0.16	-0.11
Vegetables	0.17	-0.10	**-0.38**	**-0.39**	**-0.28**	**-0.28**	0.06
Orchards	0.07	-0.06	-0.14	-0.16	**-0.26**	-0.18	0.18
Meadows, pastures	**-0.62**	0.09	**-0.24**	**-0.24**	**-0.30**	0.17	-0.08
Cattle	-0.13	1.00	-0.02	**0.58**	-0.15	**-0.25**	**0.36**
Swine	0.08	-0.02	1.00	**0.77**	0.04	**0.35**	-0.01
Ship and goats	**0.25**	0.00	-0.09	-0.11	0.15	-0.10	**-0.29**
Horses	**-0.60**	-0.11	-0.14	**-0.26**	**-0.49**	**0.23**	0.21
Livestock units	0.06	**0.58**	**0.77**	1.00	0.01	0.11	0.20

bold font – correlation significant at $\alpha = 0.01$
* measured with soil valuation index

Wheat crops are highly regionalized in the province area, which was also indicated by Jastrzębska et al. (2004) in the Warmian-Masurian region. The proportion of wheat (total spring and winter forms) in the cropland structure of communes in the region ranges from 1.5% to 54.7%. In nine communes (Papowo Biskupie, Dragacz, Radzyń Chełmiński, Kijewo Królewskie, Unisław, Łasin, Chełmża, Radziejów, and Warlubie) this proportion exceeds 40%. It should be noted that these communes have large resources of soils of a good agricultural quality, and wheat crops are strongly correlated with soil quality (Table 1). For those reasons, wheat cultivation has the highest intensity in the districts of Chełmno, Grudziądz, and Inowrocław. In 12 communes, in turn, wheat covers less than 5% area of the croplands. This particularly refers to communes lying in the districts of Rypin, Lipno, Tuchola, and Brodnica. There is a regularity that the amount of wheat cultivated is directly proportional to the quality of soils of arable land (x_1), but also inversely proportional to the intensity of animal breeding expressed in livestock units per 100 ha of agricultural acreage (x_2) according to the dependence $y = 69.46x_1 - 0.246x_2 - 30.9$ ($R = 0.82$). Wheat is also cultivated in large amounts in areas with a higher area of farms ($r = 0.29$).

Table 2. Communes with the highest intensity of particular types of plant production

Type	Commune
Total cereals	Świekatowo, Bukowiec, Drzycim, Lniano, Bobrowniki, Osie, Lubiewo, Brzozie, Pruszcz, Świecie
Wheat	Papowo Biskupie, Dragacz, Radzyń Chełmiński, Kijewo Królewskie, Unisław, Łasin, Chełmża, Radziejów, Warlubie, Wielka Nieszawka
Barley	Dąbrowa, Radomin, Łubianka, Pakość, Kowalewo Pomorskie, Lubicz, Bądkowo, Nowa Wieś Wielka, Ciechocin, Gąsawa
Rye	Śliwice, Bobrowniki, Skrwilno, Rogowo Rypińskie, Skępe, Cekcyn, Białe Błota, Baruchowo, Osielsko, Izbica Kujawska
Oats	Białe Błota, Osie, Kamień Krajeński, Osielsko, Baruchowo, Lubień Kujawski, Sępólno Krajeńskie, Skępe, Mrocza, Skrwilno
Triticale	Solec Kujawski, Lubiewo, Bobrowo, Brzozie, Jeżewo, Zbiczno, Ciechocin, Janowiec Wielkopolski, Grążawy, Topólka
Cereal mixtures	Brzozie, Świedziebnia, Osiek, Górzno, Grążawy, Zbiczno, Drzycim, Lniano, Wielgie, Rypin
Maize for grain	Świekatowo, Bukowiec, Zła Wieś Wielka, Sicienko, Chodecz, Pruszcz, Rogowo, Dębowa Łąka, Waganiec, Barcin
Legumes for grain	Wielka Nieszawka, Łysomice, Inowrocław, Gniewkowo, Rojewo, Strzelno, Kruszwica, Dąbrowa Biskupia, Gruta, Świecie n. Osą
Rape and turnip-like rape	Łasin, Świecie nad Osą, Gruta, Radzyń Chełmiński, Kijewo Królewskie, Rogóźno, Lisewo, Łysomice, Sadki, Koronowo
Sugar beet	Bądkowo, Brześć Kujawski, Lubraniec, Kowalewo Pomorskie, Radziejów, Włocławek, Zakrzewo, Dobre, Strzelno, Janikowo
Potatoe	Kowal, Kamień Krajeński, Papowo Biskupie, Baruchowo, Cekcyn, Skępe, Waganiec, Białe Błota, Skrwilno, Śliwice
Fodder plants	Świedziebnia, Chrostkowo, Brzuze, Wąpielsk, Czernikowo, Nakło n. Notecią, Osięciny, Zbójno, Kruszwica, Piotrków Kujawski
Vegetables	Choceń, Unisław, Fabianki, Dąbrowa Biskupia, Chełmno, Pakość, Koneck, Radziejów, Gniewkowo, Wielka Nieszawka
Orchards	Choceń, Fabianki, Górzno, Świedziebnia, Złotniki Kujawskie, Waganiec, Raciążek, Osielsko, Koronowo, Świecie
Meadows and pastures	Nowa Wieś Wielka, Białe Błota, Skrwilno, Skępe, Wielka Nieszawka, Śliwice, Włocławek, Dragacz, Łabiszyn, Rojewo

Rye is a species which tolerates different soils, including those acidified and of small water retention, and thus, low agricultural quality. Therefore, in studies by Kuś (2002) and Rudnicki (1999), the proportion of rye in the cropland structure was related mostly to soil quality. The soil conditions in Kuyavian-Pomeranian Province determine rye cultivation in 74% (r^2 = 0.74). The proportion of rye in the cropland structure decreases by 6.8 pp with an increase of soil valuation index by 0.1 point. This dependence indicates evidently that rye crops are located mainly on weak soils (Table 1). Consequently, in the group of communes with soils of a valuation index less than 0.9 the average rye proportion amounts to 25%, whereas in the areas with the best soils (soil valuation index > 1.1) it is only 3.7%. It follows from these results that rye and wheat are regionalized in the opposite way, due to their different soil requirements.

Relation between barley cultivation and soil quality is significant, but considerably weaker (r = 0,57) than that of rye or wheat (Table 1). This means that the regionalization of cultivation of this species is determined also by non-soil factors. According to Kuś (2002), farm size is one of such factors. However, relationships between barley cultivation and farm size or the scale of animal breeding were not observed in this study. In 11 communes barley accounts for over 20% of cropland area (Table 2), and in four communes (Skępe, Skrwilno, Śliwice, and Wielgie) its proportion does not exceed 5%. Barley cultivation is more developed in the west part of the province than in the east (Table 1).

In 10 communes (Table 2) barley accounts for over 4% of cropland area, but in as many as 52 communes this percentage does not exceed 1%. Barley cultivation is regionalized mainly in areas with soils of a low quality (r = -0.57), as well as in those with quite large horse livestock (r = 0.31), which confirms the opinion of Kuś (2002). Larger amounts of oats crops occurs in the west part of the province, as compared with the east (Table 1).

Triticale is mainly a fodder cereal. Therefore, the distribution of triticale cultivation around the region is related to the farm animal livestock (x_2), particularly swine, and to soil quality (x_1) according to the dependence $y = 16.1 - 12.89x_1 + 0.124x_2$ (R = 0.54). From this dependence it follows that the proportion of triticale in crops increases with the livestock and it is inversely proportional to the quality of soils of the arable land in the communes. In seven communes triticale accounts for over 20% of cropland area, but in 13 communes its percentage is less than 5%. Triticale is least cultivated in the areas with soils of high quality such as in the communes: Kruszwica, Radziejów, Inowrocław, Papowo Biskupie, Janikowo, and Unisław. From a geographical perspective, the intensity of triticale cultivation grows from the south towards the north of the region (Table 1).

Cultivation of cereal mixtures, as a source of concentrated feeds, is regionalized in the same way as triticale, under the influence of fodder needs of the livestock (x_2) and soil conditions (x_1), and those two factors together determine the proportion of cereal mixtures in cropland area in 48% (y) according to the equation $y = 33.7 - 34.69x_1 + 0.204x_2$ (R = 0.69). Furthermore, this way of obtaining fodder is more often used in areas with more fragmented farms than in the areas where they are bigger. In 23 communes cereal mixtures account for over 20% of cropland area, and in the communes Brzozie, Świedziebnia, Górzno, and Osiek even more than 30%. The intensity of mixture cultivation in the area of the province increases towards the east, and particularly the north-east.

Maize cultivation for grain is highly regionalized. In 13 communes its proportion in the cropland structure exceeds 5% and in the communes Świekatowo and Bukowiec it amounts to over 12%. In 29 communes, in turn, its proportion is less than 0.5% of cropland area. A lack of relation between soil quality and the proportion in maize crops is characteristic (Table 1). This probably results from the low soil requirements of this plant and a possibility of its cultivation on various soils, from the best to the light and sandy. Kuś (2002) claims that maize evidently is regionalized on the basis of the thermal criterion. However, the distribution of its cultivation around the province does not confirms this on a scale of the region. A higher intensity of cultivation of this plant can be found in communes with well developed swine breeding and where the farms have a relatively large agricultural area.

Crops of edible legumes, first of all peas and beans, have a small proportion in cropland structure (0.5%) and show a positive correlation with soil quality ($r = 0.28$). That is why they are cultivated in greater amounts in Kuyavia (Table 2), particularly in the district of Inowrocław, where they account for 1.8% of crops, but they have the highest proportion (more than 3%) in the communes Wielka Nieszawka and Łysomice. In as many as 62 communes, however, their proportion is slender and does not exceed 0.2%.

Great concentration of crops of rape and turnip-like rape occurs in the north-east part of the province, particularly in the district of Grudziądz, where they account for as much as 15.9% of the cropland area, whereas this proportion in the whole province amounts to 4.6%. These crops, however, are placed also in other areas, which is confirmed by the lack of significant relation between the intensity of rape and turnip-like rape cultivation and the lie of the communes (Table 1). In 16 communes, rape and turnip-like rape account for over 10% of cropland area, in the next 32 communes, 5-10%, but also in 14 communes, less than 0.5%. These crops are interrelated to soil quality (soil valuation index – x_1), cropland area in farms (ha – x_2), and farm animals livestock (x_3) according to the equation: $y = 13.33x_1 + 0.393x_2 - 0.0461x_3 - 8.89$ ($R = 0.68$). From this dependence it follows that the proportion of rape and turnip-like rape in cropland structure increases together with a better soil quality, larger farms and smaller sizes of animal breeding, particularly cattle.

Sugar beet cultivation is regionalized mainly in the south part of the region, particularly in Kuyavia, and shows a distinct relation to the soil quality of arable land (Table 1). However, a multi-variable analysis indicated that its cultivation is determined jointly by the soil quality of arable land (x_1), cattle livestock (x_2) and cropland area in farms (x_3), according to the equation $y = 21.84x_1 + 0.0676x_2 - 0.198x_3 - 16.5$ ($R = 0.65$). Thus the largest amounts of sugar beet are cultivated in the communes with large resources of good soils, with well developed cattle raising and relatively small farms. The relation to cattle raising indicates that the leaves and pulp of sugar beet are of importance in the organization of fodder resources for this group of animals. In 2002, in 18 communes sugar beet accounted for over 10% of cropland area and in 21 communes, less than 1%. It should be noted that sugar production limits and closing down some sugar factories may considerably change the former scale of beet production and its regional distribution.

Potato crops occur in all the communes of the region and do not show a distinct relation to the geographical situation of the communes. Thus, its crops are regionalized locally and structured in sub-plots around the region. In 9 communes, potato accounts for over 10% of field crop area, whereas in 33 communes, less than 3% of that area.

Potato is treated as a plant of sandy-loamy soils of a relatively low agricultural quality. Thus, the size of its cultivation shows a negative correlation with soil quality (Table 1). However, soil conditions determine potato cultivation only in 28%, which means that the regionalization of potato cultivation is largely determined by non-soil factors as well. One of them is a degree of fragmentation of farms. The less area of the farms, the higher proportion of potato in the structure of their plant production. Moreover, edible potato crops are quite often located on soils of a good quality, as for instance in the commune Papowo Biskupie. The lack of a significant relation between the scale of swine breeding and the proportions of potato cultivation is characteristic. This confirms the fact that potato is not of great importance in swine feeding nowadays.

Fodder plant crops, being bulky feeds for animals, show natural relation to the scale of animal breeding, particularly cattle breeding (Table 1). The effect of the livestock per 100 ha of agricultural acreage (x_1) determines the cultivation of those plants in interrelation with agricultural acreage on the farms (x_2) according to the dependence $y = 0.155x_1 + 0.2x_2 - 2.11$ ($R = 0.73$). Proportion of fodder plants in the cropland structure increases with the livestock and at the same time, with the farm size. In 13 communes of the region fodder plants account for over 10% of cropland area, but also in 18 communes their proportion is less than 3%. Surprisingly, there is no correlation between the proportion of permanent grassland in the agricultural acreage and the proportion of fodder plants in the cropland structure of arable land (Table 1).

Field-grown vegetables show a distinct but local regionalization. In two communes quite distant of each other (Choceń, Unisław) they account for over 10% of cropland area and in the next 10 communes, over 5%. Vegetable crops in the south part of the province tend to have larger sizes than those in the north part. Vegetable production occurs more often in areas with fragmented farm structure than where the farms are big. Farms and areas geared towards laborious animal breeding more rarely take up the equally laborious vegetable production (Table 1).

When analysing the regionalization of plant production in the area of the province, evident relations between the distribution of this production and soil quality should be noted. The soil quality does not show significant deliberate variation (Table 1), and soil areas of similar quality occur in different parts of the region. For that reason, also distribution of particular types of plant production has usually a character of sub-plots, not forming any large specialist areas. Regionalization of the given agricultural crop or commercial group of plants mostly refers to several adjoining communes.

Using the agglomeration method of k-averages, a classification of communes in the region was performed according to their similar plant production structure. 4 assemblages of communes were determined, taking into account 15 elements of the structure of croplands and agriculturally utilized area (Table 3). Communes of a given assemblage are usually situated in different parts of the region, but they form microregions including mostly the area of several adjoining communes (Fig. 1).

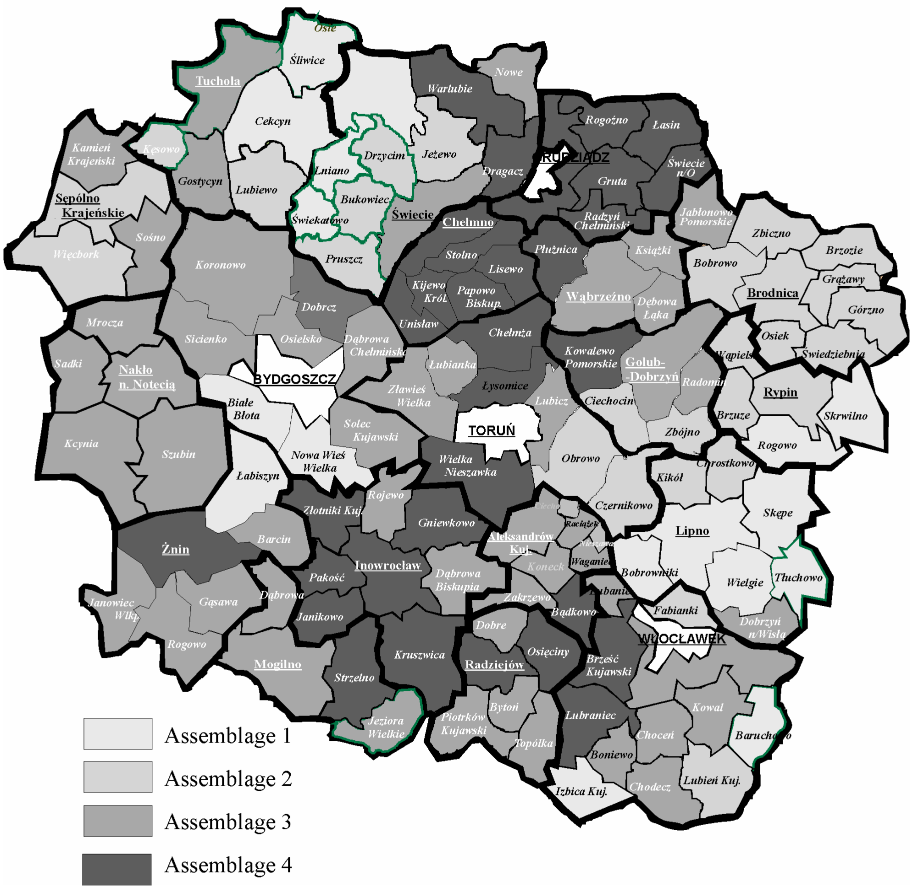

Fig. 1. Assemblages of communes of the Kuyavian-Pomeranian Province with a similar plant production structure

Plant production of communes in assemblage 1 is characterized by a relatively large proportion of rye, oat, triticale, cereal mixtures and potato in the cropland structure and a large proportion of meadows and pastures in the structure of agricultural acreage. Such a character of production results from a low quality of soils (soil valuation index = 0.75) and is related to a small average area of farms. Plant production in 32 communes of assemblage 4 has different character. The communes usually posses soils of good agricultural quality, thus the proportion of wheat, barley, sugar beet, rape and vegetables in the structure of croplands is large (Table 3).

Table 3. Plant production structure in four assemblages of communes of the Kuyavian--Pomeranian Province

Type of production	Number of assemblage (number of communes)			
	1 (18)	2 (27)	3 (50)	4 (32)
Wheat*	5.5	11.6	22.0	36.5
Rye*	32.7	12.4	11.8	4.3
Barley*	8.2	12.4	14.9	14.8
Oats*	4.1	1.8	2.0	0.7
Triticale*	11.4	16.2	11.3	7.2
Cereal mixtures*	19.1	23.1	10.3	4.7
Maize for grain*	1.9	2.4	2.5	1.5
Edible legumes*	0.1	0.2	0.4	1.0
Potatoe*	7.3	4.9	4.5	3.4
Sugar beet*	1.2	3.3	6.6	7.7
Fodder plants*	6.1	7.9	5.6	4.7
Rape and turnip-like rape*	0.7	2.1	4.8	8.8
Vegetables*	0.9	0.9	1.9	2.7
Orchards**	0.4	0.9	0.9	0.7
Meadows and pastures**	19.6	9.3	9.9	7.7
Soil value index AL	0.75	0.94	0.98	1.08
Hectare AA/farm	8.1	9.9	11.1	12.0

* proportion [%] in cropland structure
** proportion [%] in agricultural acreage structure

Regionalization of animal production

Intensity of farm animal breeding, measured in the number of livestock units (LSU) per 100 ha of agricultural acreage (AA), differs considerably in communes of the region (variation coefficient CV = 30.2%). In 17 communes the animal livestock exceeds 80 LSU/100 ha AA, and in the communes Jeżewo, Ciechocin, and Radomin it amounts to over 100 LSU·100 ha^{-1} AA. In 16 communes, in turn, this livestock does not exceed 40 LSU·100 ha^{-1} AA. Animal breeding has a particularly small scale in the communes: Janikowo, Wielka Nieszawka, Białe Błota, and Solec Kujawski. The total livestock does not show a distinct directional variation in the province area, and it is not related to soil quality or farm size (Table 1), thus, it is regionalized in small areas distributed in different parts of the region. Breeding of particular species of animals, however, is regionalized to a larger extent.

Cattle raising reached relatively high proportions in 9 communes (Table 4), where are over 60 heads of those animals per 100 ha AA, as well as in the next 15 communes with a livestock of 50-60 heads·100 ha^{-1} AA. These are mostly communes situated in the east part of the region, since the livestock generally increases in the direction from the west towards the east of the province. Cattle production is also better developed in the south region than in the north. In 22 communes the livestock does not exceed 25 heads per 100 ha AA, and it is particularly small in the communes: Osielsko, Solec Kujawski, Papowo Biskupie, Wielka Nieszawka, Warlubie, Rogóźno, and Bukowiec. It should be noted that there is no correlation between the cattle livestock and the proportion of permanent grassland in the structure of agricultural acreage (Table 1) and at the same time, a quite high positive correlation of the livestock of this group of animals with the proportion of fodder plants in cropland structure (r = 0.69). When the cattle livestock increases by 10 heads per 100 ha of agricultural acreage, the proportion of fodder plants in cropland structure grows by about 1.2 pp. On the basis of those relations one may conclude that the size of cattle breeding is not determined by the resources of permanent grassland, whereas the needs of bulky feeds for those animals are largely satisfied by means of adjusting the acreage of fodder plants on arable land to those needs. The main source of concentrated feeds for cattle, in turn, is cereal mixture cultivation (r = 0.33).

Table 4. Communes with the most intensity of particular types of animal production

Type	Communes
Cattle raising	Świedziebnia, Skrwilno, Wąpielsk, Topólka, Osięciny, Brzuze, Piotrków Kujawski, Zakrzewo, Rypin, Radomin
Swine breeding	Jeżewo, Ciechocin, Janowiec Wielkopolski, Radomin, Grążawy, Brzozie, Pruszcz, Górzno, Gąsawa, Dębowa Łąka
Horse breeding	Solec Kujawski, Śliwice, Osielsko, Nowe, Cekcyn, Skępe, Włocławek, Fabianki, Baruchowo, Dragacz
Sheep and goat breeding	Nakło n. Notecią, Janikowo, Żnin, Sadki, Unisław, Bądkowo, Pakość, Złotniki Kujawskie, Dąbrowa Chełmińska, Koneck
Total livestock	Jeżewo, Ciechocin, Radomin, Wąpielsk, Grążawy, Świedziebnia, Brzuze, Górzno, Dębowa Łąka, Janowiec Wielkopolski

Swine breeding is well developed in Kuyavian-Pomeranian Province. In as many as 30 communes there are more than 300 swine heads per 100 hectares of arable land, and in 7 communes there are even more than 400 heads. Generally, the scale of swine breeding increases from the south to the north of the province (r = 0.35). In the north part, the area with large swine production covers the communes Jeżewo, Pruszcz, Świekatowo, Lubiewo, Drzycim, Bukowiec, Osie, located in the district of Świecie. The second such area consists of several communes situated in the north-east part of the province and includes the communes: Ciechocin, Radomin, Grążawy, Brzozie, Górzno, Bobrowo, Obrowo, Golub-Dobrzyń, Kowalewo Pomorskie, Brodnica. The third important area of swine breeding is located in the south-west part of the region, mostly in Pałuki and includes the communes: Janowiec Wielkopolski, Gąsawa, Rogowo, Żnin. By contrast, in 18 communes swine livestock does not exceed 150 heads per 100 hectares of arable land. The majority of those communes are situated in Kujawy (Choceń, Kowal, Janikowo, Boniewo, Fabianki, Włocławek, Strzelno, Piotrków Kujawski, Pakość, Brześć Kujawski, Bytoń), and the smallest swine livestock occurs in the communes: Nowa Wieś Wielka, Skępe, Białe Błota, Dragacz. Significant correlations between the swine livestock and the proportions of triticale (r = 0.57), cereal mixtures (r = 0.33) and maize for grain (r = 0.24) in the cropland structure of communes (Table 1) indicate that in spite of development of fodder industry, swine feeding is largely based on own concentrated feeds of the farms, and the main sources of those feeds are triticale, cereal mixtures and maize crops.

The total scale of sheep and goat breeding is small, although those animals occur in all the communes. Their distribution in the region is greatly varied, and higher numbers of the animals are usually related to several larger stocks occurring in some communes. Therefore, only in 8 communes the sheep and goat livestock exceeds 10 heads per 10 ha AA. This refers, for instance, to the communes: Nakło n. Notecią, Janikowo, Żnin, Sadki, Unisław, Bądkowo, Pakość, Złotniki Kujawskie. Location of those communes indicates a higher sheep and goat livestock in the west part of the region than in the east part (r = -0.29).

Horse breeding occurs in all the communes of the province, although often in a slight proportion, as for instance in the communes: Janikowo, Strzelno, Zakrzewo, Papowo Biskupie, Radzyń Chełmiński, Bądkowo, Dąbrowa, Gostycyn. Due to a small current importance of horses as of draught power in agriculture, together with their growing function in sport and recreation, the largest horse livestock per 100 ha of agricultural acreage usually occurs near big cities. In the vicinity of the city of Bydgoszcz it refers to the communes: Solec Kujawski, Osielsko, Dąbrowa Chełmińska, Białe Błota, Sicienko, in the vicinity of Toruń, the communes Lubicz and Wielka Nieszawka, in the vicinity of Włocławek, the rural commune Włocławek and Fabianki, in the vicinity of Grudziądz, the rural commune Grudziądz and Dragacz. Horse breeding has also considerable proportions in some other communes such as: Śliwice, Cekcyn, Skępe, Baruchowo, Lipno, usually those which have soils of a low agricultural quality (r = -0.60) and fragmented farm areas (r= -0.49). Totally, only in 8 communes the horse livestock amounts to over 2 heads per 100 ha of agricultural acreage, and in 41 communes it is less than 0.5 head.

The 4 assemblages of communes determined (5 classifying variables) with a similar livestock structure of major farm animals mostly differ in the proportion of swine breeding and, consequently, in the number of livestock units (Table 5, Fig. 2). This results from a large variation in swine breeding intensity in the province. It should be noted that the swine livestock is related to the proportion of triticale and cereal mixtures in the structure of croplands. It also appears that proportions of animal production in communes and groups of communes do not show a significant relation to the soil quality and to the size of farms in those communes (Tables 1 and 5).

Table 5. Characteristics of animal production in 4 assemblages of communes of the Kuyavian--Pomeranian Province

Type of production	Assemblage number (number of communes)			
	1 (37)	2 (40)	3 (33)	4 (17)
Cattle*	36.0	40.7	39.0	36.8
Swine**	137.3	210.2	292.0	443.4
Sheep and goats*	3.5	3.9	3.5	2.5
Horses*	1.1	0.9	0.7	0.8
LSU***	45.1	59.9	69.0	85.5
Triticale****	8.6	9.6	13.1	17.6
Cereal mixtures****	9.7	12.3	14.1	18.8
Fodder plants in AL****	5.4	6.3	6.6	5.1
Meadows and pastures*****	12.9	10.9	8.7	8.6
Soil value index AL	0.95	0.96	0.99	0.96
Hectare AA/farm	9.6	11.0	11.8	10.0

* heads per 100 ha of agricultural acreage
** heads per 100 ha of arable land
*** livestock units per 100 ha of agricultural acreage
**** % in cropland structure
***** % in structure of agricultural acreage

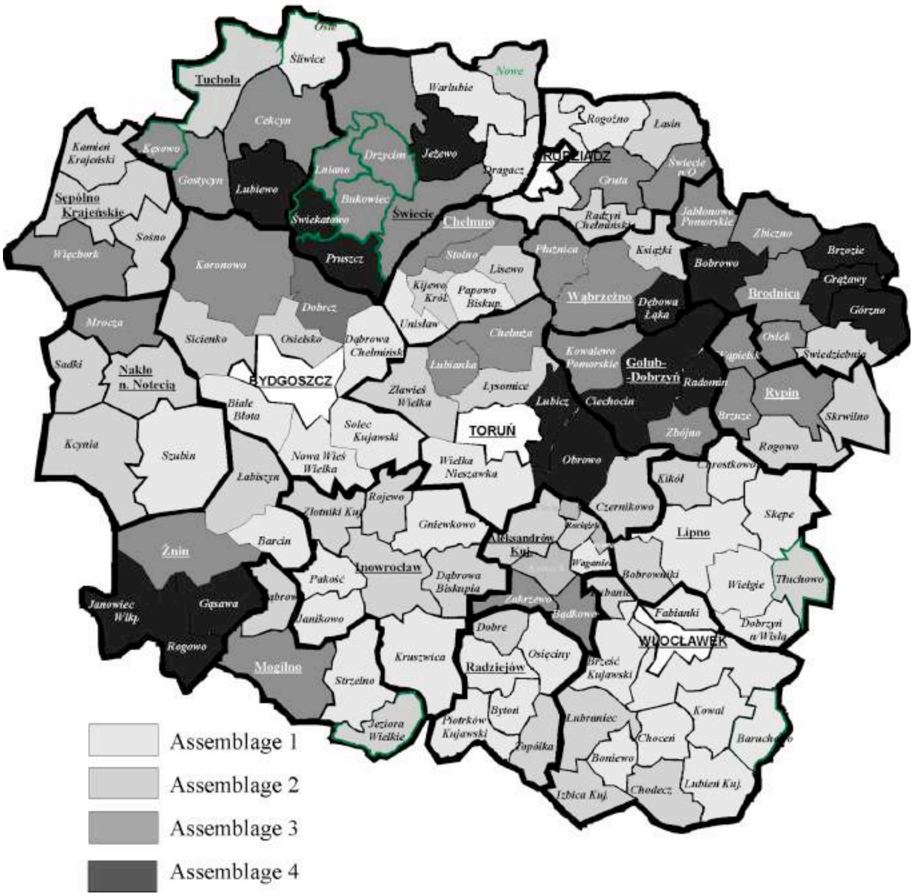

Fig. 2. Assemblages of communes of the Kuyavian-Pomeranian Province with a similar structure of animal production

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ENVIRONMENTAL CONDITIONS OF AGRICULTURAL ACTIVITY IN THE AREAS OF UNFAVOURABLE FARMING CONDITIONS WITH THE ŚLIWICE COMMUNE IN THE TUCHOLA FOREST AS AN EXAMPLE

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The Kuyavian-Pomeranian Province is known in the country for its efficient production of cereals, rape and sugar beet. On the other hand, much of it covers the areas where intensive agriculture cannot operate; these are the so-called less favoured areas (LFA). Upon Poland joining the European Union, farming in these areas have been covered by special co-financing. The basic objective of defining less favoured areas is providing support to farms in the areas threatened with depopulation and preventing from landscape degradation as a result of laying poorest land fallow. The LFA payments create conditions favorable to maintaining agricultural production in the areas of low production potential caused by habitat limitations. Such limitations include mostly the soil quality determined by agricultural applicability complexes, local climate, landscape and water relations. In such areas an effective farm operation in today's economic reality poses many difficulties. Many of them surely would not survive without tangible financial assistance as part of the Common Agricultural Policy and additional payments in the LFA.

The Kuyavian-Pomeranian region includes 45 communes of less difficulty for agricultural production (LFA I) and 10 communes of considerable difficulty for agricultural production (LFA II). The other of the categories are represented only by extensive farms on poor soils for which the calculated coefficient of valorization of the agricultural productive areas in the range from 19.5 to 120 reaches not more than 52. The area of high concentration of communes with agricultural production difficulties is the northern part of the province, the Tuchola Forest. The area is almost completely covered by LFA II, and three most southern communes (Cekcyn, Osie, and Śliwice) constitute almost half of the Kuyavia and Pomerania areas of this type (Fig. 1); of which Śliwice is least fortunate. Soils available on these farms show very low potential for the cultivation of most crops. Rye, potato and lupin are the only ones the yielding potential of which is satisfactory (Rudnicki 1999). Almost 90% of soils represent V and VI soil valuation class, which could be why almost 70% of the commune area is covered by woodland. Agricultural land covers a total of 4577 ha, and about 1/3 of it is covered by meadows (Stosik 2007). The area changes from year to year. Prior to Poland's joining

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the European Union, almost 20% of the land was not used (Stosik and Korczyński 2004). Currently in many areas cultivation was resumed and some areas have been converted into forest. Mostly due to a high share of grasslands in the commune, there is still a high number of cattle, thus defining the mainstay of production (Synthesis of Development Conditions for the Tuchola County and its Communes).

The valorization of the agricultural productive areas made based on different synthetic indicators is only limited to defining its production potential. The floristic structure of segetal or meadow communities exposed to analysis at specific time facilitates, on the one hand, defining habitat parameters, while, on the other hand, evaluating the farming method.

The present paper provides the phytosociological characteristics of agricultural productive space of the Śliwice commune as well as demonstrates a variation in agrotechnical practices, shows unfavorable changes as well as, especially in the case of meadows, points to precious environmental areas.

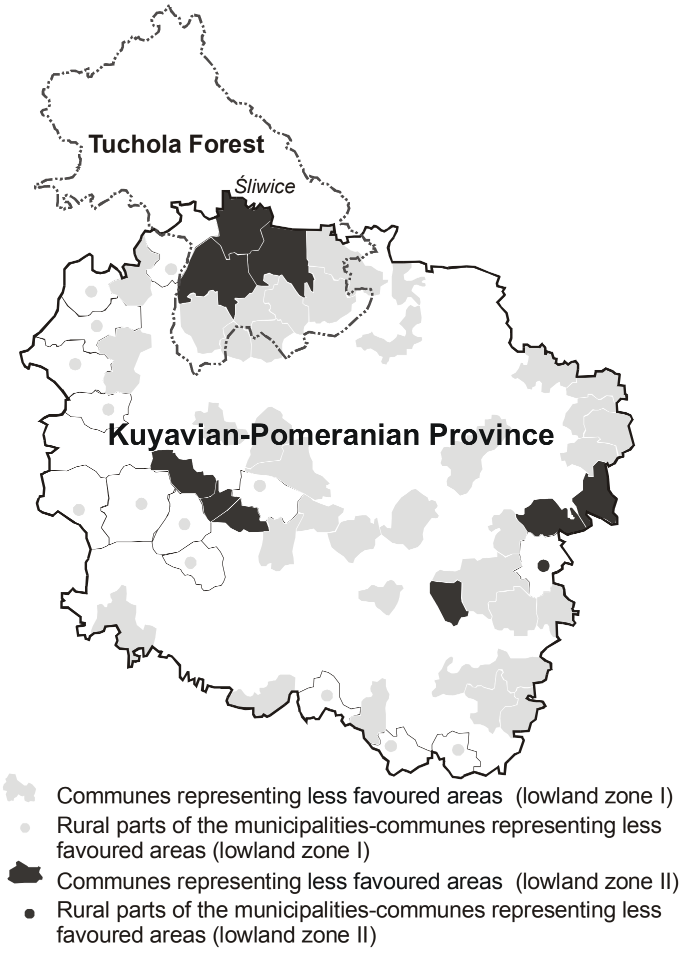

Fig. 1. Location of the research area against the less favoured areas in the Kuyavian-Pomeranian Province

Materials and methods

The research material is made up of 405 phytosociological images made applying the Braun-Blanquet method (Pawłowski 1972). The community taxonomy is given after Matuszkiewicz (2002) and species names according to Rutkowski (2004). There has been developed a phytosociological table from which the paper provides a systematic list of the plant communities and assemblages identified in three biocenosis types: in the field, fallow land, and in meadow.

Results

In agricultural land of the Śliwice commune there was identified a total of 40 different phytocenoses; 14 of which has been ranked as assemblages, while the others – mostly no-rank communities with a dominance of a single or a few species (Table 1).

In the cereal and potato fields 11 communities were noted, including three assemblages: *Scleranthus annuus*, *Echinochloo-Setarietum* and representing class *Bidentetea Tripartiti – Polygono-Bidentetum* (Table 1, items 1, 10, and 16). In the other cases the structure of segetal phytocenoses, due to the dominance of a single species, was considerably simplified. Frequently weeds dominated the field and the entire pattern was determined by a single taxa, including, Corn Spurrey *Spergula arvensis*, cornflower *Centaurea cyanus*, wild oat *Avena fatua*, loose silkybent *Apera spica-venti*, lambsquarters *Chenopodium album*, *Polygonum lapathifolium* ssp. *pallidum*, *Galinsoga parviflora.*

Sometimes untypical patterns appear in the fields, e.g. *Phragmitetum australis* in triticale or *Polygono-Bidentetum* with water pepper in root crops. In the fields obviously one can also find crops where from the perspective of potential yields the closing of crop is satisfactory and weeds are rare.

Such a picture of crops was due to specific agrotechnical practices. The commune is dominated by a few-hectare, extremely low-input farms where the basic income is generated outside agriculture. For that reason many farmers use their land mainly because of land-related payments.

One cannot therefore expect the situation to change drastically in the near future. Today one can claim that LFA and other payments effectively reduce laying the land fallow. The effectiveness of the financial assistance offered to farmers is also seen from changes in the acreage of fallow land. Still before 2004 in the commune almost 20% of the arable land had not been used. Then one could observe fallow land at successive stages of natural succession (Stosik and Korczyński 2007).

Table 1. Plant communities identified in agricultural land of the Śliwice commune in the Tuchola Forest. Plant associations in bold

Fields	Fallow land	Meadows	Community no	Systematics of plant communities
▼	▼	▼		
				***Bidentetea Tripartiti* R. Tx., Lohm. et Prsg 1950**
				Bidentetalia tripartiti Br.-Bl. et R. Tx. 1943
				***Bidenion tripartiti* Nordh. 1940**
■			**1**	*Polygono-Bidentetum* (Koch 1926) Lohm. 1950
				***Stellarietea mediae* R. Tx., Lohm. et Prsg, 1950**
■			2	com. with *Phragmites australis*
■			3	com. with *Bilderdykia convolvulus*
■			4	com. with *Spergula arvensis*
				***Centauretalia cyani* R.Tx. 1950**
■			5	com. with *Anthemis arvensis*
■			6	com. with *Centaurea cyanus* and *Avena fatua*
■			7	com. with *Centaurea cyanus* and *Apera spica-venti*
				***Aperion spicae-venti* R.Tx. et J.Tx. 1960**
■			8	com. with *Apera spica-venti*
				***Arnoseridenion minimae* Malato-Beliz, J.Tx. et R.Tx. 1960**
	■		**9**	*Arnoserido-Scleranthetum* (Edouard 1925) R.Tx. 1937
■			**10**	com. *Scleranthus annuus*
				***Aphanenion arvensis* R.Tx. et J.Tx. 1960**
	■		**11**	*Papaveretum argernones* (Libb. 1932) Krusem. et Vlieg. 1939
				Polygono-Chenopodietalia (R. Tx. et Lohm. 1950) J. Tx. 1961
				***Polygono-Chenopodion* Siss. 1946**
	■		12	com. with *Chenopodium album*
	■		13	com. with *Conyza Canadensis*
■			14	com. with *Chenopodium album* and *Polygonum lapatifolium* ssp. *Pallidum*
■			15	com. with *Galinsoga parviflora*
				***Panico-Setarion* Siss. 1946**
■			**16**	*Echinochloo-Setarietum* Krusem. et Vlieg. (1936) 1940
				***Artemisietea vulgaris* Lohm., Prsg et R.Tx. in R.Tx. 1950**
				Artemisienea vulgaris
	■		17	com. with *Artemisia vulgaris*
	■		18	com. with *Cirsium arvense*
				***Agropyretea intermedio-repentis* (Oberd. et al. 1967) Müller et Görs 1969**
				***Agropyretalia intermedio-repentis* (Oberd. et al. 1967) Müller et Görs 1969**
				***Convolvulo-Agropyrion repentis* Görs 1966**
	■		**19**	*Convolvulo arvensis-Agropyretum repentis* Felföldy 1943
	■		20	com. with *Phragmites australis*

	***Phragmitetea* R. Tx. et Prsg 1942**
	***Phragmitetalia* Koch 1926**
	***Magnocaricion* Koch 1926**
21	*Caricetum ripariae* Soó 1928
22	*Caricetum rostratae* Rübel 1912
23	*Caricetum elatae* Koch 1926
	***Koelerio glaucae-Corynephoretea canescentis* Klika in Klika et Novak 1941**
	***Corynephoretalia canescentis* R. Tx. 1937**
	***Vicio lathyroidis-Potentillion argenteae* Brzeg in Brzeg et M. Wojt. 1996**
24	*Diantho-Armerietum elongate* Knausch 1959
	***Corynephorion canescentis* Klika 1934**
25	*Spergulo vernalis-Corynephoretum* (R. Tx. 1928) Libb. 1933
26	com. with *Helichrysum arenarium*
27	com. with *Jasione Montana*
	***Molinio-Arrhenatheretea* R. Tx. 1937**
	***Trifolio fragiferae-Agrostietalia stoloniferae* R. Tx. 1970**
	***Agropyro-Rumicion crispi* Nordh. 1940 em. R. Tx. 1950**
28	com. with *Potentilla anserina*
29	*Ranunculo-Alopecuretum geniculati* R. Tx. 1937
30	com. *Ranunculus repens*
	***Molinietalia caeruleae* W. Koch 1926**
	***Filipendulion ulmariae* SEGAL 1966**
31	com. with *Thalictrum flavum*
	***Calthion palustris* R. Tx. 1936 em. Oberd. 1957**
32	com. with *Juncus conglomerates*
33	*Angelico-Cirsietum oleracei* R. Tx. 1937 em. OBERD. 1967
34	com. with *Urtica dioica,*
35	com. with *Antoxanthum odoratum*
36	com. *Deschampsia caespitosa*
	***Alopecurion pratensis* Pass. 1964**
37	*Alopecuretum pratensis* (Regel 1925) Steffen 1931
	***Arrhenatheretalia* Pawł. 1928**
	***Arrhenatherion elatioris* (Br.-Bl. 1925) Koch 1926**
38	com. *Poa pratensis-Festuca rubra* Fijałk. 1962
39	com. with *Holcus lanatus*
	***Scheuchzerio-Caricetea* (Nordth. 1937) R. Tx 1937**
	***Caricetalia nigrae* Koch 1926 em. Nordh. 1937**
	***Caricion nigrae* Koch 1926 em. Klika 1934**
40	com. with *Carex nigra*

In fallow land 12 different phytocenoses were identified, including five ranking as assemblage (Table 1, items 9, 11, 19, 25). Part of communities is a repetition of the situation found in crops in the first year after growing was given up (Table 1, items 9, 11, 12). In the course of succession, depending on the habitat quality, there occur ruderal communities dominated by mugwort *Artemisia vulgaris* or creeping thistle *Cirsium arvense* (Table 1, items 17 and 18). Sometimes such areas are taken over by field bindweed *Convolvulus arvensis* and couch grass *Elymus repens* (Table 1, item 19). The poorest, dry poor and sandy habitats are sometimes grown with, at least for a few years, dwarf everlast *Helichrysum arenarium* (Table 1, item 26), which makes non-agricultural use possible since it is a precious herbal species, obtained from natural stands. In other cases gray hair grasses are produced, which, in turn, as part of environmental packages of the Agri-Environmental Program can be protected in a form of environmental land. Sometimes in a course of succession there emerges a pattern typical for poorer forms of fresh meadows (Table 1, item 38). Such area can be converted into grassland and one can benefit from payments addressed to precious natural meadows as part of Agri-Environmental Program.

Grasslands of the area analyzed include a dozen or so different communities, mostly representing class *Molinio-Arrhenetheretea* (Table 1, items 28-39). In most cases these are patterns heavily transformed, dominated by species of low animal feed value and as such they are not an efficient source of animal feed for cattle. However, the structure of about 30% of all the meadows examined makes their protection possible as part of 'Protection of the endangered bird species and natural habitats' package. This criterion is also met by other, less typical, meadow habitat communities: *Diantho-Armerietum Elongatae* (Table 1, item. 24). These are mainly areas used as extensive, sometimes cut-down pasture land, and their characteristic feature is a mass occurrence thrift seapink *Armeria maritima* ssp. *elongata.* Environmentally precious are also *Caricion elatae* reed beds; in the commune they are mostly made up by: great pond-sedge *Carex riparia*, bottle sedge *C. rostrata* and Bowled golden sedge *C. elata* (Table 1, items 21-23). Their protection prevents overgrowing with shrubs and, as a result, a decrease in the grassland area. On meadows the most precious parts are the so-called moss-grown areas; maintaining their use can also result in tangible financial assistance.

Discussion

The Śliwice LFA just like other areas of this type is not a place of effective agricultural production, which is confirmed by the structure of plant communities in all the biocenose types analyzed.

Over 60% of agricultural land of this area has been declared for payments due to their location in the LFA zone (Czapiewski and Niewęgłowska 2006). In the case of small farms with the main source of income generated outside agriculture, it is cost-effective to finance inputs connected with a simplified farming not expecting the yield at a reasonable level. Reducing inputs to minimum makes it possible to produce some surplus, although tangibly they are reflected in the crop quality. It is possible that, to some extent, such situation is also due to insufficient farmer's knowledge and skills (Jankowska-Huflejt et al. 2004). Today's payment system, however, is an effective tool in protecting the rural landscape and maintaining biodiversity. It is also confirmed by the fact that upon joining the European Union in land successively lain fallow crops were resumed sometimes after many years of progressive succession.

In exceptional cases the communities developing in fallow land can become a tangible source of income, e.g. sandy grasses with payments for environmental land or the site where helichrysum occurs.

Somehow grasslands are predestined for the use of environmental values in the areas of unfavorable farming conditions. The chance is offered by a maximum use of assistance funds, especially that the state of use of grasslands in Poland is generally bad. Many areas of pasture land and meadows are made up by wasteland, which results in sward degradation. However, it requires a creative approach of farmers and effective approach of agri-environmental advisers (Klepacki and Szymańska 2004).

Paradoxically, however, according to Niewęgłowska (2006), Agri-Environmental Program in its former edition 2004-2006 was not popular with small extensive farms, which could gave been due to difficulties in completing the required applications and some problems in reaching agri-environmental advisors.

Most meadows of the Śliwice commune are extensive phytocenoses and so covering them with payments as part of Package 3 Agri-Environmental Program 'Extensive permanent grasslands' is not troublesome. Besides almost 1/3 of them is referred to as environmentally precious, which makes it possible to implement Package 4 – Protection of endangered bird species and natural habitats.

It is true that some farmers of that area benefited from meadow and extensive pasture land packages over 2004-2006. However, today no increased interest in environmental protection on farms is observed. The need of making farmers aware of the natural value of the local grasslands and real possibilities of receiving additional payments has been already paid attention to earlier (Stosik 2008, 2009). Hopefully, to the benefit of both farm owners and their land, it will be possible to attract more interest in environmental protection on the farm.

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ENVIRONMENTAL DETERMINANTS OF STUBBLE INTERCROP CULTIVATION IN THE KUYAVIAN-POMERANIAN PROVINCE

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Due to the geographical situation of our country in the moderate climate zone, in the transitional type between the marine climate of West Europe and continental of East Europe type, plant growth conditions in Poland are fairy unstable. Great changeability of our climate results from the alternate inflow of maritime polar and continental air masses and periodically, of the air from the neighbouiring zones (arctic and tropical) (Kossowska-Cezak 2003). Because of a high variety of air masses, the weather conditions prevailing in Poland during the growing season are very changeable over years and difficult to predict. A significant, negative result of this climatic unstability is an increased risk of field plant production management. It referres to plant cultivation both in the main crop and in stubble intercrop, whose growth coincides in time with summer droughts occurring every few years in Poland. The droughts cause limiting of seed germination, leading to a decrease in plant density and delay of plant growth. This is very unfavourable for generating green mass yield, since with the passage of time, the day lenght is shortened and mean daily air temperatures are lowered. On the other hand, autumn frosts, which damage plants and speed up the end of their growth, constitute the factor limiting the possibility of obtaining high biomass yield.

Also edaphic factors play an important role in affecting yields of plants cultivated in stubble intercrop. On light soils of a poor water retention, plants more severely suffer the effects of rainfall deficiency. Difficulty in intercrop cultivation occurs also on very tight soils, which cannot be properly prepared for sowing in conditions of summer drought as well as at the excessive precipitation. Moreover, on very tight soils maturation and harvesting of plants preceeding intercrop cultivation occurs later than on lighter soils, which leads to a delay of sowing and shortening of plant growth.

Materials and methods

The importance of soil conditions for plants cultivated in stubble intercrop was presented on the basis of the results of studies conducted in the period of the past 40 years available in the Polish literature. Evaluation of the importance of weather conditions for yielding of plants cultivated in stubble crops was based on four field

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experiments carried out at the Experimental Station in Mochełek (17°51' E; 53°13' N) on a grey-brown podsolic soil over 1996-2007. The subject of the study was the oilseed radish cultivar 'Adagio' and the field pea cultivars 'Grapis' (2001-2004) and 'Winerek' (2005-2007). Research referring to radish was conducted over 1996-1999 and 2001--2004. Seeds were sown from 5th to 12th August and plant harvesting was made 71-78 days after sowing. Fertilization with nitrogen (80-90 $kg \cdot ha^{-1}$), phosphorus (26 $kg \cdot ha^{-1}$) and potassium (66 $kg \cdot ha^{-1}$) was applied in oilseed radish cultivation. Dry matter yield of radish from the years 1996-1998 was presented by Wilczewski (2004), and the results from the years 2002-2004 by Wilczewski et al. (2006).

The research concerning pea involved two field experiments carried out in the periods 2001-2004 and 2005-2007. The plants were fertilized preplant only with phosphorus (26 $kg \cdot ha^{-1}$ P) and potassium (66 $kg \cdot ha^{-1}$ K). Dry matter yield of pea from the years 2002-2004 was presented in a study by Skinder et al. (2007).

An analysis of weather conditions was conducted on the basis of observations made at the local observation and measurement point and the meteorological date for Kuyavian-Pomeranian Province (Żarski and Dudek 2000).

Sielianinov hydrothermal coefficients were calculated based on the equation:

$$K = \frac{P}{0.1\sum t}$$

where: P means the monthly total precipitation [mm] and $\sum t$ – total mean daily air temperatures from this month (Radomski 1987).

Results and discussion

Soil conditions

Domestic studies concerning the effect of different factors on the growth, development and yielding of plants cultivated in stubble intercrop were conducted on soils of different quality. These were mostly soils of the good and very good rye complexes (Gromadziński 1976; Songin 1978; Sadowski 1990; Sypniewski and Skinder 1993; Kopczyński 1994; Kuś and Jończyk 2000; Wilczewski 2004; Wilczewski et al. 2006; Skinder et al. 2007) and the good wheat complex (Zieliński and Zielińska 1975; Kopczyński 1994; Sowiński et al. 1995; Jaskulski et al. 2000; Kuś and Jończyk 2000). Research was conducted more rarely on soils of weak and very weak rye complexes (Boguszewski et al. 1972; Gruczek 1994). The research was usually conducted in very different weather and agrotechnical conditions, which makes it impossible to compare directly results obtained on soils of particular complexes. However, from these results it can be concluded that if the pluviothermal conditions are favourable for the growth and develpment of plants cultivated in stubble intercrop and the proper mineral fertilization for a given species is applied, a dry matter yield of about 2-3 $t \cdot ha^{-1}$ can be achieved even in worse soil conditions (the very weak rye complex; Boguszewski et al. 1972). In a study by Kuś and Jończyk (2000) conducted according to the same scheme in varied soil conditions, the dry matter yield of white mustard cultivated on a soil of the good wheat complex amounted on average to 3.76 $t \cdot ha^{-1}$ and was by 15.3% higher than that on a soil of the very good rye complex. Kopczyński (1994) observed a very high impact of soil conditions on the green mass yield of rape, which on a soil of the good rye complex amounted to 11.5 t·ha^{-1}, and on a good wheat soil was by 84.3% higher. Soil conditions were of less importance for rye – the difference was 27.4%. This indicates the great importance of the proper choice of plant species cultivated in stubble intercrop for the actual soil conditions.

In a study by Sypniewski et al. (1994) on grey-brown podzolic soils located in the north part of our province (Łyskowo), considerably lower fresh and dry mass yields of plants (white mustard, silage sunflower, fodder kale and Dutch ryegrass) were obtained than on a typical brown soil in the south part of the province (Lipie). It is hard to tell, however, to what extent this difference was caused by the soil conditions and to what extent by earlier occurrence of frosts in Łyskowo.

Soils which prevail in Kuyavian-Pomeranian Province are classified as rye complexes, which totally account for 69.8% of arable land area (Table 1). The worst conditions occur on the lightest soils of the very weak rye complex, accounting for 9.8% of arable land of the province. Yielding of plants cultivated in intercrop on these soils is less reliable and their cultivation can be successful only on condition of the optimal distribution of precipitation and selecting plants with deep and well developed root systems.

Table 1. Complexes of agricultural suitability of soils in the Kuyavian-Pomeranian Province (Anonim 2000)

Soil suitability complex	Area [thousand ha]	Proportion [%]
Very good wheat complex	42.4	4.2
Good wheat complex	209.0	20.7
Defective wheat complex	2.0	0.2
Very good rye complex	289.8	28.7
Good rye complex	106.0	10.5
Weak rye complex	210.1	20.8
Very weak rye complex	99.0	9.8
Cereal-fodder strong complex	27.3	2.7
Cereal-fodder weak complex	24.2	2.4
Total	1009.8	100.0

Due to the possibility of selecting of plant species cultivated in intercrop according to the actual soil conditions, they play a less important role than weather conditions.

Weather conditions

According to Demidowicz and Gonet (1976), the total precipitation occurring during the growth of plants cultivated in stubble intercrop should amount to at least to 160 mm, of which 60-70 mm should fall on the first four weeks after sowing. Sypniewski et al. (1994) claim that a relatively high yielding is conditioned by a sufficient water supply at emergence and uniform precipitation in the period from August to September, amounting to at least 90 mm.

In the present study, high green mass yields of pea and oilseed radish were obtained in years that were characterized by the total precipitation above the long-term mean in July and August or in one of these months (Figs 1 and 2).

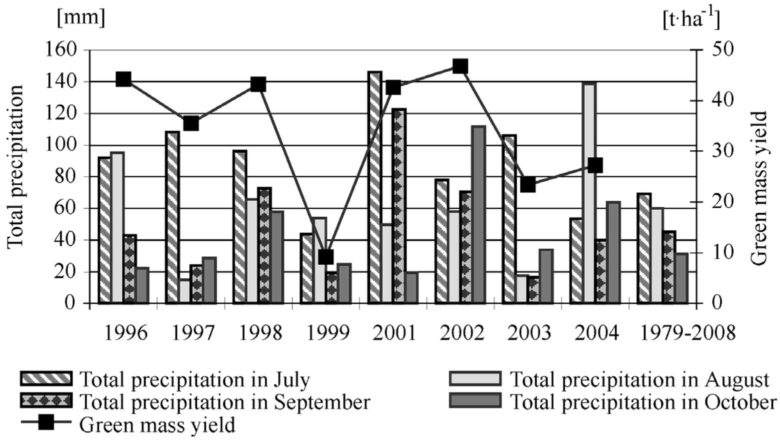

Fig. 1. Green mass yield of oilseed radish relative to monthly total precipitation

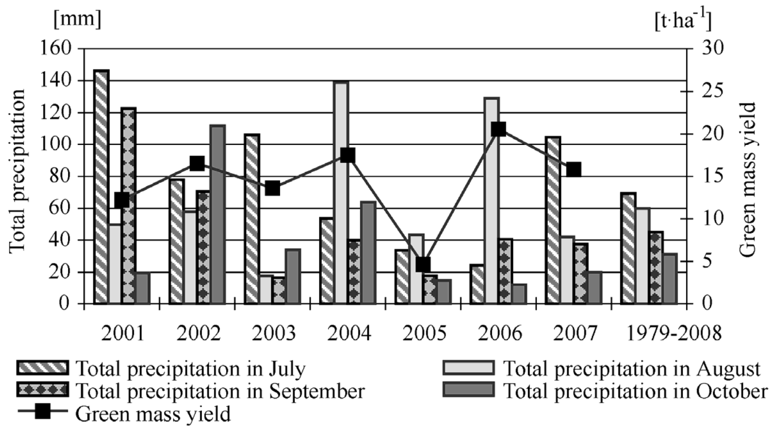

Fig. 2. Green mass yield of field pea relative to monthly total precipitation

Rainfall deficiency in July was to a great extent compensated by a higher total precipitation in August, and good water conditions in July enabled obtaining high yields even in conditions of the extremely low precipitation level in August. Unreliable yielding of plants cultivated in stubble intercrop was noted only in the years when a considerable rainfall deficit occurred in both these months, i.e. in 1999 and 2005. In these years, a higher air temperature than the mean long-term period value occurred in July, and a low level of the Sielianinov hydrothermal coefficient was noted in the whole growing period of stubble intercrop (Table 2). If the Sielianinov coefficient was very low in one of these months (August 1997 and 2003 and July 2006), and very high in the other (July 1997 and 2003 and August 2006), plant yielding was satisfactory.

Table 2. Hydrothermal conditions in Mochełek during the research period

Month	Year												Mean from
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	1996-2007
	Mean air temperature [^oC]												
Jul	15.3	17.7	16.7	20.0	15.7	19.3	18.9	19.2	16.4	19.4	22.4	18.0	18.2
Aug	18.1	19.9	15.5	17.4	17.3	18.3	19.9	18.5	17.9	16.3	16.6	17.8	17.8
Sep	10.4	13.2	12.7	15.6	11.7	11.2	12.9	13.6	12.7	14.8	15.2	12.4	13.0
Oct	8.9	6.8	7.1	7.7	5.3	10.0	6.2	4.8	8.8	8.7	9.6	6.9	8.0
Mean Jul-Oct	13.2	14.4	13.0	15.2	12.5	14.7	14.5	14.0	14.0	14.8	16.0	13.8	14.2
	Sielianinov hydrothermal coefficient												
Jul	1.94	1.98	1.85	0.71	2.07	2.44	1.33	1.78	1.05	0.56	0.35	1.88	1.46
Aug	1.69	0.24	1.37	1.00	1.09	0.88	0.94	0.31	2.50	0.86	2.51	0.76	1.16
Sep	1.38	0.61	1.91	0.42	1.65	3.65	1.82	0.41	1.05	0.40	0.89	1.01	1.20
Oct	0.81	1.37	2.63	1.03	0.45	0.63	5.82	2.28	2.34	0.56	0.41	0.93	1.40
Jul-Aug	1.80	1.06	1.62	0.84	1.56	1.68	1.13	1.06	1.81	0.70	1.27	1.32	1.31
Aug-Sep	1.59	0.39	1.61	0.73	1.31	1.91	1.28	0.35	1.91	0.65	1.75	0.87	1.18
Mean Jul-Oct	1.46	1.05	1.94	0.79	1.31	1.90	2.48	1.20	1.74	0.59	1.04	1.15	1.31

The results obtained indicate that rainfall conditions in July and August should be considered together. The total precipiation in this period is essential, and the total precipitations in particular months are of less importance. In order to get to know better the water requirements of pea and radish cultivated in stubble intercrop, a 2^o regression analysis was carried out to estimate the relation between green mass yield and the total precipitation from July 1 to August 31 (Figs 3 and 4). From the course of regression lines it follows that relatively high yields of green mass are obtained when the total precipitation in these months exceeds 110 mm, whereas their optimal amount for pea in July and August is about 150 mm, and for radish about 160 mm. Higher requirements of radish can be explained by the fact that nitrogen fertilization at a rate of 80-90 $kg \cdot ha^{-1}$ was applied in cultivation of this plant, whereas pea was grown without fertilization with this component.

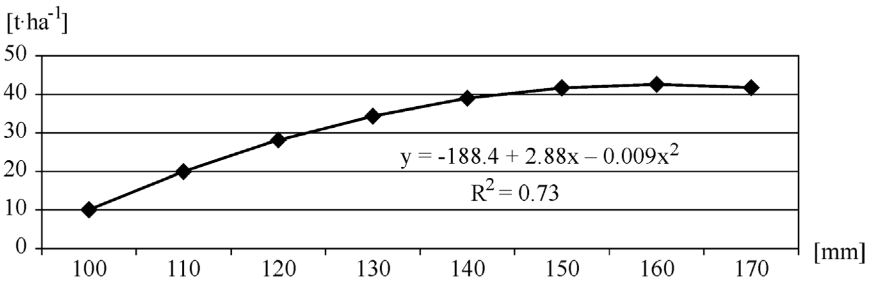

Fig. 3. Restored yield of oilseed radish green mass relative to total precipitation in July and August

The eight-year period of research concerning the effect of weather conditions on radish yield did not fully characterize their importance for the yielding of this plant. During this study, rainfall deficiency in July was observed only twice (in 1999 and

2004). In 1999, the total precipitation in this month accounted for 63.5% of the mean total precipitation for July from the years 1979-2008. Also in this year, rainfall deficiency occurred in August (89.7% of mean total of the years 1979-2008) and, as a result, the lowest yielding of radish in the whole research period was recorded. During the research period, extreme rainfall deficiency in August was recorded twice (1997 and 2003). In both cases it was preceeded by a very large amount of well distributed rainfalls in July, which enabled obtaining high green mass yields of this plant.

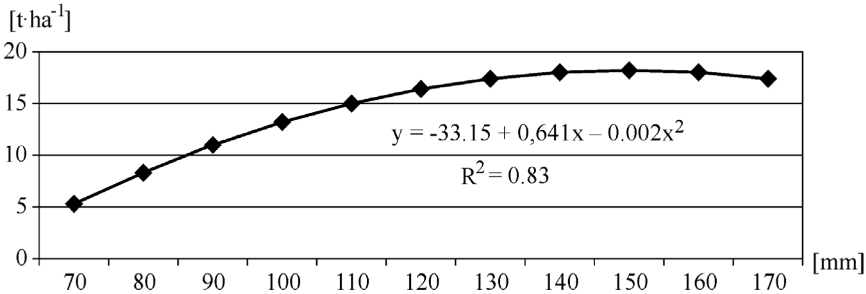

Fig. 4. Restored yield of field pea green mass relative to total precipitation in July and August

In the course of field experiments with field pea (2001-2007), only in 2005 unfavourable rainfall conditions occurred both in the period preceeding (July) and following (August and September) the establishment of the experiments. The green mass yield obtained in those conditions amounted on average to 4.66 $t \cdot ha^{-1}$ and accounted for only 32.3% of the mean yield from the period 2001-2007. A longer period with a small amount of precipitation occured also in August and September 2003. However, thanks to a large total precipitation in July, the green mass yield obtained was similar to the mean yield from those years.

In 12 out of the last 30 years, the total precipitations of July, August, and September accounted for less than 80% of the mean long-term precipitation for particular months (Table 3). Small or very small amounts of precipitation for the period July-August were observed in 9 of 30 years, whereas in the period from July to September, in 8 of 30 years. In the period from 1979 to 2008, there were 8 years when the total precipitation for the period from July 1 to August 31 amounted to below 100 mm (Table 4). From the present study discussed above it follows that in years characterized by such low precipitation, plants cultivated in stubble intercrop develop very poorly and do not give satisfactory yields. The probability of success in cultivation of pea and radish in stubble intercrop can be determined as about 75%. Distribution of years when the growth conditions of plants cultivated in stubble intercrops were unfavourable was very irregular. Sometimes, two consecutive years were characterized by unfavourable water conditions (e.g. 1983 and 1984 as well as 1994 and 1995), whereas sometimes the total precipitation in July and August was suitable for several years (2001-2004).

Table 3. Precipitation conditions in the area of research over 1979-2008

Month	Mean total precipitation in 1979-2008 [mm]	Number of years with total precipitation				
		very small below 50% long-term mean	small 50-80% long-term mean	medium 80-120% long-term mean	large 120-150% long-term mean	very large above 150% long-term mean
Jul	69.1	7	5	7	4	7
Aug	60.0	6	6	11	3	4
Sep	45.2	9	3	9	1	8
Jul + Aug	129.2	3	6	13	6	2
Aug + Sep	105.3	4	8	7	7	4
Jul + Aug + Sep	174.4	2	6	13	7	2

Table 4. Precipitation conditions in July and August in the area of research over 1979-2008

Total precipitation	Years	Number of year
Below 100 mm	1983, 1984, 1989, 1992, 1994, 1995, 1999, 2005	8
100-140 mm	1979, 1982, 1986, 1987, 1990, 1991, 1993, 1997, 2002, 2003	10
140-180 mm	1988, 1998, 2000, 2006, 2007, 2008	6
Above 180 mm	1980, 1981, 1985, 1996, 2001, 2004	6

The experimental station where the present study was conducted is situated in the mid-west of Kuyavian-Pomeranian Province. Water conditions in the research area are typical of the whole province which, according to Żarski and Dudek (2000), is characterized by little spatial diversity of precipitation (Table 5).

Also thermal conditions occurring in September and October are of significant importance for yielding of plants cultivated in stubble intercrop (Demidowicz and Gonet 1976; Wilczewski 2004). High air temperatures in these months enable prolongation of the period of plant dynamic growth and can partially eliminate the worse conditions that occur in July and August.

Table 5. Meteorological conditions in the Kuyavian-Pomeranian Province – means from 1966-1995 (Żarski and Dudek 2000)

Month	North part of province		South	
	District			
	Grudziądz	Sępólno Krajeńskie	Włocławek	Żnin
	Total precipitation [mm]			
Jul	73	70	73	70
Aug	62	57	63	57
Sep	52	50	50	46
Oct	39	43	38	39
Sum Jul-Oct	226	220	224	212
	Mean air temperature [^{o}C]			
Jul	17.6	17.4	18.1	18.1
Aug	17.1	17.0	17.5	17.6
Sep	12.9	12.7	13.2	13.3
Oct	8.1	8.0	8.3	8.5
Mean Jul-Oct	13.9	13.8	14.3	14.4

The growing season in Kuyavian-Pomeranian Province usually ends within the period November 2-6 (Żarski and Dudek 2000). At intercrop sowing in the first week of August, it is possible to obtain from 83 to 98 days of growth. This period can be shortened by occurring autumn frosts which damage plant cell structures and stop their growth.

During the research period (1996-2007), in 4 out of 12 years the first frosts occurred between the 20th and 30th September (Table 6). However, these were short-lived drops in temperature, reaching from -0.5 to -2.0°C, which did not damage the tested plants cultivated in stubble intercrop. Only in one year, frost occured on the first ten days October, whereas ground frosts occurred more often and more intensively in the second half of this month. In these conditions, ends of leaf blades of oilseed radish were damaged. This, however, did not cause plant dying out. In the present study, intercrops were harvested in the second half of October, which made it impossible to conduct further observations of the effect of temperature on plants cultivated in stubble intercrop. Drops in temperature in November were deeper and occured mostly in all the weeks of this months.

Table 6. Absolute minimum of air temperature at the ground in the research period [°C]

Month	10-day periods	Year											
		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Sep	I	4.5	5.5	5.0	6.0	3.0	7.0	7.5	4.0	2.0	5.5	8.5	4.0
	II	1.0	1.0	4.5	0.5	0.5	5.5	4.5	5.5	2.0	0.0	6.0	2.0
	III	-0.5	-1.0	4.5	7.0	0.5	1.0	-2.0	-0.5	3.5	4.0	6.0	4.5
Oct	I	0.0	1.0	-1.5	1.5	5.5	4.0	1.5	2.5	2.0	2.0	4.0	0.0
	II	0.0	-3.5	-1.0	-2.5	3.0	1.5	-2.0	-4.0	-3.5	-3.0	-3.0	-3.0
	III	-2.0	-4.5	0.0	-3.5	-1.5	-2.5	-1.5	-5.5	0.5	-2.5	0.5	-3.0
Nov	I	-2.5	-6.0	-2.0	0.0	-2.5	-3.5	-5.0	-1.5	-1.0	-3.0	-4.5	-5.5
	II	-3.5	-4.5	-5.5	-4.0	-3.0	-5.0	-4.0	-4.5	-4.0	-3.5	-2.5	-8.0
	III	-4.5	-4.0	-14.0	-5.5	1.0	-2.5	-5.0	-1.0	-6.5	-4.5	1.0	-6.0

Conclusions

Success in stubble intercrop cultivation is determined by the proper soil moisture during the sowing period, resulting from the amounts of precipitation at the time and soil ability to retain water. Also the proper selection of a species and cultivar of the plant, accordingly to the complex of agricultural suitability of a soil, plays an essential role. On soils classified as the wheat complexes and the very good rye complexes, high green mass yields can be obtained when cultivating oilseed radish, fodder kale, white mustard, field peas and vetch in stubble intecrop. Yellow lupine, winter vetch and common rye are more suitable for weaker soils. The precipitation occurring in the province indicates a certain risk of failure in cultivation of plants in stubble intercrop. It resulted from the deficiency of water available for germinating seeds in conditions of very small amounts of precipitations in July and August occurring in some years. Cultivation of plants in stubble intercrop is not successful when the total precipitation in July and August is less than 100 mm. The risk of occuring such precipitation deficiency in this period amounts to about 25%.

The level of obtained yields of plants cultivated in stubble intercrop is also dependent on pluviothermal conditions occurring in September and October. Good soil moisture and more than average air temperatures in the second half of September enables prolonging the period of plant dynamic growth and development and to some extent eliminate the negative effects of previous deficiencies. Frosts occurring sometimes at the end of September may damage plants and shorten the period of yield storing. The effect of weather conditions in September is considerably weaker than in the earlier period.

From the present study and the literature data it follows than the growing period of plants cultivated in stubble intercrop in Kuyavian-Pomeranian Province lasts about 90 days and it contains about 70 days free of frosts or with minimal drops in temperature (to -2^{o}C). It is possible to produce a high green mass yield on condition of a good water supply of plants in the period July-August, which occurs on average in three out of four years. The probability of success in cultivation of stubble intercrops in Kuyavian-Pomeranian Province amounts to about 75% and increases to nearly 100% if a large or very large amount of precipitation occurs in July. Recognition of the precipitation conditions that occur in July may be a good basis for making decisions about stubble intercrop cultivation in a given year.

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CHARACTERISTIC OF AGRICULTURAL STRUCTURE IN THE SYSTEM OF DISTRICTS ON THE EXAMPLE OF THE KUYAVIAN-POMERANIAN PROVINCE

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Common Agricultural Policy (CAP) of the European Union assumed the considerable acceleration of agricultural changes in rural areas. In order to do this, a series of programs and actions were developed which were supposed to favour new phenomena in agriculture. For instance, a system of earlier agricultural pensions assumed making over lands to younger agricultural producers for extending farms or for their independent farm management. The program of natural environment protection implemented special bonuses for farmers who would follow the rules of sustainable agriculture. In turn, action related to a change of part of agricultural farms into forest enterprises constituted the alternative forms of arable land utilization. Action related to forestation of arable lands aimed to remove soils that are useless in agriculture, and thus, to free agriculture from the lands of low soil quality classes.

On the other hand, the aims contained in CAP involved supporting poorly market oriented farms, in order to ensure an improvement of their financial situation and increase the possibilities of investments for farmers contending with little profitability. Action connected with joining and exchanging lands taken in areas characterizing by large fragmentation aimed to improve the land distribution and, consequently, to increase the effectiveness of farming. Thus, agricultural structure constitutes a specific supporting structure, on which the farms are founded, along with their area, income, production, specialization and economic properties.

Agricultural structure is a primary socio-economic category, which exerts particular effect on basic production factors in the form of land, work and capital. By means of an analysis of agriculture structure we get to know the special distribution of farms, the patchwork of lands, production possibilities and methods for shaping rural areas. According to the definition given by Szemberg (1998), agricultural structure „is a distribution of farms according to their area, at the assumption that land is a decisive production factor, and all the other factors are linearly correlated with it". According to Woś (2000), agricultural structure is „a complex of mutual assigning of elements and joining them in a whole or a system of dependences between the elements of a given system and between particular elements and the whole of the system".

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At the same time, agricultural structure is a historical category, since it came into being in the historical process, as a result of accumulation of factors of inner and outer character. Kuyavian-Pomeranian Province along with Greater Poland Province is held up as an example of a proper agricultural structure, where agricultural reforms started the earliest and where the system of relations in the country lead to creating economically strong farms. One of the most essential elements determining the economical and social situation of people and agricultural competitiveness is this area is a structure of farms. The appropriate view of agricultural relations can be obtained if the research is conducted at a low level of the functioning of administration units. District, which constitutes a bridge between the commune and the province, and at the same time is vested with a series of regulating powers, was chosen as the basic unit.

The aim of this study was to present the scale of differentiation in the size of farms from a district perspective. The investigation was based on analytical and statistical methods, which represent the current scale of the phenomena. Statistic material was obtained from Statistical Office in Bydgoszcz (WUS).

General characters of agricultural structure in the Kuyavian-Pomeranian Province

Agricultural structure focuses as in a lens the whole of ownership relations and principles of agricultural production organization in connection with agricultural market. It provides information about the system of land management, the size of production units, and characterizes legal and economic elements affecting the position of the owner of a family farm. Furthermore, agricultural structure depicts the type and character of agricultural production, as well as possibilities for land configuration in connection with the entire socio-economic conditions. The structure of farms is a factor which illustrates the way of arable land utilization. According to the general registration of 2002 in the area of Kuyavian-Pomeranian Province, 85.1 thousand of farms were recorded, and the farms within the range from 1 to 10 ha accounted for 61.2% of all the production units, the proportion of farms with a size from 10 to 50 ha was 37.1%, and farms of bigger area (50 ha and more) accounted for 1.7%. The average area of a farm amounted to 14.4 ha, of which agricultural acreage was 13.1 ha.

At the beginning of the 90s, favourable factors appeared in the form of a high percentage of agricultural acreage which came to the private sector from agricultural resources of the State Treasury. According to data of the Local Department of the State Treasury Agricultural Property Agency (AWRSP) in Bydgoszcz, over 1991-1996 8470 farms purchased land in the Kuyavian-Pomeranian region. The total area of purchased land amounted to 54,142 ha. The land intended for sale included mostly enclaves, remainders and settlements remote or not lying within a given estate. The research indicated that more than 8.8 thousand farmers gained a possibility of enlarging their farms. It may be assumed that nearly 10% of farmers extended their farms thanks to the activity of the Agency. The average increase in one farm area amounted to 1.5 ha. This mostly referred to the farms of above 15 ha. At the second stage (from 1998), when the economic situation in agriculture considerably weakened and the number of attractive plots intended for sale decreased, the possibility of the improvement of agricultural structure in this way was distinctly limited (Wawrzyniak 2004).

While the farms having 50 ha and more accounted for 1.7% in respect of number, they were 15.0% in respect of agricultural acreage. The largest amount of farms of great area was observed in the area of the districts of Sępólno, Mogilno, Nakło, Żnin etc. Running agricultural activity belongs to the basic canons of farm users. This activity is carried out in the sectors of plant and animal production, and, additionally, in the sector of special sections. 74.8% of farm owners dealt exclusively with agricultural production, moreover, 10.4% combined agricultural and non-agricultural activities and 2.5% run only non-agricultural activity. A relatively large number of farms (12.2%), did not run business activity.

Looking at the problem from the angle of the time of running a farm by the person managing a given agricultural workshop, a certain regularity can be found, consisting in a quite uniform distribution of people in particular time periods. Duration of managing a farm indirectly indicates the farmer's age. Farms, according to the time of running a unit by the managing person was as follows: 28.8 % of farmers managed a farm more than 21 years, 32.2% of farmers managed agricultural workshops from 11 to 20 years and 39.0% remained below this ceiling.

Knowing the characteristics of farms running agricultural activity, it is worthwhile getting to know the reasons of abandoning production activity, which accompanies agricultural changes. In the structure of farms according to the reasons of abandoning, economic motives (35.4%) and then health and family (18.3%) definitely predominated. An increasing number of agricultural units remains without primary agricultural activity (14.9%).

Agricultural structure in view of districts

When analysing agricultural structure from a perspective of districts, it should be noted that the structures became similar to one another and it is difficult to distinguish the districts of unfavourable structures or those of very beneficial agricultural structures. We can obtain indirect information about this from the size of one farm, which amounted to 14.4 ha of farm land for the province. 10 districts were placed above this size and respectively, 9 districts were below the average. In 2002, the average agricultural acreage of one farm in Poland amounted to 5.76 ha and was higher by 1.8% than in 1996, and the area of one farm with an area above 1 ha of agricultural acreage was 8.44 ha. The average economic size of private farms in Poland amounted to 2.5 ESU, and Kuyavian-Pomeranian Province 5.24 ESU. It appears that in EU according the data from 1999/2000 the average economic size of a farm amounted to 18.7 ESU, ranging from 6.3 ESU in Greece to 89.6 ESU in the Netherlands and 61.8 ESU in Denmark. Thus, differences between the average economic size in Poland and UE countries are larger than in the case when we will use only the average area of a farm.

The first in the ranking of the province in respect of the average size of a farm is the district of Sępólno (21.6 ha), the second is the district of Nakło (21.2 ha), and the third the district of Żnin (20.3 ha). At the opposite end of the average size we can note the district or Rypin (10.0 ha) and the district of Aleksandrów (10.4 ha). A difference of over 10 ha in the agricultural structure is very essential and shows how fragmented the agriculture still is in the two latter districts (Fig. 1).

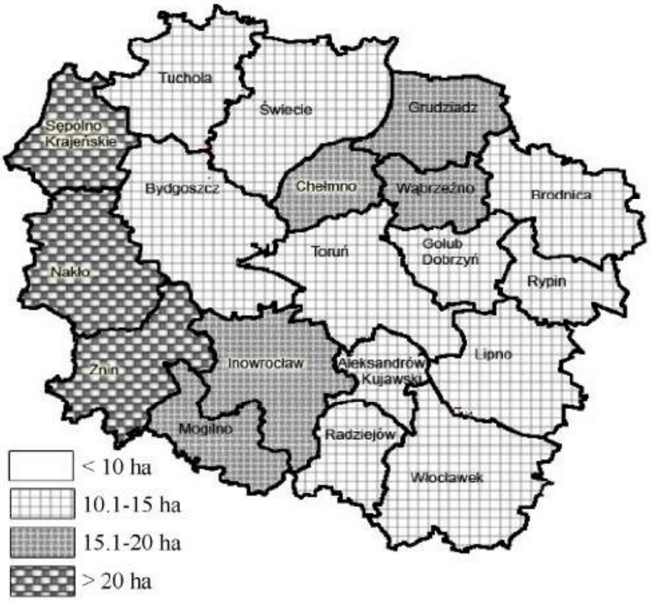

Fig. 1. Average size of farms in districts of the Kuyavian-Pomeranian Province

Small farms (1-5 ha) do not have production capacity with respect of the market, since a part of produced goods is intended for own consumption. The sources of supporting families and of household supplies come from non-agricultural work, hired labour and additionally, incomes in the form of pensions (Pawłowska-Tyszko 2003). Poczta and Wysocki (2001) indicate that in such farms usually occur unfavourable relationships between land and labour resources, and between labour and capital, and a low income from a farm is a result of a small scale of production. Possibilities for the improvement in size of such a small farm are limited due to the lack of capital for the purchase of ever more expensive land, the phenomenon of reconciliation to the situation and the age of owners of such a farm, who can exercise their right to structural pensions. In respect of quantity, small farms account for one third of all the farms, but in the district of Bydgoszcz their proportion increases up to 45.3%, in the district of Świecie – up to 44.2% and in the district of Tuchola – up to 42.4%. Those farms are doomed to stagnation, since on the one hand, the owner of a farm is not interested in investing and does not strive for development, and on the other hand, those farms constitute the place of residence, patrimony and homestead, which is difficult to part with.

The first position in the respect of quantity is taken by medium farms (5-15 ha; 41.4%), which are placed between small and dependent farms and larger and commercial farms. Depending on the extent of production intensity, they can function efficiently on the market in the respect of gaining profits that enable extended production, or concentrate on looking for the additional sources of income. In Lipno and Radziejów districts, farms having from 5-15 ha constitute over 50% of the general number of farms (Table 1).

Table 1. Agricultural structure according to districts division

District	Number/structure of farms											Average size of a farm
	Total	1-5 ha	Structure [%]	5-15 ha	Structure [%]	15-30 ha	Structure [%]	30-50 ha	Structure [%]	50 and more ha	Structure [%]	
Aleksandrów	3485	1258	36.1	1505	43.2	558	16.0	132	3.8	32	0.9	10.4
Brodnica	5076	1714	33.8	2114	41.6	941	18.5	225	4.4	82	1.7	12.6
Bydgoszcz	3943	1785	45.3	1262	32.0	562	14.3	212	5.4	122	3.0	14.7
Chełmno	2773	864	31.2	1235	44.5	520	18.7	97	3.5	57	2.1	15.2
Golub-Dobrzyń	3588	1119	31.3	1680	46.8	601	16.7	138	3.8	50	1.4	12.0
Grudziądz	3166	1145	36.2	1183	37.4	567	17.9	165	5.2	106	3.3	16.4
Inowrocław	5057	1494	29.6	2015	39.8	1083	21.5	291	5.7	174	3.4	17.2
Lipno	5766	1727	29.9	2903	50.4	896	15.5	188	3.3	52	0.9	10.5
Mogilno	2703	764	28.3	1059	39.2	601	22.2	194	7.2	85	3.1	17.0
Nakło	3157	990	31.4	1043	33.0	765	24.3	206	6.5	153	4.8	21.2
Radziejów	4020	1016	25.3	2018	50.2	777	19.3	158	3.9	51	1.3	12.4
Rypin	3706	1060	28.6	1931	52.1	603	16.3	93	2.5	19	0.5	10.0
Sępólno	2127	585	27.5	626	29.4	609	28.6	177	8.3	130	6.2	21.6
Świecie	5248	2319	44.2	1694	32.3	841	16.0	251	4.8	143	2.7	13.4
Toruń	4970	1850	37.2	2151	43.3	720	14.5	174	3.5	75	1.5	12.3
Tuchola	3102	1316	42.4	1009	32.5	549	17.7	153	4.9	75	2.5	13.8
Wąbrzeźno	2426	687	28.3	963	39.7	556	22.9	154	6.4	66	2.7	16.2
Włocławek	8120	2395	29.5	3920	48.3	1416	17.4	291	3.6	98	1.2	11.5
Żnin	3218	982	30.5	1005	31.2	750	23.3	311	9.6	170	5.4	20.3
Total	75651	25070	33.1	31316	41.4	13915	18.4	3610	4.8	1740	2.3	14.4

In restructuring agriculture, larger farms (15-30 ha), as well as large (30-50 ha) and farms of great area (50 and more ha) are of great importance. In respect of quantity, they occupy only 25.5%, yet with their position and the type of production they exert the decisive effect on agriculture development as a whole.

Possibilities for changing agricultural structure towards land consolidation in farms of larger areas were limited by the situation in agriculture. This is closely related to constant high unemployment, tendencies for migration from cities to the country, and the limited structure-forming functions of structural pensions, which do not liberate the sufficient amount of land supply.

Agricultural structure is the economic category which is the least prone to changes, in spite of introducing regulations concerning land joining and integration. The average number of plots in a farm is still 3.42, and the average area of one plot is only 2.28 ha. This structural fragmentation makes it difficult to introduce larger and more efficient machines, the existing boundaries and field (access) roads take up too much area, whereas work organization is hindered.

In the past, the only source of land supply having the influence on the improvement of agricultural structure in the past was the state sector in agriculture, which after restructuring lost its structural properties. However, besides the big property, the so-called public sector still exists in agriculture, including the land of research and experimental units, schools, hospitals, prisons etc. The state exercises ownership over a part of former landed estates, which perform their public functions for the sake of all the society.

The current agricultural structure of the farms on the province highly differs not only from the average in the European Union but also from the modern model we should aim for. Although this model was not clearly defined, we can get indirectly information concerning its shape from the act on the development of agrarian system of 2003. According to the act, a farm that is run by a private farmer and in which the total area of agricultural acreage is not more than 300 ha is referred to as a family farm.

A private farmer, in turn, is thought to be a natural person who personally runs a farm, possesses agricultural qualifications and lives in the area of the commune in which one of the fixed properties is located. Requirements for agricultural qualifications are met if a person has received at least vocational or higher agricultural education or she has personally managed a farm for a period of at least 5 years (Journal of Laws No. 64, item 592 of 2003).

Changes in agricultural structure are among the most essential processes agriculture transformation. The pace of land concentration will depend on the supply of agricultural land which, in turn, arises as a result of implementing programs contained in plans for development of rural areas; for instance, action was taken connected with structural pensions, the forestation of arable land, or farm and environment programs. Within the framework of Rural Development Program (RDP) structural pensions, realized in the years 2004-2006, totally 480.7 thousand ha of agricultural acreage, including 261.8 thousand ha were made over for enlarging other farms and 218.9 thousand ha were made over for successors. Respectively, in Kuyavian-Pomeranian Province 46.1 thousand ha farm land were made over, including 27.3 thousand ha made over for enlarging other farms and 18.8 thousand ha farm land made over for successors. The importance of structural pensions for accelerating the process of land concentration is to some extend weakened by the possibility of making over the land to natural successors contained in this procedure.

The other source of land, which can enrich the agricultural system, is the grounds of the agricultural resources of the State Treasury, which remain on lease (about 3 million ha on a scale of the country). In this connection, a part of those lands will be subjected to further restructuring, which on one hand must take into account the aspiration of most leaseholder to purchase those fixed properties, and on the other, the need to the further support of the process of enlarging private farms in regions where they can be offered the arable land of the State Treasury. Kuyavian-Pomeranian Province, which is characterizes by a high content of farms of a great area, is one of such regions.

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CHANGES OF AIR TEMPERATURE IN BYDGOSZCZ AREA OVER THE 60-YEAR PERIOD 1949-2008

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Long-term series of measurements of meteorological elements are of primary importance in research on valuation and expected changes in the agroclimate of the whole Poland and its particular regions. Air temperature plays a special role in this research, since its variability affects conditions of plant growth, development and yielding, and constitutes an important indication of climatic risk of their cultivation. Air temperature is the primary meteorological element, which constitutes the base for determination of many indexes characterizing climatic determinants of agricultural production of a given region.

The research carried out so far, concerning the whole country and the regions, indicate the upward tendencies of air temperature in periods covering the second half or the last decades of the 20th century. According to Fortuniak et al. (2001), warming took place in Poland over the second half of the 20th century, which is expressed by an increase of mean annual temperature value by 0.9°C. Prevailing part of this warming fell on the 80s and 90s. According to most authors, these results are in accordance with observations from other countries and lead to the general conclusion that climate is warming both on a global and regional scale (Kożuchowski and Żmudzka 2001; Musiał et al. 2004; Michalska and Kalbarczyk 2005; Zawora 2005; Jędrys and Leśny 2007). According to Boryczka and Stopa-Boryczka (2007), climate warming over the 19th-20th centuries was caused by an increase of Sun activity, a decrease in volcanic activity on Earth and the growing greenhouse effect of the atmosphere.

Most scenarios of climatic changes assume the further increase of air temperature in Poland in the 21st century. For example, according to the climatic forecast derived from the model HadCM2(GS), mean annual air temperature until the middle of the 21st century will grow by 1.4°C, and the mean temperature in winter by as much as 3.3°C (Fortuniak et al. 2001). According to studies by Boryczka and Stopa-Boryczka (2007) resultants from superimposing of air temperature cycles detected in chronological sequences of measurements results indicate that the most frosty winters in Warsaw with a mean temperature of -4 to -7°C will occur about 2050, and cool years in the two first decades of the 21st century.

Previous studies concerning estimation of thermal conditions of agricultural production in the Bydgoszcz area (Żarski et al. 2001, 2004, 2007) have indicated mostly

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a high temporal variation of different agrometeorological indexes calculated on the basis of measurements of air temperature. It has been stated that the times of the beginning and end as well as durations of agricultural periods did not show significant trends towards changing over 1971-2000 (Żarski et al. 2004). Research on extreme temperatures, in turn, indicated that the mean maximal air temperature during the years 1971-2005 was characterized by an increase and the mean minimal temperature by a decrease with time. However, equations of linear trends were significant only at few time intervals (Żarski et al. 2007).

The aim of this study was to present the courses of mean monthly and yearly values of air temperature in the Bydgoszcz area with special attention paid to their tendencies over 1949-2008. Due to the problem of warming of Poland's climate, which has been widely raised and lively discussed, particularly in recent years, air temperature characteristics in the whole 60-year research period (1949-2008) and the recent 15-year period (1994-2008) were also compared.

Materials and methods

Continuous sequences of mean air temperature from 1949-2008 were analyzed in this study. The measurements were made in standard way, according to the procedures of State Hydrological and Meteorological Institute – Institute of Meteorology and Water Management (PIHM-IMGW), at the Experimental Station in Mochełek, the University of Technology and Life Sciences in Bydgoszcz, situated about 20 km from Bydgoszcz, at the south-east edge of Wysoczyzna Krajeńska. Agrometeorological measurement point in Mochełek (φ = 53°13', λ = 17°51', h = 98.5 m ASL) has been working constantly since 1949. It is worthy of note that the procedure of calculating the mean daily air temperature has changed three times during the tested 60-year period. Initially (until 1970), according to the binding methodology, the measurement of air temperature made at 9 p.m. by means of a common thermometer was considered. Then, the night temperature value read from a thermograph was taken into account, and in recent years (since 1996), it has been calculated as the arithmetic mean of values measured at the morning and evening times and the maximal and minimal temperatures.

Characteristics, statistical methods and ways of presenting the results that are commonly applied in agroclimatology were used in this study. The method of trends, with the use of linear regression equations, was particularly useful with reference to 60-year measurement period (Garnier 1996; Kossowska-Cezak et al. 2000). The frequency of occurrence of normal, warm, cool and cold months and years was worked out according to the method proposed by Lorenc (2000). The method involves relating the difference in air temperature between the value in a given month or year and the right long-term mean value to the standard deviation.

Results and discussion

Mean long-term yearly air temperature in the Bydgoszcz area in the period 1949--2008 was 7.8°C (Table 1). The yearly course was typical of the temperate and transitional climate of Poland, which is characterized on average by the lowest air temperature in January (a mean of -2.2°C), and the highest in July (a mean of 18.0°C). Air temperatures at all the analyzed time intervals were characterized by a very high time variability. The highest mean yearly temperature was recorded in 1989 (9.6°C), and the lowest in 1956 (6.0°C). The highest mean monthly temperature in the analyzed 60-year period was 22.7°C (July 1994), and the lowest amounted to -11.4°C (January 1987). Higher time variability occurred in temperatures of winter months, particularly February and January, while the lowest – in those of June, August, September and October. The highest and lowest mean air temperatures of the long-term period occurred quite evenly in all the decades. In the last fifteen years (1994-2008), accounting for 25% of the tested long-term period, 6 such cases were recorded (23%).

Table 1. Air temperature in Bydgoszcz area (1949-2008) [°C]

Month	Mean air temperature			Difference	Standard deviation
	Long-term mean	Highest in long-term period	Lowest in long-term period		
January	-2.2	3.4 (1983)	-11.4 (1987)	14.8	3.2
February	-1.5	4.9 (1990)	-10.2 (1956)	15.1	3.3
March	1.9	6.4 (1990)	-2.6 (1964)	9.0	2.4
April	7.3	**11.0 (2000)**	4.1 (1956)	6.9	1.5
May	12.8	17.3 (1993)	9.6 (1965, 1980, 1991)	7.7	1.7
June	16.3	19.5 (1979)	14.0 (1985)	5.5	1.3
July	18.0	**22.7 (1994)**	15.1 (1974)	7.6	1.7
August	17.4	20.9 (1992)	14.3 (1956)	6.6	1.3
September	13.2	16.9 (1975)	**10.4 (1996)**	6.5	1.3
October	8.2	**10.8 (2000)**	**4.7 (2003)**	6.1	1.3
November	3.0	6.0 (1963)	-2.0 (1993)	8.0	1.7
December	-0.5	**3.7 (2006)**	-8.4 (1969)	12.1	2.4
January – December	7.8	9.6 (1989)	6.0 (1956)	3.6	0.9

As compared with the whole period 1949-2008, mean yearly air temperature in the recent 15-year period 1994-2008 was higher by 0.3°C. Seven months were warmer (February – by 0.9°C, July – by 0.8°C, January, April and August – by 0.6°C, May by 0.3°C and March by 0.2°C), the mean temperature of June was the same, whereas months from October to December were colder by 0.1-0.2°C in the years 1994-2008 than in the long-term period 1949-2008 (Fig. 1).

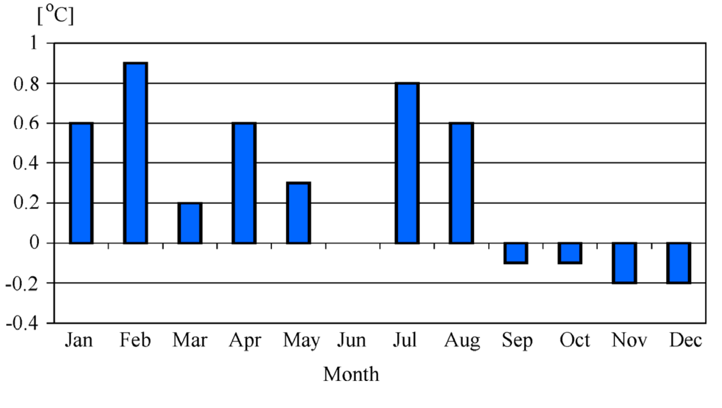

Fig. 1. Differences in mean monthly temperatures in 15-year period 1994-2008 as compared with 60-year period 1949-2008

A very high temporal variation of thermal conditions in particular years, and especially in particular months of the successive years, has been proved by the analysis of their count, involving 11 classes, from extremely warm to extremely cold periods (Table 2). The analysis indicates that years or months with normal thermal conditions close to average occur in 30-48% of the whole long-term period. The air temperatures were the most often similar to the average in June (29 cases) and November (28 cases), and the least often in March (18 cases) and in July (19 cases out of 60 analyzed). Anomalous and extreme periods occurred 26 times, which accounted for 3.3% as compared with the classified 780 (60 years x 13 periods). Of those periods, the count was higher in extremely and anomalously cold periods (17 cases), and lower – in warm periods (9 cases). In the last fifteen years (25% of the long-term period tested), a total of 7 periods with extreme or anomalous thermal conditions were recorded, which accounts for 27% of all such events. Thus it cannot be stated that in recent years in the Bydgoszcz area thermal extremes have occurred more frequently than usual.

Table 2. Count of months and years with different thermal conditions in the long-term period 1949-2008 (including 15-year period 1994-2008) according to classification by Lorenc (2000); EC – extremely warm, AC – anomalously warm, BC – very warm, C – warm, UC – moderately warm, N – normal (typical), UCH – moderately cool, CH – cool, Z – cold, AZ – anomalously cold, EZ – extremely cold

Month	EC	AC	BC	C	UC	N	UCH	CH	Z	AZ	EZ
January	0	0	3(1)	4(1)	14(5)	23(4)	6(2)	6(1)	2(1)	0	2(0)
February	0	0	2(0)	8(5)	8(1)	25(6)	8(1)	3(1)	3(1)	2(0)	1(0)
March	0	0	2(0)	9(1)	11(4)	18(7)	7(1)	7(1)	6(1)	0	0
April	1(1)	0	1(0)	7(2)	9(3)	25(7)	9(1)	3(0)	3(1)	2(0)	0
May	1(0)	0	1(1)	7(1)	10(3)	25(8)	5(2)	5(0)	6(0)	0	0
June	1(0)	1(0)	2(1)	8(2)	2(0)	29(9)	4(0)	8(2)	5(1)	0	0
July	2(2)	0	1(1)	5(1)	13(5)	19(2)	11(2)	5(1)	4(1)	0	0
August	1(0)	0	3(3)	6(1)	6(2)	24(6)	12(2)	7(1)	1(0)	1(0)	0
September	1(0)	0	5(2)	3(1)	9(1)	24(6)	6(2)	9(2)	2(0)	1(1)	0
October	0	0	6(2)	3(2)	9(1)	25(4)	6(3)	7(1)	2(1)	1(0)	1(1)
November	0	0	1(0)	8(2)	10(3)	28(7)	4(0)	5(2)	1(0)	0	3(1)
December	0	0	1(1)	6(0)	14(5)	25(4)	3(1)	4(1)	5(2)	1(1)	1(0)
January – December	0	1(0)	3(0)	4(3)	9(4)	26(7)	6(0)	4(0)	6(1)	1(0)	0

According to statistical calculations made concerning trends towards changes, in the years 1949-2008 the mean air temperature in the vicinity of Bydgoszcz in the majority of the tested time intervals was characterized by an increase with time (Table 3). However, equations of linear trends were significant only in three cases and referred to May, August, and the whole year (Fig. 2). In the other months, the equations were insignificant. A small and insignificant decrease in mean monthly air temperature with time was recorded in September and November.

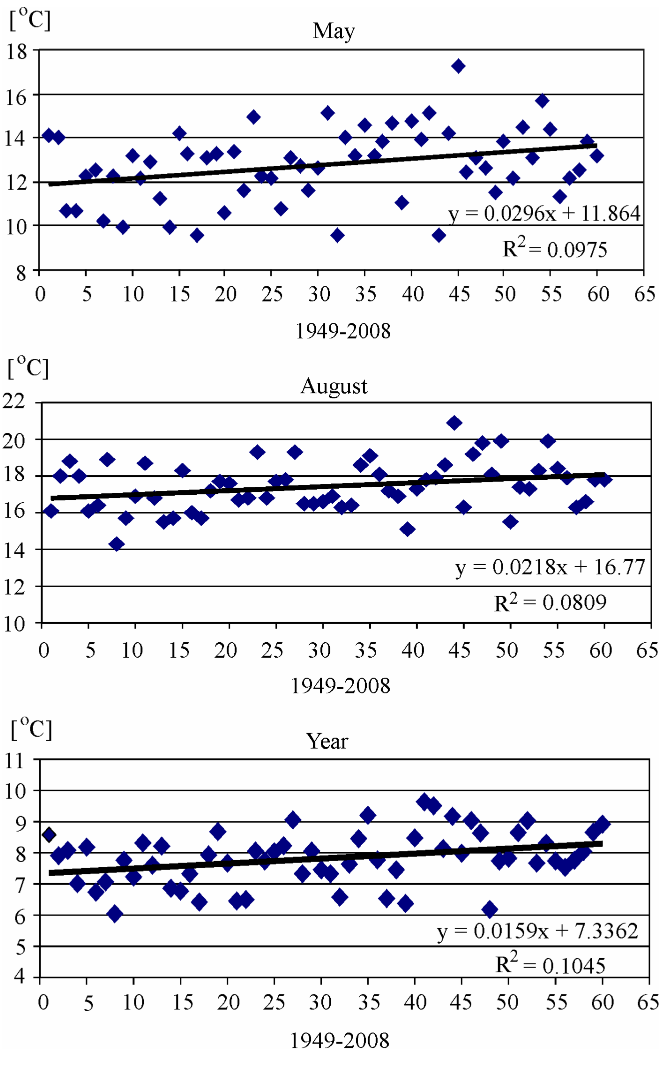

Fig. 2. Trends towards variation of air temperature in Bydgoszcz area over 1949-2008

Mean long-term yearly air temperature in successive 30-year periods from 1949--1978 to 1979-2008 increased from 7.58 to 8.07°C (Fig. 3). However, when analyzing trends towards changes in mean yearly temperature in these successive 30-year periods, it was stated that they were significant only in relation to long-term periods 1954-1983, 1962-1991, 1963-1992, and 1965-1994. This leads us to the conclusion that the main reason for the growth in mean yearly temperature observed was the occurrence of a series of six warmer years in the period from 1989 to 1994, particularly 1989, 1990, 1992 and 1994. During those years, the mean yearly temperature amounted to 9.34°C, and thus it was higher by about 20% than the normal value for the whole 60-year period (7.82°C).

Table 3. Trend equations of mean air temperature in Bydgoszcz area (1949-2008)

Month	Trend equation	Determination index	Increase in temperature °C/10 years
January	Y = 0.0301x – 3.136	0.0266	0.30
February	Y = 0.0369x – 2.594	0.0384	0.37
March	Y = 0.0328x + 0.867	0.0585	0.33
April	Y = 0.0188x + 6.749	0.0504	0.19
May	**Y = 0.0296x + 11.864**	**0.0975x**	**0.30**
June	Y = 0.0025x + 16.185	0.0011	0.02
July	Y = 0.0250x + 17.208	0.0627	0.25
August	**Y = 0.0218x + 16.770**	**0.0809x**	**0.22**
September	Y = -0.0035x + 13.268	0.0021	-0.03
October	Y = 0.0004x + 8.201	0.0001	0.00
November	Y = -0.0085x + 3.306	0.0073	-0.08
December	Y = 0.0055x – 0.652	0.0015	0.05
January – December	**Y = 0.0159x + 7.336**	**0.1045x**	**0.16**

x – significant trend p = 0.05

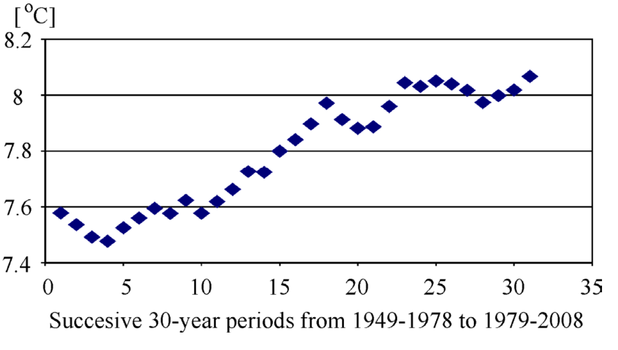

Fig. 3. Changes in mean long-term yearly air temperature in successive 30-year periods from 1949-1978 to 1979-2008

Conclusions

1. Presented results characterizing variation of mean air temperature in Mochełek can be regarded as representative for the Bydgoszcz area.
2. Mean air temperature in the Bydgoszcz area was characterized by a very high temporal variation, typical of the temperate and transitional climate of Poland, particularly in the winter months.
3. Over 1949-2008, mean air temperature in the vicinity of Bydgoszcz in 3 of 13 time steps analyzed (May, August, and the whole year) was characterized by an increase with time. This mostly resulted from the occurrence of a series of warmer years 1989-1994, when air temperature was higher by about 20% than average conditions.
4. Statement about the climate warming in the vicinity of Bydgoszcz should be treated with great caution due to different equations of linear trends with predominance of insignificant equations and the reported lack of a higher frequency of periods with anomalous and extreme thermal conditions in the last fifteen years.

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TECHNOLOGICAL REQUIREMENTS FOR DEVELOPMENT OF AGRICULTURAL PRODUCTION AND OF RURAL AREAS IN THE KUYAVIAN-POMERANIAN PROVINCE

SELECTED ELEMENTS OF TECHNOLOGY OF WINTER RAPE CULTIVATION IN THE KUYAVIAN-POMERANIAN REGION

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The quality of agricultural production space and the conditions of plant production in the field in the Kuyavian-Pomeranian Province are better than on average in Poland, but they differ across the territories (Rudnicki and Skinder 2001). The soil quality differs specially (Stuczyński et al. 2000). The specific conditions of the agroclimate of the region are: low total annual precipitation, semi-drought periods, and high air temperature (Lorenc 2005). The natural conditions and the social and economic development of the region affect the character of the agricultural production. The field plant production is dominated by cereals. Their share in the crop structure in 2008 accounted for 67.9% and it was lower than the country's average; hence an increased share of other crops in the crop structure, including winter rape. In the last decade in Poland and in other countries, the interest in growing of this crop has been increasing, mainly due to the demand for seeds. In 2007 the rape acreage in the country was 797,000 ha, which accounted for about 7.0% of the sown area. Rape and turnip-like rape in the Kuyavian-Pomeranian Province, at the same time, was grown on 104,000 ha, which accounted for 11.4% of the sown area (http://www.stat.gov.pl/).

The attractiveness of rape growing comes from the seed price, crop-rotation qualities and development of agrotechnical practises, which makes the cultivation of this crop less risky and more economically attractive (Rosiak 2005). At the same time intensive breeding research and research into the cultivation technology of this species have been continued. The breeding and agrotechnical progress has resulted not only in an increase in the yield and its quality but also in the potential of growing rape in variable and regionally-specific habitat and economic conditions (Faber 2002; Wielebski et al. 2002; Bartkowiak-Broda et al. 2005; Budzyński et al. 2005).

Materials and methods

Over 2005-2008 there were carried out 7 multiple field experiments which aimed at enhancing some elements of agrotechnical practises of winter rape under the habitat conditions of the Kuyavian-Pomeranian region. The aim of the present research was to compare the yielding of winter rape cultivars in this region and to determine the effect of selected elements of agrotechnical practises on the seed yield of this crop. The

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research investigated the yield-forming effect of single-grain sowing, seeding rate and the plant density, sulphur fertilisation and foliar application of macro- and microelements.

The experiments were located at the Experimental Station of the Faculty of Agriculture at Mochełek, the University of Technology and Life Sciences in Bydgoszcz and on four farms located in the Kuyavian-Pomeranian region and co-operating with the Department of Plant Production and Experimenting. The present results were statistically verified (using an analysis of variance, Tuckey's test) by verifying the hypothesis of a varied yielding of cultivars and the significant dependence of the seed yield on the level of the elements of agrotechnical practises researched.

The many-year research carried out by COBORU show that hybrid cultivars yield a few, or even a dozen or so percent higher than population cultivars (COBORU 2008). A high potential of yielding of hybrid cultivars is also highlighted by other authors (Bartkowiak-Broda 1998). A comparison over the years 2006-2008 which involved yielding in the Kuyavian-Pomeranian Province of 38-40 winter rape cultivars entered into the domestic register as well into the Community Catalogue of Cultivars of Agricultural Crops demonstrated a variation in the seed yield both depending on the cultivars and in the research years (Table 1). Over 2006 and 2007 two of the three highest-yielding cultivars were the restored hybrids, and in 2008 three population cultivars. The average yield of hybrid cultivars, depending on the year, was 1.7-6.6% higher that the yield of population cultivars.

Table 1. Seed yield of the winter rape cultivars tested; ^{P} – population cultivar, ^{M} – hybrid cultivar

Characteristics	Year		
	2006	2007	2008
Number of the cultivars tested, in the	41	39	38
population cultivars	27	24	21
hybrid cultivars	14	15	17
Seed yield [t·ha^{-1}]			
mean for cultivars – standard	4.05	4.74	5.28
population cultivars	3.96	4.68	5.24
hybrid cultivars	4.22	4.79	5.33
Number of cultivars yielding			
100% of the standard	21	19	23
105% of the standard	7	5	14
Highest-yielding cultivars	Elektra^{M} Cabriolet^{P} Herkules^{M}	PR46W10^{M} Cabestan^{P} Herkules^{M}	Catalina^{P} Casoar^{P} Castille^{P}

The element which is significant and dependent on habitat and agrotechnical conditions, developing the rape plant, as the field and the yield is the plant density (Wielebski and Wójtowicz 2001). In the experiments performed in the Kuyavian--Pomeranian Province on the good rye complex soil, the winter rape seed yields of the autumn plant density of 50, 75 and 100 plants per m^2 did not differ considerably, although the yield of the plants growing at the density of 100 no·m^{-2} was 3.4% higher than that of the plants at the density of 50 no·m^{-2} (Fig. 1). Only the rape at the density of 25 plants per m^2 yielded significantly lower. Its yield was 0.31 t·ha^{-1}, 11.3%, lower than the yield of rape growing at the plant density of 100 no·m^{-2}. Malarz et al. (2006), performing research in the Lower Silesia did not identify a significant effect of the plant density between 40 and 80 plants per m^2 on the winter rape seed yield.

Winter rape grown in the Kuyavian-Pomeranian region on wheat complex soils sown at the lower density yielded higher than that grown at a high density. The rape plant density of the seeding rate of 3 $kg \cdot ha^{-1}$ was in autumn, on average for 3 years and three farms, 44 $no \cdot m^{-2}$, and at the rate of 5 $kg \cdot ha^{-1}$ – 81 $no \cdot m^{-2}$. The seed yield at the seeding rate of 3 $kg \cdot ha^{-1}$ was 5.5% higher than at the higher density sowing (Fig. 2).

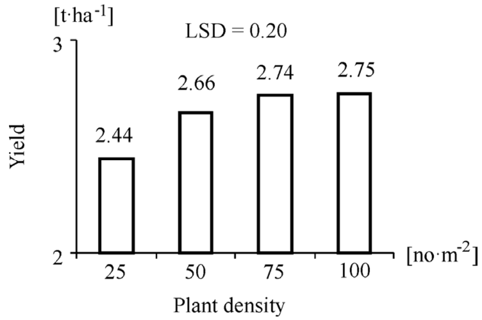

Fig. 1. Winter rape seed yield depending on the plant density

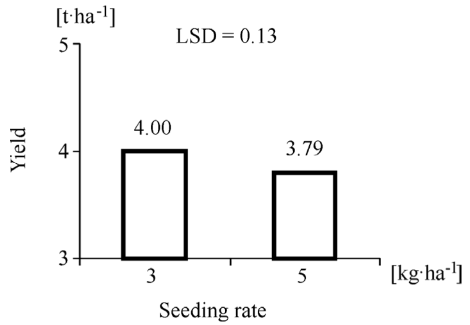

Fig. 2. Winter rape seed yield depending on the seeding rate

The research into the agrotechnical practises of winter rape carried out in the Kuyavian-Pomeranian region support a favourable effect of an evenly-distributed, single-grain sowing distribution of plants in the row on yielding. This sowing method has been more and more frequently applied in the technology of growing crops in the field not only in reference to the species which traditionally involved precision drilling (to stand), including sugar beet, maize and vegetables, but also to the plants which so far has not involved precision drilling, e.g. legumes (Podleśny 2005) or rape (Griepentrag 1996).

In the present research the rape yield sown in rows at the row spacing of 20.0 cm and the plant density of 60 $no \cdot m^{-2}$ and the plants which occur in the rows individually was 5.9% higher than the rape yield with the plants distributed two per row and 10.9% higher than the variant with 3 plant-clusters evenly spaced in the row (Fig. 3).

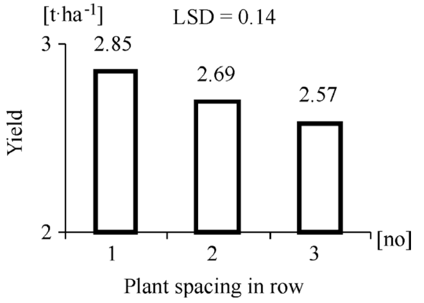

Fig. 3. Effect of plant spacing in the row on the winter rape seed yield

Of the agrotechnical factors, it is macro- and microelements fertilisation which has a considerable effect on the winter rape yield. The requirements and the effectiveness of fertilising crops with boron are high (Wróbel and Sienkiewicz-Cholewa 2003). The fertilisation with this microelement has a special effect on Brassicaceae plants, including winter rape (Sienkiewicz-Cholewa 2005). Winter rape grown in the Kuyavian-Pomeranian region and exposed to foliar application of boron as well as treated with the fertiliser with combined micro- and macroelements yielded higher than unfertilised rape (Figs 4 and 5). Symfonia B fertiliser, containing 20% of B in a form of polyboranes, applied in spring following the restored vegetation and at the stage of green compact bud at a combined dose of 1 or 2 kg·ha^{-1} resulted in an increase in the seed yield by about 4.0% (Fig. 4). The effect of Sonata makro fertilisers, of the average composition of N – 10%, P_2O_5 – 28%, K_2O – 21.5%, MgO – 2%, B – 0.015%, Cu – 0.025%, Fe – 0.075%, Mn – 0.035%, Zn – 0.025%, Mo – 0.001%, applied three times over the spring vegetation of winter rape, was even higher than that in the case of Symfonia B fertiliser. The foliar application of 9 kg of the fertiliser per ha increased the seed yield by 7.5%, and 15 kg·ha^{-1} by 11.2% (Fig. 5).

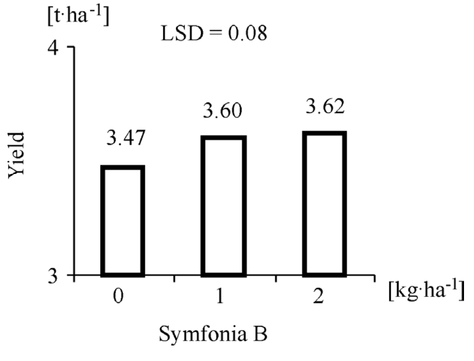

Fig. 4. Effect of Symfonia B fertiliser on the winter rape seed yield

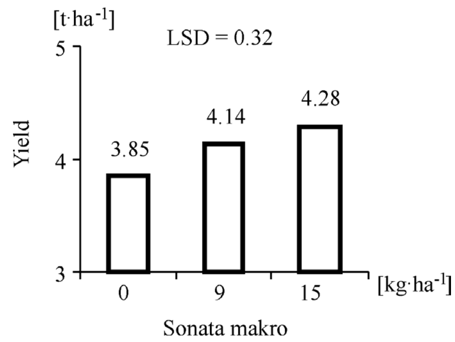

Fig. 5. Effect of Sonata makro fertilizer on the yield of winter rape seeds

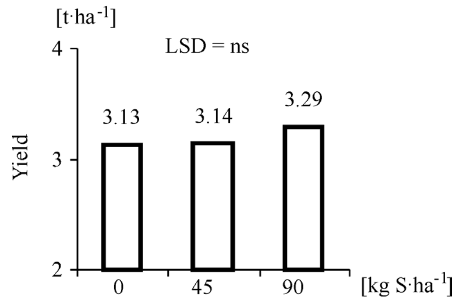

Fig. 6. Effect of sulphur fertilization on the winter rape seed yield

However, there was no significant effect of sulphur fertilisation on the winter rape seed yield (Fig. 6), even though the results reported in literature point to its favourable effect on the growth and yielding of Brassicaceae plants (Wielebski and Muśnicki 1998), especially under a limited availability of sulphur in soil (Wielebski 2006). Despite a low content of sulphate sulphur in soil on three farms in the Kuyavian-Pomeranian region covered by the experiment, from 8.8 to 14.1 mg $S_{SO4}\cdot kg^{-1}$ of soil – elemental sulphur applied at the dose of 90 kg $S\cdot ha^{-1}$ increased the seed yield only by 4.3%, which was statistically non-significant.

The present results demonstrate that the agrotechnical practises for winter rape in the Kuyavian-Pomeranian region should be similar to the commonly applied technology of cultivating this crop in the country. The advantage of hybrid cultivars in yielding over the population cultivars is smaller than it would seem from the reports by the Research Centre for Cultivar Testing (COBORU 2008), which can result from growing winter rape on poorer soils and from low precipitation in the region. Hybrid cultivars, to reveal its genetic potential must also have favourable habitat and agrotechnical conditions. In the Kuyavian-Pomeranian region it is favourable to provide foliar fertilisation of rape with boron and the application of macro- and microelement fertiliser. This treatment can increase the seed yield even by about 10%, while the effect of sulphur fertilisation on rape yielding is not high, even though with its low content in soil it can increase the seed yield by a few percent. Neither is high density sowing, as a result of which the plant density in autumn is over 50-75 plants$\cdot m^{-2}$, justifiable. With the soils of good wheat complexes it is possible to decrease the sowing rate to 3 kg of seeds per ha, whereas even distribution of plants in the row is favourable. As for the single-grain sowing, the seed yield can be even almost 10% higher than the yield of plants irregular in the row, and even in the clusters, including a few in the spot.

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EFFECTIVENESS OF FOLIAR FERTILISATION OF CROPS GROWN IN THE KUYAVIAN-POMERANIAN PROVINCE

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Fertilisation is the basic yield-forming element of agrotechnical practise but, at the same time, the energy-consuming input and the main cost component of plant production technology (Budzyński et al. 1995; Jankowski and Budzyński 2000). The effectiveness of fertiliser application in the field plant production depends on many natural and economic factors, e.g. on the application method (Kamionka 2008). In modern technologies of cultivation of field crops, both agricultural crops (Czuba 1993; Koziara 2004) and vegetables (Rożek et al. 2000; Sady 2000), increasing the production and cost-effectiveness of fertilisation in foliar application of fertilisers. It allows for supplying the plants with macro-, and especially with microelements over the periods of intensified requirements and their uptake from the soil solution being more difficult. The use of fertiliser nutrients in a form of foliar application and their effectiveness are many-fold higher than if applied into soil (Wałkowski 2002). The effectiveness of this fertilisation method can be increased also by a combined application of solutions of fertilisers with plant protection agents (Wróbel and Domaradzki 2006; Brzozowska et al. 2008).

Materials and methods

Over 2006-2008 on 5 farms in the Kuyavian-Pomeranian region, cooperating with the Department of Plant Production and Experimenting, the University of Technology and Life Sciences in Bydgoszcz, there was carried a series of field experiments which involved fertilisation and foliar application of fertilisers to crops. The aim of the present research was to determine the production- and cost-effectiveness of foliar application of fertilisers of different chemical composition and applied at different doses in growing of 11 agricultural plant species and field vegetables.

On production plantations plots were separated, following the field experiment methodology, where under controlled conditions, the following were applied, depending on the research location, water solutions of: urea – 46% N (a single treatment of 15 kg of the fertiliser per ha, and two treatments 15 kg·ha^{-1}); Symfonia B fertiliser containing 20% of boron (two treatments at the dose of: 0.5 and 1.0 kg·ha^{-1} each); fluid fertiliser PK – 38% P_2O_5, 43% K_2O (three treatments at the dose of 3 and 5 dm^3·ha^{-1} each) and

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Sonata makro fertiliser of the following composition: N – 10%, P_2O_5 – 28%, K_2O – 21.5%, MgO – 2%, B – 0.015%, Cu – 0.025%, Fe – 0.075%, Mn – 0.035%, Zn – 0.025%, Mo – 0.001% (three treatments at the dose of 3 and 5 kg·ha^{-1} each).

The production effect of the foliar fertiliser application has been determined as a difference between the yields of crops fertilised and non-fertilised following the formula: $\Delta P = Pn - Po$, where: ΔP – yield difference [t·ha^{-1}], Pn – fertilised plant yield [t·ha^{-1}], Po – non-fertilised plant yield [t·ha^{-1}]. The economic effect was verified according to the applicable variants: not factoring in the costs borne, fertiliser costs, the costs of fertiliser and its application, the costs of fuel and fertiliser, and the costs of plantation fertiliser application services. The calculations (in Polish zloty; PLN) were made according to the algorithm $\Delta W = (Wn - Wo) - K$, where: ΔW – value in the yield difference [PLN·ha^{-1}], Wn – of the fertilised plants yield value [PLN·ha^{-1}], Wo – non-fertilised plant yield value [PLN·ha^{-1}], K – the cost of variants: no costs, fertiliser, fertiliser and fuel, fertiliser and services [PLN·ha^{-1}].

The production effectiveness (Ep) and cost-effectiveness (Ee) of foliar fertiliser application was calculated according to the respective formula: $Ep = \Delta P / D$ and $Ee = (Wn - Wo) / K$, where: ΔP – yield difference [kg·ha^{-1}], D – fertiliser dose [kg·ha^{-1}], Wn – fertilised plant yield value [PLN·ha^{-1}], Wo – non-fertilised plant yield value [PLN·ha^{-1}], K – the cost of variants: fertiliser, fertiliser and fuel, fertiliser and services [PLN·ha^{-1}].

With the prices, variable in time and from territory to territory, of crops, production means and services, the present research assumed their average values for the period and region analyzed.

Results and discussion

The results of the present research show that the production and economic effects of foliar fertilisation of plants with urea solution were, in general, favourable, however, depending on the crop species and the fertiliser dose. This treatment increased the yields from 0.08 t of maize grain to 1.86 t of carrot root per hectare (Table 1), and the productivity of 1 kg of urea applied in that way ranged from 2.7 to 124 kg of the yield and for all the crops it was higher at a lower fertiliser dose (Table 2). As a result of foliar application of urea solution, the highest value of the yield increase and the economic effectiveness of the inputs borne were recorded for broccoli (a vegetable grown in the field) and winter rape (an agricultural crop). Even considering the services costs, not only the fertiliser costs, the economic effect for broccoli and winter rape was 488-573 and 182-264 PLN·ha^{-1}, respectively. The cost-effectiveness was, however, depending on the cost components, 30.33-9.41 PLN for broccoli and 13.33-4.14 PLN for winter rape (Tables 1 and 2). The yield of onion fertilised twice over its vegetation period with area solution was the only one which was 0.12 t·ha^{-1} lower than the non-fertilised crops. The lower yield resulted in a deteriorated economic effect, considering different cost components, even by 176 PLN·ha^{-1}. Similarly, fertilizing maize twice was also economically unjustified, especially when considering the costs of fuel and services. In onion growing a higher dose of urea was ineffective (Table 2).

Table 1. Production- and cost-effectiveness of foliar application of urea solution

Crop	Urea dose [kg·ha^{-1}]	Yield difference [t·ha^{-1}]	Value of the yield difference for cost components [PLN·ha^{-1}]			
			without fertiliser	fertiliser	fertiliser + fuel	fertiliser + services
Winter wheat	15	0.26	143	125	115	85
	30	0.35	193	157	137	77
Maize	15	0.15	75	57	47	17
	30	0.08	40	4	-16	-76
Winter rape	15	0.24	240	222	212	182
	30	0.38	380	344	324	264
Sugar beet	15	1.28	154	136	126	96
	30	1.11	133	97	77	17
Onion	15	1.03	515	497	487	457
	30	-0.12	-60	-96	-116	-176
Broccoli	15	0.42	546	528	518	488
	30	0.53	689	653	633	573
Carrot	15	1.86	465	447	437	407
	30	1.22	305	269	249	189

Table 2. Production- (Ep) and cost-effectiveness (Ee) of foliar application of urea solution

Crop	Urea dose [kg·ha^{-1}]	Production effectiveness (Ep)	Cost-effectiveness for cost components (Ee)		
			fertiliser	fertiliser + fuel	fertiliser + services
Winter wheat	15	17.3	7.94	5.11	2.47
	30	11.7	5.36	3.45	1.66
Maize	15	10.0	4.17	2.68	1.29
	30	2.7	1.11	0.71	0.34
Winter rape	15	16.0	13.33	8.57	4.14
	30	12.7	10.56	6.79	3.28
Sugar beet	15	85.3	8.56	5.50	2.66
	30	37.0	3.69	2.38	1.15
Onion	15	68.7	28.61	18.39	8.88
	30	-4.0	-1.67	-1.07	-0.51
Broccoli	15	28.0	30.33	19.50	9.41
	30	17.7	19.14	12.30	5.94
Carrot	15	124.0	25.83	16.61	8.02
	30	40.7	8.47	5.45	2.63

The foliar application of fluid fertiliser PK in growing four agricultural crops produced, except for maize and sugar beet – 15 dm^3·ha^{-1}, resulted in a lower production effect than the urea solution application, although it was economically justified even when factoring in the costs of fuel for the treatments (Table 3). The production- and cost-effectiveness of treating winter wheat and maize with PK fertiliser were higher at its lower dose. In winter rape and sugar beet growing, an increase in the yield as an effect of the application of 1 dm^3·ha^{-1} of fertiliser at the dose of 15 dm^3·ha^{-1} was higher than at the dose of 9 dm^3·ha^{-1}; similarly, the relationships between the cost-effectiveness of the foliar application of PK fertiliser depending on its dose (Table 4).

Table 3. Production- and cost-effectiveness of foliar application of fluid PK fertiliser

Crop	Fertiliser dose [$dm^3 \cdot ha^{-1}$]	Yield difference [$t \cdot ha^{-1}$]	Value of the yield difference for cost components [$PLN \cdot ha^{-1}$]			
			without fertiliser	fertiliser	fertiliser + fuel	fertiliser + services
Winter wheat	9	0.11	61	34	4	-86
	15	0.14	77	32	2	-88
Maize	9	0.19	95	68	38	-52
	15	0.15	75	30	0	-90
Winter rape	9	0.06	60	33	3	-87
	15	0.11	110	65	35	-55
Sugar beet	9	0.66	79	52	22	-68
	15	1.40	168	23	93	3

Table 4. Production- (Ep) and cost-effectiveness (Ee) of foliar application of fluid PK fertilizer

Crop	Fertiliser dose [$dm^3 \cdot ha^{-1}$]	Production- -effectiveness (Ep)	Cost-effectiveness for cost components (Ee)		
			fertiliser	fertiliser + fuel	fertiliser + services
Winter wheat	9	12.2	2.26	1.07	0.41
	15	9.3	1.71	1.03	0.47
Maize	9	21.1	3.52	1.67	0.65
	15	10.0	1.67	1.00	0.45
Winter rape	9	6.7	2.22	1.05	0.41
	15	7.3	2.44	1.47	0.67
Sugar beet	9	73.3	2.93	1.39	0.54
	15	93.3	3.73	2.24	1.02

The application of fertiliser containing boron was production- and economically-justified, even having factored in the foliar application services costs. An increase in the yield of all the crop species as well as the value of this increase were higher following the application of 2 kg of fertiliser per ha, despite higher costs, than 1 $kg \cdot ha^{-1}$ (Table 5). The production effectiveness of 1 kg of Symfonia B was, however, higher after the application of the lower dose (Table 6). The value of the increase in the yield per 1 PLN of the costs of foliar application of fertiliser containing boron differed and ranged, depending on the crop, the dose of the fertiliser, and cost components, from 1.48 to 54.00 PLN.

Table 5. Production- and cost-effectiveness of foliar application of Symfonia B fertiliser

Crop	Fertiliser dose [$kg \cdot ha^{-1}$]	Yield difference [$t \cdot ha^{-1}$]	Value of the yield difference for cost components [$PLN \cdot ha^{-1}$]			
			without fertiliser	fertiliser	fertiliser + fuel	fertiliser + services
Winter rape	1	0.13	130	122	102	42
	2	0.15	150	134	114	54
Sugar beet	1	1.32	158	150	130	70
	2	1.41	169	153	133	73
Cauliflower	1	0.48	432	424	404	344
	2	0.86	774	758	738	678
Broccoli	1	0.33	429	421	401	341
	2	0.40	520	504	484	424

Table 6. Production- (Ep) and cost-effectiveness (Ee) of foliar application of Symfonia B fertiliser

Crop	Fertiliser dose [kg·ha^{-1}]	Production-effectiveness (Ep)	Cost-effectiveness for cost components (Ee)		
			fertiliser	fertiliser + fuel	fertiliser + services
Winter rape	1	130	16.25	4.64	1.48
	2	75	9.38	4.17	1.56
Sugar beet	1	1320	19.75	5.64	1.80
	2	705	10.56	4.69	1.76
Cauliflower	1	480	54.00	15.43	4.91
	2	430	48.38	21.50	8.06
Broccoli	1	330	53.63	15.32	4.88
	2	200	32.50	14.44	5.42

The foliar application of the multi-component macro- and microelement fertiliser, Sonata makro, had a favourable effect on yielding of all the 11 fertilised agricultural crops and field vegetable species. The yield increase ranged from 0.08 t of tomato fruit to 4.38 t of carrot root per ha, and the yield increase value from 16.00 PLN·ha^{-1} for tomato to 2799 PLN·ha^{-1} for broccoli (Table 7). The favourable economic effect of the foliar application of a higher dose of Sonata makro fertiliser, having considered the cost of the fertiliser and fuel, was recorded on the plantations of almost all the crops, except for tomato, while considering the fertilisation application services costs, was justified in the cultivation of the other vegetables and winter rape.

Table 7. Production- and cost-effectiveness of foliar application of Sonata makro fertiliser

Crop	Fertiliser dose [kg·ha^{-1}]	Yield difference [t·ha^{-1}]	Value of the yield difference for cost components [PLN·ha^{-1}]			
			without fertiliser	fertiliser	fertiliser + fuel	fertiliser + services
Winter wheat	9	0.16	88	25	-5	-95
	15	0.42	231	96	66	-24
Maize	9	0.14	70	7	-23	-113
	15	0.40	200	65	35	-55
Winter rape	9	0.29	290	227	197	107
	15	0.43	430	295	265	175
Sugar beet	9	0.68	82	19	-11	-101
	15	1.71	205	70	40	-50
Tomato	9	0.08	16	-47	-77	-167
	15	0.78	156	21	-9	-99
Onion	9	0.55	275	212	182	92
	15	3.20	1600	1465	1435	1345
Cucumber	9	0.63	504	441	411	321
	15	1.15	920	785	755	665
Cauliflower	9	1.22	1098	1035	1005	915
	15	3.11	2799	2664	2634	2544
Broccoli	9	0.88	1144	1081	1051	961
	15	0.91	1183	1048	1018	928
Carrot	9	2.82	705	642	612	522
	15	4.38	1095	960	930	840
Celery	9	2.35	1175	1112	1082	992
	15	3.60	1800	1665	1635	1545

The production effectiveness of Sonata makro applied at a lower dose in growing winter rape, broccoli, carrot and celery was greater than the fertiliser applied at the dose of 15 kg·ha^{-1}. In the case of the other plants, the application of a greater fertiliser dose was most production-effective (Table 8). The most cost-effective, even considering the fertiliser application services costs, was foliar application of Sonata makro in growing field vegetables, except for tomato. Foliar application of tomato plants with Sonata makro fertiliser solution at the dose of 9 kg·ha^{-1} was cost-ineffective, and winter wheat, maize and sugar beet – little effective. The cost-effectiveness of the fertiliser itself, neither with fuel nor services costs, in foliar fertilisation of plants was below 1.5. Similarly, the foliar application of 15 kg·ha^{-1} of fertiliser in growing maize, sugar beet and tomato was also of low effectiveness.

Table 8. Production- (Ep) and cost-effectiveness (Ee) of foliar application of Sonata makro fertiliser

Crop	Fertiliser dose [kg·ha^{-1}]	Production- -effectiveness (Ep)	Cost-effectiveness for cost components (Ee)		
			fertiliser	fertiliser + fuel	fertiliser + services
Winter wheat	9	17.8	1.40	0.95	0.48
	15	28.0	7.71	1.40	0.91
Maize	9	15.6	1.11	0.75	0.38
	15	26.7	1.48	1.21	0.78
Winter rape	9	32.2	4.60	3.12	1.58
	15	28.7	3.19	2.61	1.69
Sugar beet	9	75.6	1.30	0.88	0.45
	15	114.0	1.52	1.24	0.80
Tomato	9	8.9	0.25	0.17	0.09
	15	52.0	1.16	0.95	0.61
Onion	9	61.1	4.37	2.96	1.50
	15	213.3	11.86	9.70	6.27
Cucumber	9	70.0	8.00	5.42	2.75
	15	76.7	6.81	5.58	3.61
Cauliflower	9	135.6	17.43	11.81	6.00
	15	207.3	20.73	16.96	10.98
Broccoli	9	97.8	18.16	12.30	6.25
	15	60.7	8.67	7.17	4.64
Carrot	9	313.3	11.19	12.30	6.25
	15	292.0	8.11	7.17	4.64
Celery	9	261.1	18.65	12.63	6.42
	15	240.0	13.33	10.91	7.06

The results of the many-year and multi-point field experiments carried out in the Kuyavian-Pomeranian region support the yield-forming effect of the foliar application and fertilisation of plants. The production effect defined by the yield increase and amounting to an average of a few hundred kilograms of cereal grain and winter rape seeds and a few tons of sugar beet root and root vegetables is similar to the one reported by other authors (Czuba 1996). The reported yield increase guaranteed, in general, a positive economic effect since its value exceeded the fertiliser costs and 1 PLN of these costs resulted in an increase in the yield value by a few PLN (fluid fertiliser PK). A similar or slightly greater effectiveness of foliar fertilisation of some agricultural crops with the solutions of multi-component fertilisers, including those containing microelements, was reported earlier by Jabłoński (1999) and Jaskulski (2004). The effectiveness of the fertiliser containing boron, Symfonia B, on the other hand, was many-fold higher, and 1 PLN of the cost of this fertiliser resulted in, in the cultivation of some vegetables, an increase in the yield value even by about 50 PLN. The effectiveness of the foliar fertiliser application decreased, however, when the cost calculus included fuel, and especially the treatment services. Then in many cases, it was not economically justified, which supports a combined application of agrochemicals (Pruszyński and Mrówczyński 2002).

The foliar application of fertilisers containing macro- and microelements is an agrotechnical treatment which has a favourable effect on crop yielding. Its effectiveness remains related to the increase in the yield, its value in respective plant species and fertiliser application costs. The highest effectiveness of the foliar fertiliser application occurs on the plantations of crops showing a strong reaction to the foliar fertilisation and in the species of relatively high prices of crops, including field vegetables and winter rape.

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EFFECT OF LEGUMINOUS PLANTS GROWN IN STUBBLE INTERCROP ON THE HEALTH STATUS OF STEM BASE OF SPRING WHEAT

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Bread wheat (*Triticum aestivum* ssp. *vulgare*) is a plant susceptible to infection with fungal pathogens. The spring form, due to a shorter vegetation period, is definitely less infected than the winter form, however when grown after cereal forecrops, it is frequently attacked by fungal pathogens. When exposed to a high share of cereals in crop rotation, there is mostly recorded an increase in the infection with pathogens causing take-all diseases (Gawrońska-Kulesza and Roszak 1987; Deryło 1991; Parylak and Kita 2000; Lemańczyk and Wilczewski 2008). Of them all, the greatest importance is attributed to *Gaeumannomyces graminis* as well as fungi of *Oculimacula* and *Fusarium* genera (Pląskowska 2005; Lemańczyk and Wilczewski 2008; Majchrzak et al. 2008). As a result of that infection, in general, the values of structural yielding components of that plant decrease significantly; similarly, the grain yield gets very much lower (Augustin et al. 1997; Lemańczyk et al. 2001b; Cook 2003; Majchrzak et al. 2004; Lemańczyk and Wilczewski 2006).

Due to today's low plantation area of non-cereal crops, which could naturally limit the soil population of fungi causing take-all diseases of cereals, and due to no realistic potential for enhancing the crop structure in the successive years, some replacement of the adequate forecrop for spring cereals can be offered by crops grown in stubble intercrop. Those especially valuable are leguminous plants which, once they have been ploughed-in, undergo fast decomposition and enhance the bioactivity of soil. Stachowiak et al. (2003) demonstrated high value of lupine biomass in which there was identified the presence of a group of *Bacillus* genus strains, being antagonistic towards plant pathogens. Besides, the crops grown in stubble intercrop make it possible to manage fertiliser components unused by the forecrop and limiting their leaching to ground waters (Thorup-Kristensen 1994; Berntsen et al. 2006) and to provide considerable amounts of easily-decomposable organic matter to soil (Thorup-Kristensen 1994; Parylak 1996). Under a high share of cereals in crop rotation, the use of leguminous plants grown in intercrop can increase the spring wheat yield considerably (Haymes and Lee 1999).

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The results of research on the importance of leguminous plants for the health status of spring wheat grown after them are ambiguous. In general, their effect is positive, even though, as reported by the applicable research, they can lead to the proliferation of *Fusarium* genus fungi (Bojarczuk and Bojarczuk 1988; Truszkowska et al. 1991). According to Pląskowska et al. (2002), those fungi are the main cause of stem base wilting in spring wheat.

To determine the effect of leguminous crops grown in stubble intercrop on the health status of stem base of spring wheat, a strict many-year field experiment was performed to determine the intensity of the occurrence of take-all diseases against varied-in-years weather conditions. Spring wheat was grown on light soil, under cereal crop rotation, in which spring barley was the forecrop and the fore-forecrop – winter wheat.

Materials and methods

Field experiments were performed over 2002-2005, at the Experimental Station in Mochełek (17°51'E, 53°13'N) of the Faculty of Agriculture of the University of Technology and Life Sciences in Bydgoszcz. The strict experiment was set up with the randomised split-plot method in four replications, on lessive soil, produced from heavy loamy sand, representing very good rye complex. The plot size was 24 m^2.

The first experiment factor was made up of the type of the biomass ploughed-in: A – the entire biomass produced, B – biomass of post-harvest residue. The second factor was the species of the crop in stubble intercrop: serradella cv. 'Igela' (*Ornithopus sativus*), pea cv. 'Grapis' (*Pisum sativum*), yellow lupine cv. 'Legat' (*Lupinum luteus*), and the control – without intercrop.

The research involved spring wheat cv. 'Nawra' which demonstrates resistance to take-all diseases lower-than-the-average for all those registered in Poland (Cyfert and Najewski 2007). Spring wheat was grown in the stand with ploughed-in post-harvest residue or the total intercrop biomass. Grains were conditioned prior to sowing with Vitavax 200 FS (carboxin + thiram). Sowing was performed from March 31 to April 5. Weeds were controlled over tillering by applying Puma Super 069 EW herbicides mixture (fenoxaprop-P-ethyl + fenchlorazole-ethyl) and Granstar 75 WG (tribenuron methyl). Pre-sowing wheat was fertilised with nitrogen (40 $kg \cdot ha^{-1}$ N), phosphorus (22 $kg \cdot ha^{-1}$ P) and potassium (58 $kg \cdot ha^{-1}$ K). Besides, at the shooting phase the second N dose was applied (40 $kg \cdot ha^{-1}$).

The observations of the health status of the stem base in wheat were made at the shooting phase (GS 34-36 according to Zadoks et al. 1974) and milk maturity phase (GS 75-77). The evaluation involved the infection of stem base with *Fusarium* spp., *Oculimacula* spp. and with *G. graminis*, using the 0-3° scale. Each time there was analyzed the health status of 25 randomly sampled plants from each plot. The degrees of infection were converted into the DI (disease index) according to the transformation by Townsend and Heuberger (Wenzel 1948). The analysis of variance was made using the AWAR software. The significance of differences was determined using the Tukey's test, at $\alpha = 0.05$.

The macroscopic evaluation of the health status of plants was supported by the mycological analysis of the infected stem bases. The material used to isolate fungi infesting stem bases was randomly sampled from plants demonstrating disease changes, irrespective of the experimental combination. One hundred of 5 mm fragments were cut from the border of healthy and diseased tissue. The material was rinsed for 1 minute in sterile distilled water, disinfected for 20 seconds in 1% $AgNO_3$ solution and then rinsed three times in sterile water and placed onto acidified PDA medium with streptomycin onto Petri dishes.

Results and discussion

Over the research years weather conditions varied a lot (Table 1). The year 2002 recorded high total rainfall during wheat vegetation, especially in May, and higher air temperature than the other years. Based on the present research there was reported a relationship between the weather pattern during spring wheat vegetation and the occurrence of *Fusarium* foot rot. A greater intensity of that disease at the shooting phase of wheat was positively correlated with the average monthly temperature of April (Table 2). There was also shown a relationship between the total rainfall in June and the occurrence of symptoms of *Fusarium* foot rot at the milk maturity phase. High total rainfall recorded in that month increased infection.

Table 1. Weather conditions over spring wheat cultivation

Month	Year				1949-2005 mean
	2002	2003	2004	2005	
Total monthly rainfall [mm]					
March	38.2	11.9	35.8	22.5	22.9
April	17.7	18.5	32.1	34.8	27.2
May	111.5	18.1	54.4	82.6	41.4
June	31.3	30.4	39.6	30.5	53.8
July	77.9	106.2	53.5	33.6	71.3
August	58.0	17.7	138.7	43.4	49.3
Total March – August	334.6	202.8	354.1	247.4	265.9
Mean air temperature [°C]					
March	3.7	1.5	2.9	-0.4	1.9
April	7.5	6.4	7.5	7.4	7.3
May	15.7	14.4	11.3	12.2	12.7
June	16.3	17.6	14.7	14.9	16.2
July	18.9	19.2	16.4	19.4	17.8
August	19.9	18.4	17.9	16.3	17.4
Mean March – August	13.7	12.9	11.8	11.6	12.2

High, although non-significant, positive coefficients of correlation were recorded for the interaction between the total rainfall in May and a greater intensity of eyespot at the shooting phase (Table 2). Negative coefficients of correlation were reported for the interaction between the average monthly air temperature in May and greater intensity of *Fusarium* foot rot at milk maturity phase. A decrease in the occurrence of that disease was also reported at higher temperature in July.

The infection of the stem base in spring wheat with *G. graminis* at the milk maturity phase was positively correlated with the total rainfall in June. No significance of the interaction between rainfall in the other months and the occurrence of that pathogen was reported. An increase in air temperature May through July enhanced limiting the infection of wheat by *G. graminis*, however, that negative interaction was significant only for July.

Table 2. Correlation between infection of stem base of spring wheat by fungi and weather conditions

Variable	Shooting phase		Milk maturity phase		
	Fusarium spp.	*Oculimacula* spp.	*Gaeumannomyces graminis*	*Fusarium* spp.	*Oculimacula* spp.
Rainfall					
April	0.69	-0.07	0.27	0.67	-0.59
May	0.69	0.88	0.00	-0.16	0.73
June	0.46	-0.57	0.97*	0.96*	-0.14
July	–	–	-0.21	-0.50	0.21
Air temperature					
April	0.97*	0.49	0.48	0.45	0.41
May	-0.51	0.44	-0.47	-0.84	0.72
June	-0.94	-0.13	-0.51	-0.73	0.17
July	–	–	-0.98*	-0.93	0.09

* significant at $\alpha = 0.05$

As reported by Majchrzak et al. (2004), the weather pattern also determined the degree of infection of spring wheat by pathogens causing stem base diseases. Those interactions were observed especially for *Fusarium* foot rot and eyespot, which occur at high intensity in wet years. According to Mikołajska (1993), weather conditions in the vegetation period are often a factor determining the degree of plant infection. Bottalico and Perrone (2002) report on *F. tricinctum*, *F. poae* and *F. culmorum* predominating in spring wheat when weather in spring is warmer and drier than in general. A colder and moister weather enhances infection with *F. avenaceum* and *F. graminearum*. Similarly, Błaszkowski et al. (1999) report on higher harmfulness of *Fusarium* spp. in wet and cold soils. At the same time they claim that higher soil moisture can sometimes result in lower infection of the stem base of cereals by *F. roseum* and *G. graminis*. A considerable role of soil moisture for the development of *G. graminis* is also reported by Augustin et al. (1997), which can be due to an increase in the activity of antagonistic microorganisms, developing better in soils rich in water. According to Martyniuk (1986), the development of *G. graminis* is enhanced by high rainfall in late spring and soil temperature ranging from 5 to 20°C, which coincides with the results of the present research. Korbas (2008), investigating winter wheat, did not report on a significant relationship between infection with *Oculimacula* spp. and total rainfall, which was also reported in the present research with spring wheat, however, recorded an increase in the intensity of disease symptoms at an increasing number of days with rainfall higher than 1 mm during the vegetation period. No clear relationship between air temperature and infection is accounted for by Korbas (2008) with the fact that *Oculimacula* spp. can develop in a wide temperature range, however, an optimal range is 8-10°C and high air humidity for a dozen or so hours.

In the present research which involved spring wheat, similarly as in the experiments by Majchrzak et al. (2004), the highest intensity of occurrence was reported for *Fusarium* foot rot, followed by eyespot. Pląskowska (2005) also considers *Fusarium* genus fungi to be the most important group of pathogens which occur on the stem base of that plant. Korbas (2008) refers less importance of eyespot in spring cereals to their growing period in which they could get more infected with *Oculimacula* spp. being too short. In the present research a greater infection of the stem base by

G. graminis as compared with the results of other authors was observed. Such severe infection symptoms are rarely observed in spring cereals, which could be due to, i.a. a high share of cereals in crop rotation. Cook (2003) claims that under such conditions of spring wheat growing, roots are most infected by that pathogen, and then symptoms can appear on stems. Majchrzak et al. (2004) observed sporadic infection of stem base in spring wheat by *G. graminis*.

The wheat stem base infection by *Fusarium* genus fungi at the shooting phase was inconsiderable (Table 3). A clear effect of plants grown in stubble intercrop on the occurrence of *Fusarium* foot rot at the shooting phase was recorded only in 2005. The least disease symptoms were observed after pea and in the control, whereas most – after serradella. At the milk maturity phase a considerably higher disease index value than at the preceding one was found (Table 4), however, no significant variation in the infection for the years mean was noted. The years 2004 and 2005 were the only ones in which a considerable effect of the species of the crop grown in intercrop on the infection with *Fusarium* spp. was recorded. In the first year the most severe symptoms were observed after lupine and in the second year – on the plots without the intercrop. No development stage recorded a significant variation in infection depending on the kind of the biomass ploughed-in.

Table 3. Intensity of *Fusarium* foot rot (*Fusarium* spp.) on spring wheat at the shooting phase – disease index [%]; A – underground and aboveground parts biomass; B – post-harvest residue biomass

Year	Ploughed-in biomass kind (I)	Intercrop (II)				
		Serradella	Pea	Yellow lupine	Control	Mean
2002	A	8.0	6.0	7.7	5.0	6.67
	B	5.3	5.7	10.0	7.3	7.08
	Mean	6.67	5.83	8.83	6.17	6.88
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2003	A	2.5	2.5	1.4	2.5	2.23
	B	2.2	1.7	3.3	1.9	2.28
	Mean	2.37	2.08	2.37	2.22	2.26
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2004	A	7.0	5.0	8.0	10.7	7.67
	B	9.0	6.7	7.7	10.7	8.50
	Mean	8.00	5.83	7.83	10.67	8.08
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2005	A	9.7	6.3	10.7	6.3	8.25
	B	11.6	5.3	6.7	7.3	7.73
	Mean	10.63 b*	5.83 a	8.67 ab	6.83 a	7.99
	LSD for:	I ns	II 3.143	II × I ns	I × II ns	
2002-2005	A	6.8	5.0	6.9	6.1	6.20
	B	7.0	4.8	6.9	6.8	6.40
	Mean	6.92	4.90	6.93	6.47	6.30
	LSD for:	I ns	II ns	II × I ns	I × II ns	

* values followed by the same letter are not significantly different at $\alpha = 0.05$
ns – no significant difference

A greater intensity of eyespot at the shooting phase was very low and DI value was 1.3 % (Table 5). An effect of neither the species of the plant grown in stubble intercrop nor the kind of biomass ploughed-in on the intensity of that disease was reported. At the milk maturity phase many more infection symptoms were observed, and the mean DI value accounted for 15.89% (Table 6). At that phase wheat grown on the stand with the entire pea biomass ploughed-in was significantly less infected than when exposed to post-harvest residue of that plant ploughed-in only. In the case of serradella and lupine no such relationship was found.

Table 4. Intensity of *Fusarium* foot rot (*Fusarium* spp.) on spring wheat at the milk maturity phase – disease index [%]; A – underground and aboveground parts biomass; B – post-harvest residue biomass

Year	Ploughed-in biomass kind (I)	Intercrop (II)				
		Serradella	Pea	Yellow lupine	Control	Mean
2002	A	5.4	4.6	3.8	4.2	4.48
	B	6.7	5.4	3.8	1.7	4.38
	Mean	6.04	5.00	3.75	2.92	4.43
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2003	A	6.7	5.7	3.7	1.7	4.42
	B	5.3	4.7	6.7	5.0	5.42
	Mean	6.00	5.17	5.17	3.33	4.92
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2004	A	45.0	43.7	51.3	34.3	43.58
	B	41.0	52.0	50.3	34.3	44.42
	Mean	43.00 ab*	47.83 ab	50.83 b	34.33 a	44.00
	LSD for:	I ns	II 14.609	II × I ns	I × II ns	
2005	A	10.5	15.2	14.4	18.8	14.73
	B	14.6	10.5	11.0	18.7	13.69
	Mean	12.55 a	12.85 a	12.72 a	18.72 b	14.21
	LSD for:	I ns	II 4.208	II × I ns	I × II ns	
2002-2005	A	16.9	17.3	18.3	14.7	16.80
	B	16.9	18.1	17.9	14.9	16.98
	Mean	16.90	17.71	18.12	14.83	16.89
	LSD for:	I ns	II ns	II × I ns	I × II ns	

* values followed by the same letter are not significantly different at $\alpha = 0.05$
ns – no significant difference

Symptoms of stem base infection with *G. graminis* were observed only at the milk maturity phase and their greater intensity was not quite high as compared with the other diseases. The highest disease index value was reported in 2004 (Table 7). The occurrence of foot rot caused by that pathogen depended significantly on the kind of biomass ploughed-in. Considerably more disease changes were observed once the entire biomass of plants grown in intercrop had been ploughed-in, which was especially clear in serradella. No significant effect of the species of the plant grown in intercrop on the occurrence of that disease was noted.

Table 5. Intensity of eyespot (*Oculimacula* spp.) on spring wheat at the shooting phase – disease index [%]; A – underground and aboveground parts biomass; B – post-harvest residue biomass

Year	Ploughed-in biomass kind (I)	Intercrop (II)				
		Serradella	Pea	Yellow lupine	Control	Mean
2002	A	2.0	1.3	1.7	3.7	2.17
	B	1.7	3.0	3.0	2.0	2.42
	Mean	1.83	2.17	2.33	2.83	2.29
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2003	A	0.1	1.3	1.0	0.3	0.67
	B	0.1	0.7	0.3	0.7	0.42
	Mean	0.10	1.00	0.67	0.50	0.54
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2004	A	0.0	0.3	0.3	0.0	0.17
	B	0.7	1.7	0.0	0.0	0.58
	Mean	0.33	1.00	0.17	0.00	0.38
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2005	A	2.3	0.7	1.0	2.3	1.58
	B	1.1	4.0	2.7	2.0	2.43
	Mean	1.70	2.33	1.83	2.17	2.01
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2002-2005	A	1.1	0.9	1.0	1.6	1.15
	B	0.9	2.3	1.5	1.2	1.46
	Mean	0.99	1.63	1.25	1.38	1.30
	LSD for:	I ns	II ns	II × I ns	I × II ns	

ns – no significant difference

A positive effect of stubble intercrop on the health status of the stem base of spring wheat in the field experiment was also reported by Wojciechowski (2005), which was later confirmed in a pot experiment (Wojciechowski 2008). Post-harvest residue or the biomass of entire plants can cause i.a. an increase in the bioactivity of soil, which can enhance its phytosanitary condition, and thus the health status of cereals grown after intercrops (Klima 1992). A favourable effect of leguminous plants is referred to an increased abundance of microorganisms in soil as a result of growing those plants. Enriching the composition of microorganisms in soil makes the development of species antagonistic to pathogens possible (Dorenda 1974). Strong fungistatic properties are found in the straw of lupines, especially high-alkaloid lupines. From composts of that plant a group of strains of *Bacillus* genus, antagonistic towards plant pathogens, was isolated (Stachowiak et al. 2003). In the present research no greater variation in the intensity of *Fusarium* foot rot in wheat was observed, which could have been due to the fact that roots and root necks of leguminous plants grown in intercrop were mainly attacked by *Fusarium* genus fungi, which have been presented in an earlier paper (Skinder et al. 2007). Lupine was most heavily infected, and serradella – least. Bojarczuk and Bojarczuk (1988) report on leguminous fodder crops making it also possible for the *Fusarium* species to survive, also those pathogenic towards cereals. However, relatively poor infection of plants acting as the intercrop and a relatively low share of pathogenic fungi isolated from infected organs of plants grown in stubble intercrop can point to a considerable value of those plants as those alleviating the effects of frequent succession of cereals in crop rotation.

Table 6. Intensity of eyespot (*Oculimacula* spp.) on spring wheat at the milk maturity phase – disease index [%]; A – underground and aboveground parts biomass; B – post-harvest residue biomass

Year	Ploughed-in biomass kind (I)	Intercrop (II)				
		Serradella	Pea	Yellow lupine	Control	Mean
2002	A	52.9	48.4	50.9	52.5	51.18
	B	53.4	51.3	51.7	50.0	51.58
	Mean	53.15	49.82	51.27	51.28	51.38
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2003	A	4.7	4.5	2.8	4.7	4.17
	B	1.9	1.1	2.5	2.5	2.01
	Mean	3.32	2.80	2.63	3.60	3.09
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2004	A	5.7	2.3	7.0	7.7	5.67
	B	7.0	17.0	7.3	7.7	9.75
	Mean	6.33	9.67	7.17	7.67	7.71
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2005	A	1.0	0.0	1.0	2.3	1.08
	B	0.7	3.0	1.3	1.7	1.70
	Mean	0.85	1.51	1.17	2.03	1.39
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2002-2005	A	16.1	13.8 a*	15.4	16.8	15.52
	B	15.8	18.1 b	15.7	15.5	16.26
	Mean	15.91	15.95	15.56	16.15	15.89
	LSD for:	I ns	II ns	II × I ns	I × II 2.809	

* values followed by different letters differ significantly at $\alpha = 0.05$
ns – no significant difference

Slightly different results, which covered the method of intercrop biomass management, were reported by Majchrzak et al. (2004) who identified their significant effect on the occurrence of *Fusarium* foot rot, which was lower in the treatments in which stubble was ploughed-in with straw of *Brassicaceae* plants, and significantly higher in the combination with ploughed-in stubble only. The weakest eyespot symptoms were recorded in the combination in which, besides stubble and straw mineral nitrogen was also introduced into soil, whereas the heaviest – in the treatments where stubble was ploughed-in with straw without additional fertilisation. In our earlier research on growing spring barley after intercrops there was identified a favourable effect on the health status of the stem base of the entire wheat straw biomass ploughed-in, constituting the forecrop. It decreases the infection of barley with *Oculimacula* and *Rhizoctonia* genera fungi (Lemańczyk et al. 2001a). A positive effect of the biomass ploughed-in was also visible by increasing the spike density and the yield of grain and straw of spring wheat, which has been presented in an earlier paper (Wilczewski et al. 2007).

Table 7. Infection of spring wheat stem base by *Gaeumannomyces graminis* at the milk maturity phase – disease index [%]; A – underground and aboveground parts biomass; B – post-harvest residue biomass

Year	Ploughed-in biomass kind (I)	Intercrop (II)				
		Serradella	Pea	Yellow lupine	Control	Mean
2002	A	0.83	0.87	1.27	2.97	1.48
	B	0.43	0.43	1.70	2.93	1.38
	Mean	0.63	0.65	1.48	2.95	1.43
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2003	A	0.00	1.33	0.00	0.33	0.42
	B	0.00	0.00	0.33	0.00	0.08
	Mean	0.00	0.67	0.17	0.17	0.25
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2004	A	6.33	3.00	4.67	5.00	4.75
	B	1.33	4.33	4.00	5.00	3.67
	Mean	3.83	3.67	4.33	5.00	4.21
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2005	A	0.00	0.00	0.00	0.33	0.08
	B	0.00	0.00	0.00	0.33	0.08
	Mean	0.00	0.00	0.00	0.33	0.08
	LSD for:	I ns	II ns	II × I ns	I × II ns	
2002-2005	A	1.79 b*	1.30	1.48	2.16	1.68 b
	B	0.44 a	1.19	1.51	2.07	1.30 a
	Mean	1.12	1.25	1.50	2.11	1.49
	LSD for:	I 0.088	II ns	II × I ns	I × II 0.176	

* values in columns followed by different letters differ significantly at $\alpha = 0.05$
ns – no significant difference

From the infected stem base at the shooting phase of wheat grown after leguminous intercrops saprotrophic fungi were isolated in big numbers (Table 8). Pathogenic fungi were dominated by *Fusarium* spp., and among them: *F. avenaceum*. *G. graminis* was isolated in considerably big numbers. Besides, the following were isolated: *Aureobasidium bolleyi*, *Bipolaris sorokiniana*, *Rhizoctonia cerealis* and *R. solani*. At the milk maturity phase from the stem base there were mainly isolated *Fusarium* spp. genus fungi, especially *F. equiseti*, *F. avenaceum*, *F. culmorum* and *F. solani*. Similarly, *G. graminis*, *B. sorokiniana* and *A. bolleyi* were also isolated. *G. graminis* was mostly isolated in 2004 in which foot rot symptoms were most intensive. The high number of isolates of that pathogen identified confirms that it was one of the main causes of the disease symptoms observed. Many authors consider *G. graminis* to be the main cause of root rot in spring wheat, whereas infection symptoms are visible on the stem base much less considerably (Augustin et al. 1997; Duffy 2000; Cook 2003).

From the stem base of spring wheat, Pląskowska (2005) isolated *G. graminis* much less frequently, and much more frequently – *Fusarium* spp., especially *F. avenaceum*, which can be accounted for by abilities of those fungi to saprotrophic life in soil, their fast growth, producing numerous conidial spores and chlamydospores.

Table 8. Percentage of fungi species isolated from the stem base of spring wheat

Fungal species	Shooting phase					Milk maturity phase				
	2002	2003	2004	2005	Mean	2002	2003	2004	2005	Mean
Arthinium phaeospermum (Cord) Ellis	–	–	5.3	–	1.3	–	–	–	–	–
Aspergillus niger van Tieghen	8.5	–	–	4.1	3.1	–	–	–	–	–
Aureobasidium bolleyi (Sprague) von Arx	4.3	–	5.3	20.4	7.5	1.7	–	2.0	3.8	1.9
Bipolaris sorokiniana (Sacc. in Sorok.) Shoem	–	–	9.2	10.2	4.9	–	–	–	5.7	1.4
Cylindrocarpon radicicola Wollenw.	2.1	–	–	–	0.5	–	–	–	–	–
Fusarium avenaceum (Fr.) Sacc.	10.6	23.7	1.3	12.2	12.0	46.6	1.8	31.4	22.6	25.6
Fusarium culmorum (W.G. Smith) Sacc.	–	–	1.3	–	0.3	12.1	21.1	7.8	15.1	14.0
Fusarium equiseti Sacc.	–	7.9	1.3	4.1	3.3	24.1	43.9	13.7	22.6	26.1
Fusarium graminearum Schwabe	–	–	1.3	–	0.3	–	–	–	–	–
Fusarium oxysporum Schlecht.	–	–	1.3	–	0.3	–	–	2.0	–	0.5
Fusarium solani (Mart.) Sacc.	2.1	5.3	1.3	2.0	2.7	6.9	24.6	7.8	11.3	12.7
Fusarium tricinctum (Corda) Sacc.	–	–	–	–	–	1.7	–	2.0	1.9	1.4
Fusarium total	12.8	36.8	7.9	18.4	19.0	91.4	91.2	64.7	73.6	80.2
Gaeumannomyces graminis (Sacc.) Arx et Olivier	–	–	23.7	8.2	8.0	–	–	3.9	5.7	2.4
Gliocladium catenulatum Gilman et Abbott	14.9	10.5	–	12.2	9.4	1.7	–	–	1.9	0.9
Gliocladium roseum (Link) Bainier	–	2.6	10.5	–	3.3	–	–	–	–	–
Mucor spp.	27.7	18.4	2.6	–	12.2	5.2	–	–	–	1.3
Penicillium spp.	12.8	–	1.3	6.1	5.1	–	–	–	–	–
Pythium sp.	–	2.6	–	–	0.7	–	–	–	–	–
Rhizoctonia cerealis van der Hoeven	–	10.5	1.3	4.1	4.0	–	–	–	–	–
Rhizoctonia solani Kühn	–	5.3	–	2.0	1.8	–	–	–	–	–
Rhizopus nigricans Ehrenberg	–	–	–	2.0	0.5	–	–	–	–	–
Trichoderma koningii Oud.	10.6	–	9.2	2.0	5.5	–	–	11.8	1.9	3.4
Trichoderma polysporum (Link ex Pers.) Rifai	–	–	1.3	–	0.3	–	1.8	5.9	1.9	2.4
Trichoderma viride Pers. ex Gray	2.1	13.2	7.9	2.0	6.3	–	3.5	11.8	3.8	4.8
Non-sporulating colonies	4.3	–	14.5	8.2	6.7	–	3.5	–	1.9	1.3
Total number of isolates	47	38	76	49	210	58	57	51	53	219

Truszkowska et al. (1991) claim that in the stand after leguminous plants an increase in the number of *Fusarium* isolates is observed. From the infected stem base at the shooting phase in wheat grown after leguminous intercrops many saprotrophic fungi were isolated, which could have been due to poor infection of plants with the pathogens which had not grown yet to deeper plant tissue layers and, when exposed to surface disinfection, they could get destroyed.

The present results coincide with the reports by Pląskowska (2005) and Lemańczyk et al. (2001b) demonstrating that *Fusarium* genus fungi, especially *F. avenaceum*, are the main cause of stem base wilting in spring wheat. Similarly, Majchrzak et al. (2008) from the spring wheat stem base, irrespective of the forecrop and the management method of post-harvest residue, most frequently isolated *Fusarium* genus fungi, especially *F. avenaceum*. According to Polley and Turner (1995), fungi of that genus most frequently colonize the stem base in cereals. *Fusarium avenaceum, F. culmorum*, *F. poae* and *F. graminearum* are most often isolated and thus most harmful for cereals grown in Poland (Kurowski 2002). According to Wagacha and Muthomi (2007) *F. culmorum* dominates in western and central Europe. *Fusarium culmorum* and *F. graminearum* can infect cereals systemically, attacking roots and then growing to the stem base (Majchrzak et al. 2008). Similarly as in the present research, Majchrzak et al. (2004) did not isolate *Oculimacula* spp. from the stem base despite the occurrence of clear disease symptoms typical for those pathogens, whereas Pląskowska (2005) isolated only *O. acuformis*, sporadically.

Drawing on the present research, an interaction between the infection of the stem base in spring wheat by *G. graminis* and the grain yield, the spike density and the number of grains per spike was identified (Table 9), however, it was clear only in 2002. A significant effect on the number of grains per spike was also reported in 2005. The higher the infection, the lower the value of the above yield structure components. However, no clear effect of that pathogen on 1000 grain weight was identified. Neither was there recorded a significant interaction between the occurrence of the symptoms of infection with *Oculimacula* and *Fusarium* genera fungi and the above yielding components. However, usually a slight decrease in their value accompanied by an increase in the intensity of disease symptoms caused by those pathogens was observed. Most authors report on a considerable effect of infection with *Oculimacula* spp., *Fusarium* spp. and *G. graminis* on cereal yielding, especially winter cereals (Martyniuk 1986; Lemańczyk et al. 2001b; Cook 2003; Majchrzak et al. 2004; Pląskowska 2005; Ray et al. 2006). Klima (1992) reports on winter wheat infection with *Oculimacula* spp. and *G. graminis* causing considerable losses of grain from the spikes of stems infected by those pathogens towards the weight of grain from spikes of non-infected stems and notes that there is no clear correlation between the plant infection level and the yield per area unit, relating it to the fact that a direct effect of infection on yielding can be distorted by factors reported at higher intensity and having a greater effect on yielding. Klima (1992) adds that the grain yield is a derivative of the effect of many factors which can get accumulated.

Table 9. Correlation coefficients between the infection of stem base and yield structure components of spring wheat

Year	Specification	Infection by		
		Fusarium spp.	*Oculimacula* spp.	*G. graminis*
2002	Grain yield	-0.24	-0.17	-0.42*
	1000 grain weight	-0.11	0.11	0.01
	Spike density	-0.24	0.13	-0.51*
	Number of grains per spike	0.11	-0.08	-0.49*
2003	Grain yield	0.05	-0.06	0.12
	1000 grain weight	0.33	-0.17	0.35
	Spike density	-0.25	0.06	0.06
	Number of grains per spike	0.22	-0.03	-0.10
2004	Grain yield	0.07	-0.32	0.03
	1000 grain weight	-0.01	-0.22	0.43
	Spike density	0.04	-0.29	0.01
	Number of grains per spike	0.07	-0.32	0.03
2005	Grain yield	-0.36	0.27	-0.17
	1000 grain weight	-0.13	0.13	-0.06
	Spike density	-0.22	-0.18	-0.20
	Number of grains per spike	-0.07	0.03	-0.43*

* significant at $\alpha = 0.05$

Conclusions

Spring wheat showed the highest intensity of disease symptoms of *Fusarium* foot rot, followed by eyespot, and, finally, by take-all. The stem base infection by *G. graminis* and *Fusarium* spp. considerably depended on the weather pattern over the vegetation period which, in turn, demonstrated less effect on the infection with *Oculimacula* spp. Considerably heavier infection with *G. graminis* was observed after ploughing in the entire biomass of plants grown in intercrop, which was most clear in the case of serradella. Ploughing-in of the entire pea biomass decreased the infection with *Oculimacula* spp. The kind of the biomass ploughed-in did not differentiate the infection with *Fusarium* spp. The occurrence of *Fusarium* foot rot was, to some extent, differentiated by stubble intercrop. There was found no significant effect of the plant species grown in intercrop on the occurrence of eyespot and foot rot. From the infected stem base mostly *Fusarium* genus fungi, especially *F. avenaceum*, *F. equiseti*, *F. culmorum*, and *F. solani* were isolated. The isolates of *G. graminis*, *B. sorokiniana*, *R. cerealis* and *R. solani* were smaller in number. An interaction between the stem base infection with *G. graminis* and the grain yield, the spike density and the number of grains per spike was identified. However, no significance of the interaction between the infection with *Oculimacula* and *Fusarium* genera fungi and the above yield structure components was found.

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EFFECT OF STERILIZING AGENT ON CUCUMBER SEED GERMINATION AND SEEDLING GROWTH *in vitro*

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Seeds infected with pathogens are the most frequent source of infection of young plants. In tissue cultures, to sterilize the plant material different agents are applied, such as 70% ethanol, calcium hypochlorite, and sodium hypochlorite at the concentration of 1-7%, chloramine at the concentration of 1-6% (Witomska et al. 1998). The effectiveness of sterilizing substances depends considerably on the type of the surface sterilized and the type of the material (Pośpieszny and Kamasa 2001). The kind of agent applied, its concentration and the time of action should be adjusted to the kind of tissue. An excessively low concentration and a short time of sterilization can give unsatisfactory results, whereas the opposite can lead to the wilting of tissues and a decrease in regeneration potential. Multistage sterilization which involves a successive application of different preparations can be more effective than the single-stage one, especially when exposed to a serious contamination with different microorganisms, however, it can deteriorate regeneration (Witomska et al. 1998). The agents applied to sterilize seeds can also damage deteriorating the germinability and causing seedling deformation (Koziara 2002).

The aim of the present research was to determine the effectiveness of the agents applied to sterilize glasshouse cucumber seeds and their effect on the rate of germination and development as well as on the selected morphological characters of seedlings.

Materials and methods

The research involved three glasshouse cucumber (*Cucumis sativus* L.) cultivars 'Marinda F_1', 'Mathilde F_1', and 'Mirabelle F_1', and it was performed from March 10 to April 1, 2008.

The experimental factors were constituted by the seed sterilization agents: ACE, Domestos, and 5% technical sodium hypochlorite, in which the content of active chlorine was earlier determined with the colorimetrically ortotolidine-arsenate method (following the PN-74/C-04600/14 standard). It was, on average, in ACE 48.58 mg $Cl \cdot ml^{-1}$, in Domestos 38.91 mg $Cl \cdot ml^{-1}$, and in technical sodium hypochlorite 41.85 mg $Cl \cdot ml^{-1}$. The seeds were soaked in the sterilizing agent for 15 minutes. After sterilization the

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seeds were rinsed three times with sterile bidistilled water, and then placed one by one to jars each containing 40 ml of sterile modified MS medium (Murashige and Skoog 1962) solidified with agar (8 $g \cdot dm^{-3}$). The medium modification involved increasing the amount of calcium and iron by 50% and decreasing the amount of sucrose to 20 $g \cdot dm^{-3}$.

The jars filled with seeds were placed in the growth chamber, exposed to 16-hour light generated by fluorescent tubes Philips TLD 36 W Daylight colour 54, emitting light similar in spectra to natural light. The intensity of the quantum irradiance at the level of jar lids was 43.5 $\mu mol \cdot m^{-2} \cdot s^{-1}$. The air temperature was 24-25°C, and the relative air humidity of 65%. The experiment was set up in 5 replicates, 5 seeds each, in completely independent design.

The following dates were recorded: the dates of the radicle protrusion (the radicle of minimum 1 mm in length), the unfolding of cotyledons, and the first leaf stage. Once the observations were completed, seedlings were taken out from the jars, the root systems were rinsed with water and dried on the filter paper. The fresh weight of a whole seedling, the epicotyl with the leaf, leaf and the axis was determined. Additionally, the length of hypocotyls was measured.

The present results were statistically verified with the two-factor analysis of variance, and the differences between means were verified with the Tukey's test at the significance level of $\alpha = 0.05$.

Results

The seed germination rate depended on the cultivar; the germination rate of 'Mirabelle F_1' cultivar seeds was higher, as compared with the seeds of the other two cultivars. The sterilizing agents affected the seed germination rate only in 'Marinda F_1'. The application of Domestos delayed the seed germination as compared with ACE sterilization.

In all the three cultivars it was observed that the time from the radicle protrusion (completing germination) to cotyledon unfolding depended on the sterilizing agent applied. In the case of 'Marinda F_1', the stage was shorter in seedlings derived from seeds sterilized with ACE than in seedlings derived from seeds sterilized with hypochlorite. 'Mathilde F_1' seedlings unfolded cotyledons faster when the seeds were sterilized with ACE and Domestos. In 'Mirabelle F_1' a better effect of ACE than of Domestos and sodium hypochlorite was recorded. Irrespective of the cucumber cultivar, a shortened stage from completing germination to cotyledons unfolding were recorded when the seeds were sterilized with ACE, and when technical sodium hypochlorite was used the seedlings needed longer period to unfold cotyledons.

Irrespective of the cultivar, hypochlorite turned to have a worse effect on the time from cotyledons unfolding to the development of the first leaf. In the case of 'Marinda F_1', hypochlorite delayed that stage more than Domestos. In a case of 'Mirabelle F_1', hypochlorite appeared inferior to ACE and Domestos. Another reaction was observed in 'Mathilde F_1' where Domestos prolonged the time from cotyledons unfolding to the development of the first leaf more than the other sterilizing agents.

The total time from seed sowing to the development of the first leaf also depended on the sterilizing agent applied. For 'Marinda F_1' better effects were reported by applying ACE than in the case of technical sodium hypochlorite, however, no differences were noted in the time from seed sowing to the development of the first leaf between ACE and Domestos as well as Domestos and sodium hypochlorite. In

'Mathilde F_1' seedlings, similar effects applying both ACE and Domestos were noted, and hypochlorite delayed the process of their development, whereas in 'Mirabelle F_1' the fastest seedlings development occurred following the sterilization of seeds with ACE, and the slowest – with technical sodium hypochlorite. Irrespective of the seed sterilization agent applied, 'Mirabelle F_1' seedlings developed fastest (Table 1).

Table 1. Rate of seed germination and seedling development depending on the cultivar and sterilizing agent

Sterilizing agent	Cultivar			Mean for sterilizing agent
	Marinda F_1	Mathilde F_1	Mirabelle F_1	
Number of days from sowing to the completion of germination				
ACE	2.7 bcd	2.8 cd	2.0 a	2.5 ns
Domestos	3.4 e	2.9 cde	2.2 ab	2.8
Sodium hypochlorite	3.0 de	3.0 de	2.4 abc	2.8
Mean for cultivar	3.0 B	2.9 B	2.2 A	–
Number of days from the completion of germination to cotyledons unfolding				
ACE	4.2 abc	3.9 ab	3.7 a	3.9 A
Domestos	4.6 cd	3.8 a	4.5 bc	4.3 B
Sodium hypochlorite	5.2 de	5.4 e	5.1 cde	5.2 C
Mean for cultivar	4.7 ns	4.4	4.4	–
Number of days from cotyledon unfolding to the development of the first leaf				
ACE	5.8 ab	6.3 c	5.5 a	5.9 A
Domestos	5.5 a	5.4 a	5.8 ab	5.6 A
Sodium hypochlorite	6.2 bc	6.6 c	6.5 c	6.4 B
Mean for cultivar	5.8 ns	6.1	6.0	–
Number of days from sowing to the development of the first leaf				
ACE	12.7 bc	13.0 bc	11.2 a	12.3 A
Domestos	13.5 cd	12.1 ab	12.5 b	12.7 A
Sodium hypochlorite	14.4 de	15.0 e	14.0 d	14.5 B
Mean for cultivar	13.5 B	13.4 B	12.6 A	–

Values for particular stages followed by the same letter do not differ significantly at $\alpha = 0.05$ (capital letters – means for main factors; small letters – means for interactions)
ns – no significant difference

Neither infection nor the effect of the cultivar and the sterilizing agent on the proportion of adequately developed seedlings in their total number was observed.

The sterilizing agents applied in the experiment affected the hypocotyl length in cucumber seedlings. Irrespective of the cultivar, the shortest hypocotyl was noted in seedlings obtained from seeds sterilized with sodium hypochlorite, and the longest – following the ACE application. The same reaction was observed in 'Marinda F_1' seedlings. In the case of 'Mathilde F_1', in seedlings produced from seeds sterilized with ACE and Domestos the hypocotyl length was similar, and the shortest hypocotyl was observed in seedlings from seeds sterilized with sodium hypochlorite. In 'Mirabelle F_1' seedlings obtained from seeds sterilized with ACE, the hypocotyl was longer than in seedlings from the seeds sterilized with Domestos and sodium hypochlorite.

The sterilizing agents affected the fresh weight of the leaf. Leaves of seedlings from seeds sterilized with sodium hypochlorite demonstrated greater weight as compared with the leaves of seedlings obtained from seeds sterilized with ACE and Domestos.

The effect of the sterilizing agent on the fresh weight of epicotyl was lower and observed only in ‘Mirabelle F_1’. Seedlings obtained from the seeds sterilized with Domestos demonstrated lower weight than the seedlings from seeds sterilized with ACE and sodium hypochlorite.

The fresh weight of the hypocotyl part did not depend on the sterilizing agent applied and only on the cultivar and it was greater in ‘Mirabelle F_1’.

There was no effect of the sterilizing agent on the total fresh weight of seedlings. ‘Mirabelle F_1’ was the only cultivar in which it was found that in seedlings from the seeds exposed to sterilizing with Domestos the weight was lower as compared with seedlings from seeds sterilized with ACE and sodium hypochlorite (Table 2).

Table 2. Proportion of correctly developed seedlings and their morphological characteristics depending on the cultivar and sterilizing agent

Sterilizing agent	Cultivar			Mean for sterilizing agent
	Marinda F_1	Mathilde F_1	Mirabelle F_1	
Proportion of correctly developed seedlings [%]				
ACE	96.0 ns	96.0	100.0	97.3 n.s.
Domestos	92.0	96.0	100.0	96.0
Sodium hypochlorite	92.0	100.0	96.0	96.0
Mean for cultivar	93.3 ns	97.3	98.7	–
Hypocotyl length [cm]				
ACE	5.1 g	3.6 de	4.2 f	4.3 C
Domestos	3.9 ef	3.2 cd	2.8 ab	3.3 B
Sodium hypochlorite	3.1 bc	2.6 a	2.6 a	2.8 A
Mean for cultivar	4.0 B	3.1 A	3.2 A	–
Fresh weight of a seedling [mg]				
ACE	674.5 c	593.3 ab	656.8 bc	641.5 AB
Domestos	637.7 abc	610.1 abc	561.9 a	603.2 A
Sodium hypochlorite	659.5 bc	606.5 abc	676.1 c	647.4 B
Mean B	657.2 B	603.3 A	631.6 AB	–
Fresh weight of the epicotyl [mg]				
ACE	544.6 c	472.6 ab	496.9 bc	504.7 B
Domestos	509.0 bc	473.8 ab	419.5 a	467.4 A
Sodium hypochlorite	536.8 c	490.3 bc	520.4 bc	515.8 B
Mean for cultivar	530.1 B	478.9 A	478.9 A	–
Fresh weight of the leaf [mg]				
ACE	71.4 ab	59.3 a	60.5 a	63.7 A
Domestos	81.1 bc	66.8 a	71.2 ab	73.0 B
Sodium hypochlorite	100.3 d	84.2 c	88.8 cd	91.1 C
Mean B	84.3 B	70.1 A	73.5 A	–
Fresh weight of the axis [mg]				
ACE	129.9 ab	120.7 ab	159.9 c	136.8 n.s.
Domestos	128.7 ab	136.3 abc	142.4 bc	135.8
Sodium hypochlorite	122.7 ab	116.2 a	155.7 c	131.5
Mean for cultivar	127.1 A	124.4 A	152.6 B	–

Values for particular characteristics followed by the same letter do not differ significantly at $\alpha = 0.05$ (capital letters – means for main factors; small letters – means for interactions)
ns – no significant difference

Discussion

In the present experiment, to sterilize the seeds of three cucumber cultivars three sterilizing agents were used: ACE, Domestos and sodium hypochlorite, of the content of active chlorine of, respectively, 48.58, 38.91, and 41.85 mg $Cl \cdot ml^{-1}$. Each substance applied was very effective in eliminating microorganisms. A high effectiveness of ACE and Domestos is confirmed in literature (Kraj et al. 1994; Reby and Kowalik 1998; Jerzy and Pawlak-Anhalt 2002; Koziara 2002). The application of 50% ACE solution to sterilise buds isolated from rhizomes of *Zantedeschia elliottiana* [W.Wats.] Engl. made it possible to obtain from 63.6 to 76.5% of sterile explants (Jerzy and Pawlak-Anhalt 2002). The effect of 50% solution of Domestos was slightly poorer; from 45.5 to 75% of sterile explants were obtained. However, 3% solution of sodium hypochlorite demonstrated very low effectiveness. As a result, there were obtained only 21 to 27% of sterile explants. Similarly, as reported by Koziara (2002), 10% solution of calcium hypochlorite showed little effect as the agent sterilizing seeds of cider gum (*Eucalyptus gunnii* Hook.). As a result of its application, only 55% of sterile cultures were produced, while seeds sterilized in 20% solution of Domestos were in 90% sterile. Such an effect the author refers to Domestos including surfactant compounds, facilitating the penetration of aseptic factor. A study by Reby and Kowalik (1998) on the sterilization of fungus-infected *Alternaria alternata* (Fr.) Geissler, *Botrytis cinerea* Pers. ex Nocca & Balb., and *Penicillum verucosum* Dierckx v. *verrucosum* scale fragments of morning star lily (*Lilium concolor* L.) found ACE to be ineffective. Positive effects of that preparation in the present experiment and the reports by Jerzy and Pawlak-Anhalt (2002) can be explained by a presence in sterilized plant material less resistant microorganisms. The effectiveness of the sterilizing agent can depend on the type of the explant. Kraj et al. (1994) showed that in the case of hypocotyls sampled from non-sterile seedlings of beech (*Fagus sylvatica* L.) more effective sterilizing agent was 5% solution of calcium hypochlorite, and in the case of shoots and epicotyl – 4% chloramine T. In the case of *Uapaca kirkiana* Mulle, containing hard seed coat (testa), the sterilization in 2% solution of sodium hypochlorite resulted in 78% of sterile seedlings if the seeds had been earlier derived of the external and internal testa layer. Depriving seeds of only the external layer of the seed coat, sterilization in 2% NaOCl resulted in only 43% sterility (Maliro and Kwapata 2000), which shows that what is important is not only an adequate adjustment of the type and concentration of the sterilizing agent but also an earlier preparation of sterilizing material. In some cases, while sterilising especially heavily infected material, good effects can be produced as a result of multistage sterilising, successively with a few agents, however, such a procedure can, on the other hand, deteriorate the regeneration potential (Witomska et al. 1998).

As reported by Koziara (2002), the seeds of cider gum germinated faster after sterilization with Domestos, as compared with the seeds sterilized with calcium hypochlorite. In the present research no higher rate of cucumber seed germination was showed after the application of ACE and Domestos, as compared with the germination rate of seeds sterilized with hypochlorite, however, an unfavourable effect of calcium hypochlorite on the seedling development rate was observed.

No effect of the sterilizing agent on the occurrence of cucumber seedling damage and deformations was observed. In the experiment reported by Koziara (2002) hypochlorite not only demonstrated low effectiveness in eliminating contamination but also caused heavy seedling damage. Cucumber seedlings derived from seeds sterilized with sodium hypochlorite indeed had a considerably shorter hypocotyl, as compared with seedlings obtained from seeds sterilized with ACE and Domestos, however, a greater weight of the first leaf was also recorded.

Conclusions

1. The seed germination rate depended on the kind of the sterilizing agent applied only in 'Marinda F_1' cultivar. Cotyledons and first leaves appeared fastest following the application of ACE sterilizing agent, containing most active chlorine. 'Mirabelle F_1' seedlings were the first ones to produce the first leaf, while fresh weight of seedlings was highest in 'Marinda F_1'.
2. No significant effect of the sterilizing agent on the number of adequately developed seedlings and fresh weight of seedling axis was found. However, a favourable effect of sodium hypochlorite on fresh weight of seedlings and leaves of all the cucumber studied cultivars was found.

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SOWING DATE AND NITROGEN FERTILISATION AS FACTORS DETERMINING YIELD AND BIOLOGICAL VALUE OF SPRING TRITICALE GRAIN

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Due to a large yielding potential and high nutritional value, triticale plays an ever higher role in cereals production (Varughese 1996; Maćkowiak 2003). Most studies carried out on triticale concerned its winter forms (Wróbel and Budzyński 1994; Stankowski et al. 1996; Małecka et al. 2004) or estimation of particular requirements enabling a better utilization of its productive potential (Koziara 2000; Nieróbca 2004; Ścigalska 2006). The results obtained by Gil and Narkiewicz-Jodko (1997), Pisulewska et al. (2000) and Spychaj-Fabisiak et al. (2005) indicate that spring cultivars of triticale are characterized by a higher protein content than winter ones. The factor which determines triticale grain protein quality is its amino acid composition, and particularly the content of exogenous amino acids. Amino acid composition in protein is greatly varied and depends on the cultivar, as well as on soil and climate conditions and cultivation measured applied (Starczewski et al. 2000; Stankiewicz 2005). Relations between quality features of triticale grain and cultivation measures are quite richly documented in the literature (Stankiewicz et al. 1998: Bombik et al. 2000; Starczewski et al. 2000; Mut et al. 2005; Ceglińska et al. 2006; Knapowski et al. 2009), whereas there are few publications concerning quality changes of grain, including amino acid composition, occurring under their influence. Nitrogen fertilisation is a cultivation technology factor which largely influences both grain yield quality and the full expression of genetically determined features affecting its height (Wróbel 2005; Domska and Warechowska 2006; Knapowski et al. 2009). However, nitrogen application should be viewed in connection with other factors, such as sowing date, which can determine its activity. Bearing in mind a higher genetic variation of triticale cultivars in comparison with the other cereal crops, a distinct differentiation of their cultivation requirements in relation to sowing date must be expected (Mazurek and Jaśkiewicz 1994; Maćkowiak et al. 2000).

In spite of a growing intensity of research observed in recent years, the state of knowledge of triticale cultivation technology still requires further detailed investigation, particularly in relation to the regional natural and agricultural conditions. The aim of the study was to investigate the effect of sowing date and application of varying nitrogen

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fertilisation as well as their possible interactions on yielding and amino acid composition of grain of spring triticale cv. 'Gabo' cultivated under the conditions of the Nadnotecka Valley.

Materials and methods

A field experiment was carried out over 2001-2003 in the Research Station at Minikowo (Kuyavian-Pomeranian Province, Fig. 1) on a typical grey-brown podsolic soil, which belongs to Albic Luvisols according to international classification FAO-UNESCO. The soil, classified as the very good rye complex, was characterized by high and medium contents of available forms of phosphorus, potassium and magnesium, and neutral pH. The experiment was established in a randomized split-plot design with four replications. The subject of this study was spring triticale cv. 'Gabo', which was sown at the following times (1st factor, n = 2): 1 – (optimal) sowing time (April 1-22), 2 – (delayed) sowing time (April 17-May 8).

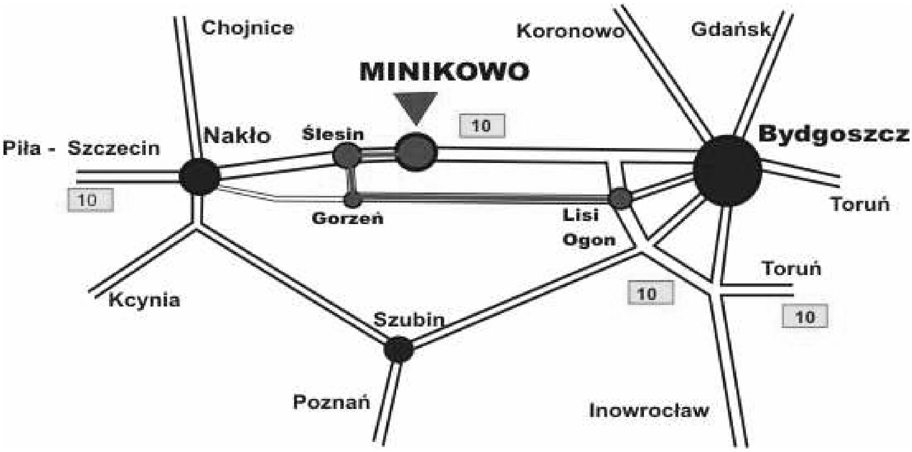

Fig. 1. Location of the field experiment (Research Station at Minikowo)

Nitrogen fertilisation (2nd factor, n = 3) was applied in the form of ammonium saltpetre, taking into consideration two nitrogen fertilisation levels (N_1 and N_2) and control treatment without nitrogen (N_0 = 0; Table 1).

Tabela 1. Nitrogen fertilisation [kg N·ha^{-1}]

Level	Rate [kg N·ha^{-1}]	Fertilisation		
		Pre-sowingly	Shooting	Beginning of earing
N_0	0	–	–	–
N_1	60	60	–	–
N_2	120	60	30	30

A uniform level of phosphorus and potassium fertilisation was applied, respectively: 26 kg P·ha^{-1} in the form of triple superphosphate and 100 kg K·ha^{-1} in the form of 60% potassium salt. The forecrop was barley harvested for green forage.

Agricultural measures, irrespective of the experimental factors, were performed in accordance with cultivation requirements for a given plant species. The yield of triticale grain was estimated. Total protein content was determined by means of the equation: protein content = N content [g·kg^{-1}]·6.25 (according to Kjeldahl; PN ISO 2000) and protein amino acid composition after acidic hydrolysis was determined by HPLC on Knauer apparatus. Amino acid detection was conducted by the fluorescence method after aldehydation with ophtaldialdehyde. Methionine content was determined in a separate analytic cycle, after prior oxidation by formic acid with H_2O_2 and acid hydrolysis.

The results obtained from the study were statistically evaluated using analysis of variance and Tukey's test, at a significance level $\alpha = 0.05$.

The weather conditions throughout the experiment (growing seasons 2001-2003) are presented in Table 2. Average air temperature in the growing season for the research years 2001-2003 was 15.0ºC, ranging from 14.3 to 15.9ºC. These amounts are similar to the means of long-time periods. Monthly total precipitations in 2001 remained at the similar level to those of the long-term period, except for August, when total precipitation was 51.2% lower as compared with the mean total of the long-term period. In 2002, however, a substantial precipitation deficit occurred in June, amounting to 66.0% of the long-term period mean, as well as the excess in August, which amounted to 83.6 mm. The highest precipitation deficits occurred in 2003, when the total precipitation for the growing period was lower by 44.7% in relation to the long-term values. Only in July the amount of precipitation was similar to the long-term period mean, while in the other months of the growing season total precipitations are considerably lower.

Table 2. Weather conditions during growing seasons 2001-2003

Year	Month					Mean/Sum
	Apr	May	Jun	Jul	Aug	
Air temperature [ºC]						
2001	7.3	12.6	14.8	18.4	18.6	14.3
2002	8.1	16.0	16.4	19.0	20.2	15.9
2003	6.8	14.0	16.6	18.5	18.3	14.8
2001-2003	7.4	14.2	15.9	18.6	19.0	15.0
Long-term period	8.3	13.5	16.4	18.6	18.4	15.0
Precipitation [mm]						
2001	31.1	42.1	47.3	85.9	26.7	233.1
2002	25.7	56.7	29.0	96.1	83.6	291.1
2003	17.0	26.1	22.6	71.8	7.0	144.5
2001-2003	24.6	41.6	33.0	84.6	39.1	222.9
Long-term period	28.0	51.5	51.8	75.3	54.7	261.3

Results and discussion

One of the factors affecting the yield of triticale grain are genetic factors of particular cultivars. In this experiment, irrespective of the research factors, the average grain yield of spring triticale was 2.18 t·ha^{-1} (Fig. 2). Definitely higher values of this parameter were obtained by Starczewski et al. (2000), Wróbel (2005), and Knapowski et al. (2009), in their studies on the triticale cultivars 'Jago' (5.46 $t \cdot ha^{-1}$) and 'Maja' (5.30 $t \cdot ha^{-1}$), 'Gabo' (5.12 $t \cdot ha^{-1}$), and 'Kargo' (5.35 $t \cdot ha^{-1}$).

Triticale yielding may be to a great extent determined by the sowing date. Rudnicki et al. (1999) report that the delay of sowing by 10, 20 or 30 days resulted in a decrease in grain yield of spring triticale from 0.5 to 23.1%. The authors recorded the highest decrease in yield in drought years and, at the same time, at high nitrogen fertilisation, whereas a low decrease was observed in the opposite rainfall and fertilisation conditions. In this study, a delay of sowing date by two weeks in relation to the optimum resulted in a decrease in grain yield of 'Gabo' spring triticale by 36%, although it was not statistically proved (Fig. 2A).

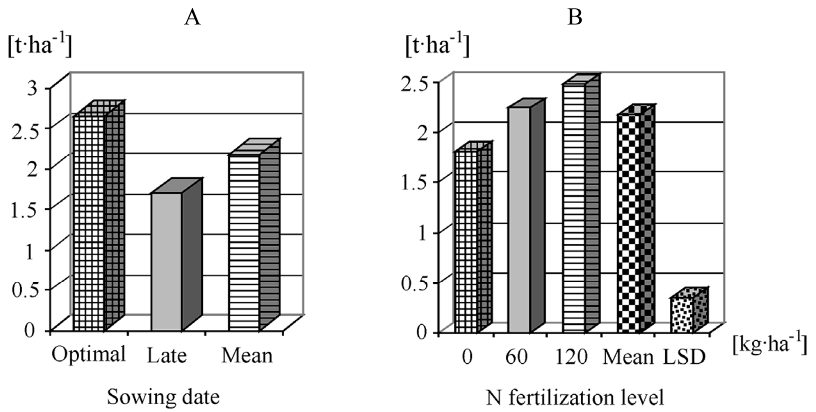

Fig. 2. Average grain yield of spring triticale depending on sowing date (A) and nitrogen fertilisation level (B)

Yield-forming activity of nitrogen is richly documented in the literature, although there is little agreement as to the optimal dose of this component under triticale (Starczewski et al. 2000; Maćkowiak et al. 2002; Nieróbca 2004; Mut et al. 2005). According to Sekeroglu and Yimez (2001), Mut et al. (2005) and Knapowski et al. (2009), a rate of 120 kg $N \cdot ha^{-1}$ proved to be significant in relation to the value of the feature in question. Koziara (2000), in turn, considers 100 kg $N \cdot ha^{-1}$ the optimal dose, and in the study by Wróbel (2005), spring triticale responded by a significant growth in grain yield up to a level of 90 kg $N \cdot ha^{-1}$. This does not correspond to the results obtained in the present study, where a dose of 60 kg $N \cdot ha^{-1}$ applied to spring triticale was justifiable, in relation to the grain yield increase (Fig. 2B). The yield obtained from that treatment was by 23.8% higher as compared with triticale yielding in the treatment without fertilisation applied. Increasing nitrogen fertilisation by the next 60 $kg \cdot ha^{-1}$ did not result in statistically significant increase of this parameter.

Triticale belongs to species with relatively large protein content, whose amount is determined genetically. In an experiment carried out by Wróbel (2005), spring triticale cv. 'Gabo' was characterized by the average value of this feature of 137 $g \cdot kg^{-1}$. Knapowski et al. (2009), in turn, recorded total protein content in grain at a level of 122 $g \cdot kg^{-1}$ for cv. 'Kargo'. In the present study, irrespective of research factors, the average total protein content in triticale grain was lower and amounted to 116 $g \cdot kg^{-1}$ (Fig. 3).

The sowing date and varied nitrogen fertilisation significantly determined the total protein content in spring triticale grain (Fig. 3). A two week delay of the sowing date in relation to the optimal date caused an increase in its content by 7.1%. This confirms the results obtained by Spychaj-Fabisiak et al. (2005).

Numerous studies report that nitrogen fertilisation is a factor determining protein content in cereal crops (Sekeroglu and Yilmaz 2001; Maćkowiak et al. 2002; Cimrin et al. 2004; Mut et al. 2005; Knapowski et al. 2009). In this study, each increase in nitrogen fertilisation level caused a significant growth in the total protein content in triticale grain. Its highest content was found after the application of 120 kg $N \cdot ha^{-1}$ and it was higher in relation to the control and to the treatment where 60 kg $N \cdot ha^{-1}$ was applied by 6.5% and 17.8%, respectively (Fig. 3). In studies by Wróbel (1997) and Knapowski et al. (2009), protein content in spring triticale grain increased significantly up to doses of 120 kg $N \cdot ha^{-1}$.

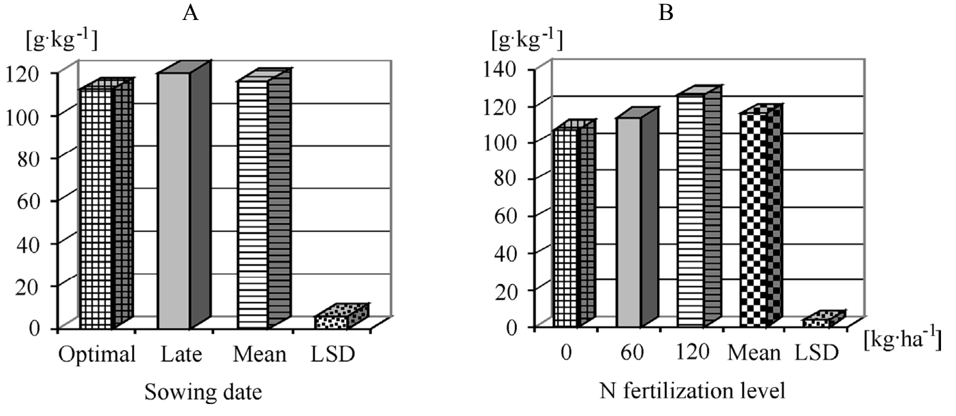

Fig. 3. Contents of total protein in spring triticale grain depending on sowing date (A) and nitrogen fertilisation level (B)

Grain of spring triticale sown at the late date, as compared with that sown at the optimal date, was characterized by a decreased content of all the tested exogenous amino acids and some endogenous amino acids (alanine, cysteine, glicyne, aspartic acid, serine) and by a higher content of such endogenous amino acids as glutamic acid, proline and tyrosine (Tables 3 and 4). A significant effect of the sowing date on the content of the tested amino acids was found only in the case of leucine as well as alanine and proline. A two week delay of the sowing date of spring triticale grain caused a significant decrease in alanine and leucine content (by 6.5% and 9.2%, respectively), whereas the proportion of proline was higher (by 10.8%). A delay of sowing date resulted in a decrease in value of the total exogenous amino acids on average by 4.7% and in an increase in value of the total endogenous amino acids by 1.7%, in relation to the optimal date. A significant effect of the interaction between the sowing date and varied nitrogen fertilisation on proline and serine content in spring triticale grain protein was also observed.

Table 3. Content of exogenous amino acids in protein of spring triticale cv. 'Gabo' [g·16 g^{-1} N] (mean of three years)

Amino acid	Sowing date (I factor)	N fertilisation (II factor) [kg·ha^{-1}]			Mean	LSD$_{0.05}$	
		$N_0 = 0$	$N_1 = 60$	$N_2 = 120$		sowing date	N fertilisation
Protein content [g·kg^{-1}]	(1) optimal	104	110	122	112		
	(2) late	110	119	131	120		
Mean		107	115	126	116	6.2	3.9
Arginine	(1) optimal	4.34	4.26	4.44	4.35		
	(2) late	4.53	4.46	3.84	4.28		
Mean		4.44	4.36	4.14	4.31	ns	ns
Phenyloalanine	(1) optimal	4.94	4.57	4.43	4.50		
	(2) late	4.74	4.29	4.04	4.36		
Mean		4.84	4.43	4.24	4.43	ns	ns
Histidine	(1) optimal	2.38	2.32	2.52	2.41		
	(2) late	2.33	2.16	2.10	2.20		
Mean		2.35	2.24	2.31	2.30	ns	ns
Isoleucine	(1) optimal	3.77	3.57	4.01	3.78		
	(2) late	3.63	3.67	2.99	3.43		
Mean		3.70	3.62	3.50	3.61	ns	ns
Leucine	(1) optimal	5.63	5.39	5.02	5.35		
	(2) late	5.49	4.96	4.57	5.00		
Mean		5.56	5.17	4.79	5.18	0.221	0.353
Lysine	(1) optimal	2.83	2.70	2.36	2.63		
	(2) late	3.14	2.44	2.16	2.58		
Mean		2.99	2.57	2.26	2.61	ns	0.389
Methionine	(1) optimal	1.60	1.52	1.43	1.52		
	(2) late	1.57	1.49	1.37	1.48		
Mean		1.59	1.51	1.40	1.50	ns	0.061
Threonine	(1) optimal	3.21	3.11	2.96	3.10		
	(2) late	3.31	2.91	2.53	2.92		
Mean		3.26	3.01	2.75	3.01	ns	0.408
Valine	(1) optimal	4.20	4.20	4.04	4.15		
	(2) late	4.41	4.09	3.64	4.05		
Mean		4.31	4.14	3.84	4.10	ns	ns
Total exogenous	(1) optimal	32.34	31.63	31.02	31.66		
	(2) late	32.80	30.27	27.45	30.18		
Mean		32.57	30.95	29.24	30.92	ns	2.967

ns – no significant difference

The results of the former studies do not estimate explicitly the effect of the varied nitrogen fertilisation of triticale on changes in protein amino acid composition (Wróbel and Budzyński 1994; Wróbel 1997). However, based on the results obtained, irrespective of the year of cultivation and the sowing date, application of growing nitrogen doses caused a decrease in contents of all the exogenous amino acids, except for histidine (Table 3). Application of a nitrogen dose of 60 kg·ha^{-1}, as compared with the control treatment, caused a decrease in proportion of particular exogenous amino acids ranging from 1.8 to 14%. Fertilisation with a dose of 120 kg N·ha^{-1} resulted in a decrease in the average content of particular exogenous amino acids, except for histidine, ranging from 3.3 to 12.1% in relation to treatment N_1, and from 5.4 to 24.4% in relation to treatment N_0 (Table 3). In the case of leucine, lysine, methionine and treonine, a decrease in their proportion in total protein of spring triticale grain under the influence of varied nitrogen fertilisation was proved statistically. A significant decrease in leucine and methionine contents was found after the application of successive nitrogen doses (60 and 120 $kg \cdot ha^{-1}$), while in lysine content (by 14%), only after the application of the first dose of this component, and in treonine content (by 15.6%), after application 120 $kg\ N \cdot ha^{-1}$ as compared with the control treatment. Nitrogen fertilisation at a dose of 60 $kg \cdot ha^{-1}$ caused a decrease in leucine and methionine contents by 7% and 5%, respectively, as compared with the control, whereas the application of a dose of 120 $kg \cdot ha^{-1}$ resulted in their further decrease by 7.4% and 7.3%. In this study, as in the study by Wróbel (1997), on average the highest proportion of exogenous amino acids in spring triticale grain protein was found in the grain obtained at the control treatment (Table 3). Of exogenous amino acids, lysine is commonly known as one of the most important amino acids, which determines grain nutritional value, and its level in protein limits the utilization of other amino acids (Wróbel and Budzyński 1994; Stankiewicz et al. 1998, Starczewski et al. 2000). In the experiment by Wróbel (1997), the application of 60 $kg\ N \cdot ha^{-1}$ caused a decrease in lysine content by 21% (in the present study, by 14%), whereas a dose of 120 $kg \cdot ha^{-1}$ resulted in a fall of 22% (in the present study, of 24.4%), as compared with the control. Similarly, in an earlier study by Wróbel and Budzyński (1994), a relative lysine content in protein of grain fertilized with nitrogen was reduced, and in the range from 0 to 60 $kg\ N \cdot ha^{-1}$ a decrease in content of this amino acid ranged from 3 to 12%, depending on the cultivar. After the application of 120 $kg\ N \cdot ha^{-1}$, a relative decrease in lysine content in relation to the control was from 15 to 20%. The authors, however, claim that if lysine content is expressed in g per kg of grain, an increase in total protein compensates a decrease in lysine, which is important from the point of view of triticale grain applications in feedstuffs. This is confirmed by the results of investigations by Bombik et al. (2000), where protein content in the grain of spring triticale cultivars was significantly, positively correlated with lysine content ($r = 0.75$). Changes in lysine content in g per 1 kg grain of spring triticale tested in the present study under the influence of increasing nitrogen fertilisation were presented in Fig. 4. Although in this study the nitrogen fertilisation at a dose of 60 $kg \cdot ha^{-1}$ caused a significant increase in proline content (by 17%) and a significant decrease in tyrosine content (by 17.4%), it did not cause statistically significant changes in the proportion of the other endogenous amino acids in total protein of spring triticale (Table 4). Application of nitrogen at a dose of 120 $kg \cdot ha^{-1}$ caused an increase in contents of alanine, cysteine, glutamic acid, and proline as well as a decrease in contents of glycine, aspartic acid, serine and tyrosine in relation to the treatment fertilized with a dose of 60 $kg\ N \cdot ha^{-1}$ and to the control treatment without fertilisation. The threshold of statistical significance for a dose of 120 $kg\ N \cdot ha^{-1}$ was reached only in comparison with the control treatment and in relation to such endogenous amino acids as glutamic acid and proline (a growth by 23.7 and 27.9 %, respectively), and tyrosine (a decrease by 29 %). In the study by Wróbel (1997), nitrogen fertilisation at a dose of 60 $kg \cdot ha^{-1}$ resulted in an increase in contents of endogenous amino acids, except for glycine, alanine, and cysteine, in relation to the control. Increasing a dose up to a level of 120 $kg\ N \cdot ha^{-1}$, as compared with a dose of 60 $kg\ N \cdot ha^{-1}$, resulted in a decrease in proportions of all the endogenous amino acids tested by this author.

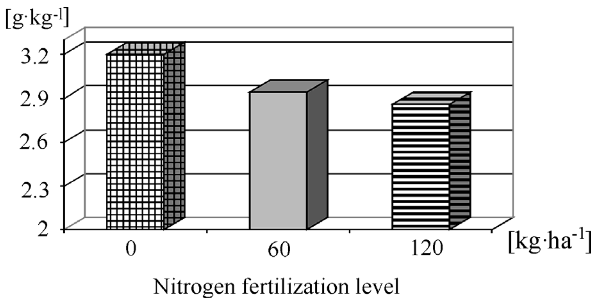

Fig. 4. Lysine content in the spring triticale protein as a function of the nitrogen fertilisation level

Table 4. Endogenous amino acid content in protein of spring triticale cv. 'Gabo' [g·16 g^{-1} N] (mean of three years)

Amino acid	Sowing date (I factor)	Nitrogen fertilisation (II factor) [kg·ha^{-1}] $N_0 = 0$	$N_1 = 60$	$N_2 = 120$	Mean	$LSD_{0.05}$ sowing date	N fertilisation
Alanine	(1) optimal	3.80	3.94	4.36	4.03		
	(2) late	3.41	3.65	3.93	3.66		
	Mean	3.60	3.79	4.15	3.84	0.315	ns
Cysteine	(1) optimal	2.36	2.30	2.42	2.36		
	(2) late	2.35	2.36	2.30	2.34		
	Mean	2.35	2.33	2.36	2.35	ns	ns
Glycine	(1) optimal	4.08	3.93	4.38	4.13		
	(2) late	3.75	4.30	3.33	3.79		
	Mean	3.92	4.12	3.85	3.96	ns	ns
Aspartic acid	(1) optimal	4.78	4.99	4.89	4.89		
	(2) late	4.55	5.35	4.39	4.76		
	Mean	4.67	5.17	4.64	4.83	ns	ns
Glutamic acid	(1) optimal	25.08	27.24	28.55	26.96		
	(2) late	23.76	27.63	31.86	27.75		
	Mean	24.42	27.44	30.21	27.35	ns	3.543
Proline*	(1) optimal	7.51	7.97	8.80	8.09		
	(2) late	7.32	9.38	10.17	8.96		
	Mean	7.41	8.67	9.48	8.52	0.655	0.928
Serine**	(1) optimal	3.59	3.50	3.81	3.63		
	(2) late	3.46	3.93	3.23	3.54		
	Mean	3.53	3.71	3.52	3.59	ns	ns
Tyrosine	(1) optimal	2.46	1.97	1.80	2.07		
	(2) late	2.72	2.32	1.89	2.31		
	Mean	2.59	2.14	1.84	2.19	ns	0.407
Endogenic sum	(1) optimal	53.67	55.84	59.00	56.17		
	(2) late	51.32	58.91	61.10	57.11		
	Mean	52.49	57.37	60.05	56.64	ns	3.969
Total amino acids sum	(1) optimal	86.01	87.46	90.22	87.90		
	(2) late	84.12	89.38	88.35	87.28		
	Mean	85.07	88.42	89.28	87.59	ns	ns

ns – no significant difference

$LSD_{0.05}$ for interaction: * I x II 0.567 II x I 0.727 ** I x II 0.461 II x I 0.592

From the present study it follows that an increase in protein content in spring triticale grain under the influence of growing nitrogen fertilisation doses was related to a decrease in total exogenous amino acid content, and an increase in total endogenous amino acid content (Tables 3 and 4). A significant decrease in the value of total exogenous amino acids (by 10.2%) was observed after nitrogen application at a dose of 120 kg·ha^{-1}, and a significant increase in the value of total endogenous amino acids (by 9.3%) after applying 60 kg·ha^{-1}, in both cases in relation to the control treatment. The results of studies obtained by Wróbel and Budzyński (1994) confirm the increase in total endogenous amino acids found in the present experiment, and a decrease in total exogenous amino acids after the nitrogen application at doses of 60 and 120 kg·ha^{-1}, as compared with the control, reported by Wróbel (1997).

On the basis of this study, it has been stated that the sowing date did not have a significant effect on the value of the exogenous amino acid index (EAI) of total protein in spring triticale grain. A considerable decrease was found, however, in the EAI value, as compared with the control treatment, after the application of the highest nitrogen dose (120 kg·ha^{-1}), as a result of which its average value decreased by 6.7% and amounted to 58.36%. The average value of the EAI calculated for grain from fertilisation with a dose of 60 kg N·ha^{-1} was higher than that in the control treatment, but the increase was not proved statistically (Fig. 5). According to Pisulewska (1995) and to Wróbel and Budzyński (1994), the intensive nitrogen fertilisation of cereal crops results in lowering of protein quality expressed by the EAI index. In the study by Barczak et al. (1994), as in the present study, a considerable decrease (by 4.6%) in the EAI index was found in winter barley grain, in relation to the control treatment, after the application of 120 kg N·ha^{-1}.

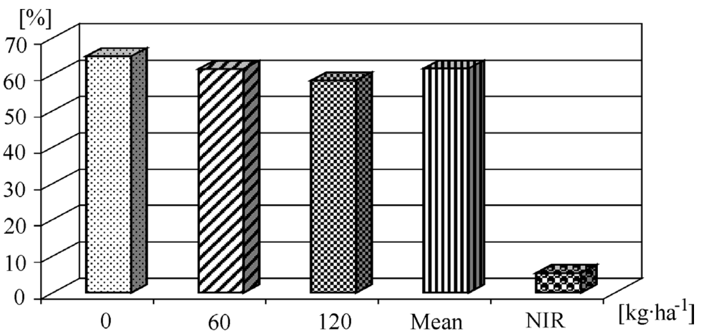

Fig. 5. Exogenous amino acid index (EAI) in spring triticale grain protein depending on nitrogen fertilisation level

From the present study it follows that under the conditions of this experiment, the first amino acid limiting biological quality of spring triticale protein was lysine, whereas the second was methionine. The study by Stankiewicz (1998) confirms that lysine is the most important amino acid limiting the quality of spring triticale protein, while valine is the next one. The author also claims that the value of limiting amino acid index (LAI) for valine decreased, and the value of LAI for lysine increased with a growth in the sowing density of triticale grain (Stankiewicz 2005). According to Makarska (1997), however, isoleucine is the first amino acid limiting the biological value of winter triticale protein and lysine is the second. In this study, it was stated that the sowing date was not a factor significantly modifying the value of LAI for lysine and methionine (Fig. 6). It was indicated, however, an effect of nitrogen doses applied on its value. Fertilizer doses applied caused a decrease in the average value of this index for lysine in relation to the control treatment, respectively, by 6.17% after applying 60 kg N·ha^{-1} and by 10.87% after applying 120 kg N·ha^{-1}. For LAI of methionine, in turn, the decrease amounted to on average 2.21% for a dose of 60 kg N·ha^{-1} and 2.42% for a dose of 120 kg N·ha^{-1}. In a study by Majcherczak et al. (2006), concerning the effect of ammonium saltpetre with an addition of microelements on amino acid content in barley grain, the lowest values of LAI for methionine and lysine were found after the application of 40 kg N·ha^{-1} in the form of ammonium saltpeter without any additives.

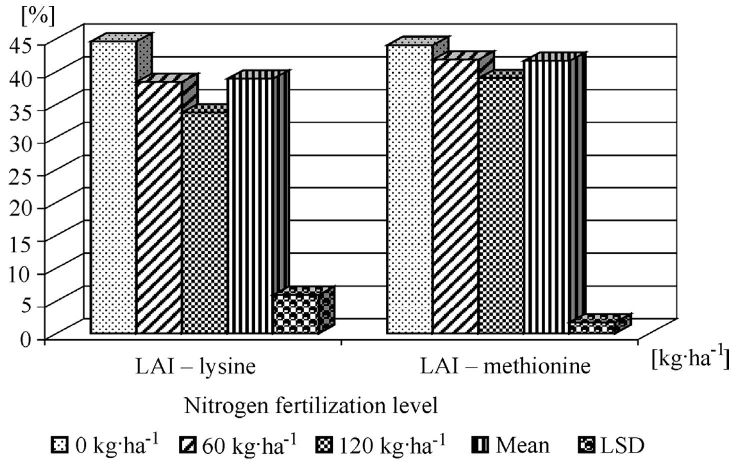

Fig. 6. Limiting amino acid index (LAI) for lysine and methionine in spring triticale grain protein depending on nitrogen fertilisation level

Conclusions

1. Increase in yield height of spring triticale grain was found with a growth of nitrogen doses applied. However, significant differences were obtained only for a dose of 60 kg N·ha^{-1}.
2. Two week delay of sowing date and nitrogen fertilisation in the whole range of the doses applied caused a significant increase in protein content in spring triticale grain.
3. Two week delay of sowing date of spring triticale grain resulted in a significant decrease in leucine and alanine contents and an increase of proline proportion in the total protein of the grain.
4. With a growth of nitrogen doses applied, a decrease in the content of exogenous amino acids, except for histidine, was observed in spring triticale grain.
5. After the application of a nitrogen dose of 60 kg·ha^{-1}, a significant increase in proline content and a decrease in tyrosine content was found, as compared with the control treatment. Nitrogen application at a dose of 120 kg·ha^{-1} resulted in an increase in

contents of glutamic acid and proline and a decrease in tyrosine content, in relation to the control treatment.

6. Fertilisation with higher nitrogen doses, caused a considerable decrease in protein quality expressed in the values of exogenous amino acid index (EAI) and limiting amino acid index (LAI) for lysine and methionine, whereas no effect of sowing date on the value of those indexes was observed.

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EFFECT OF FOLIAR FERTILISATION WITH NITROGEN AND MAGNESIUM ON CHEMICAL COMPOSITION, BIOLOGICAL VALUE AND BAKING QUALITY OF SPRING WHEAT GRAIN

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Spring wheat grain yield, its chemical composition and the biological value of protein, as well as technological parameters, are the resultant of action of many different factors (Barczak 1995; Mazurek et al. 1999; Wooding et al. 2000; Sułek et al. 2004; Majcherczak et al. 2005). These features are genetically conditioned and depend on the cultivar, but they can be diversified by both the natural environment and cultivation measures, including mineral fertilisation. The literature data indicate that nitrogen fertilisation is the most essential yield-forming factor, having the highest impact on cereal grain quality (Barczak and Nowak 1998; Kocoń 2005; Cacak-Pietrzak and Sułek 2007; Sułek and Podolska 2008). Effect of nitrogen fertilisation and its rate on the grain quality of cereal crops, due to the method of their utilization, has been the subject of many experiments (Barczak 1995; Johansson et al. 2001; Ralcewicz and Knapowski 2004). There is little detailed information in the literature concerning the implication of the application method of nitrogen jointly with magnesium. Magnesium, being a component of chlorophyll, takes part in numerous physiological processes such as photosynthesis, metabolism of fats, proteins and carbohydrates, which makes its role in plant of the utmost importance (Panak 1997; Filipek 2001). According to Czuba et al. (1999) as well as Sztuder and Świerczewska (2002), foliar application of urea solution can be a justified and highly effective measure in field crop cultivation. Such fertilisation method can prevent insufficient uptake of nutrients by the root system caused by intensive plant growth or the lack of rainfall during the growing period. The main advantage of foliar fertilisation is a fast effect and a high degree of utilization of nutrients introduced in this way (Michałojć and Szewczuk 2003).

Concerning above, a complex research was conducted with the aim to determine the grain yield, chemical composition, and biological value and baking parameters of spring wheat according to foliar application of nitrogen and magnesium against a background of constant NPK fertilisation.

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Materials and methods

Field experiment was conducted over 2005-2007 in the Research Station at Minikowo (Kuyavian-Pomeranian Province, Fig. 1) on a typical grey-brown podsolic soil, which belongs to Albic Luvisols according to international classification FAO-UNESCO. The soil, classified as the very good rye complex, was characterized by neutral pH and high or medium contents of available forms of phosphorus, potassium and magnesium (Table 1).

The experiment was established in a randomized complete block design with three replications. The experimental factor was the following fertilisation combinations (n = 5): A – control without fertilisation, B – 90 kg N·ha^{-1} in-soil, C – 90 kg N·ha^{-1} in-soil + urea foliarly, D – 90 kg N·ha^{-1} in-soil + magnesium sulphate $MgSO_4$ foliarly, E – 90 kg N·ha^{-1} in-soil + urea and magnesium sulphate foliarly.

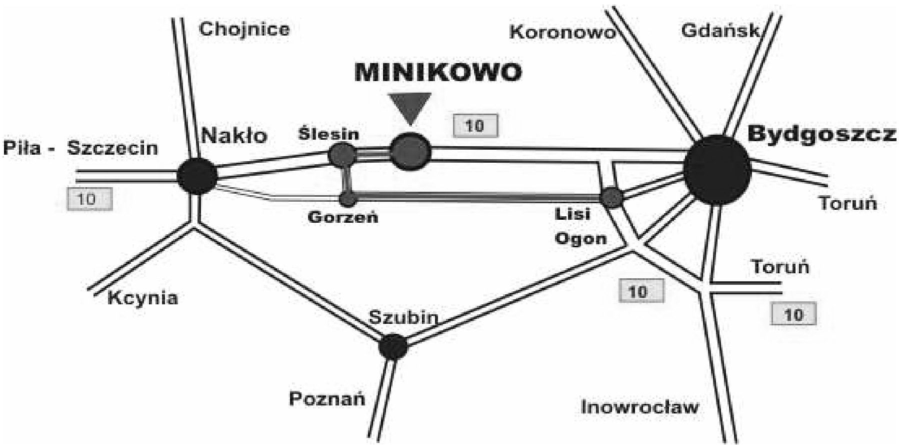

Fig. 1. Location of the field experiment (Research Station at Minikowo)

Nitrogen fertilisation at a rate of 90 kg·ha^{-1} was applied in-soil in the form of ammonium saltpetre in a divided rate: 2/3 before sowing and 1/3 at full stem elongation (stage 33 according to the Zadoks scale; Zadoks et al. 1974). Variants of foliar fertilisation were applied at the beginning of stem elongation (stage 31 according to the Zadoks scale) in the form of 10% urea solution and 5% magnesium sulphate(VI) solution and at the beginning of inflorescence emergence (stage 53 according to the Zadoks scale; 5% urea solution, 5% magnesium sulphate(VI) solution). The amount of 20.7 kg N·ha^{-1} was introduced with urea, whereas 4.8 kg MgO·ha^{-1} with magnesium sulphate(VI).

Table 1. Physico-chemical properties of soil before the establishment of experiment (2004)

pH_{KCl}	Hydrolytic acidity Hh [mmol(+)·kg^{-1} soil]	Content				
				Available forms		
		Total N	Organic C	P	K	Mg
		[g·kg^{-1}soil]		[mg·kg^{-1}soil]		
6.4-7.0	10.8-15.4	0.73-0.97	8.60-9.72	71.7-87.0	120.7-196.2	59.3-89.1

The size of the experimental plot was 20 m^2. The plant tested was spring wheat cv. 'Zebra' (qualified material – C1), and its sowing was carried out at the beginning of April with seeds conditioned with ORIUS 060 FS (60 g active compound per 1 liter), at a plant density of 5.5 mill.$\cdot$ha^{-1}.

The wheat bred by the Swedish company SVALOV WEIBULL was recorded into the List of Plant Varieties in 2001. Due to a very good technological quality, it was admitted to the group of elite wheat of E class. The cultivar is characterized by: good health and fertility, high content of protein and gluten of very good quality, medium height and resistance to lodging, rather early time of ear formation and ripening, medium grain size with medium uniformity and small content of offal, and better resistance to drought in relation to other cultivars.

The experiment was conducted based on the constant level of phosphorus and potassium fertilisation at rates of 30 kg P$\cdot$ha^{-1} and 103 kg K$\cdot$ha^{-1}, respectively. The whole fertilisation in the form of 46% triple superphosphate and 57% potassium salt was applied before sowing. The forecrop for the spring wheat was barley harvested for green forage. Cultivation measures were carried out according to the requirements typical of the species.

During the experiment, the yield of grain and protein, and the amino acid and chemical composition (N, P, K, Mg, Ca and Na) of grain was determined, as well as the following baking quality indexes: falling number (according to Hagberg, PN-ISO-3093), total protein content (%N$\cdot$5.7, PN-75A-04018), gluten content (PN-A-74-043), sedimentation index (the Zeleny's test, PN-ISO-5529), flour water absorption (PN-ISO 5530) and bread volume obtained from 100 g flour (PN-A-74108).

The results were evaluated statistically using analysis of variance and Tukey's test, at a significance level $p \leq 0.05$. In order to determine relationships between in-soil nitrogen fertilisation and the tested quality features of spring wheat, the results were analyzed by means of simple correlations and linear regression.

The weather conditions throughout the experiment (growing seasons 2005-2007) are presented in Table 2. In the first year of research, both average air temperature and total rainfall were lower than the averages of 1995-2005, by 0.8^{o}C and 41.9 mm, respectively (i.e. 15.6%). In 2006 and 2007, in turn, average air temperatures and total rainfalls were higher than the averages of long-time periods by 0.2^{o}C and 0.3^{o}C and 38.2 mm (i.e. 14.2%) and 74.7 mm (i.e. 27.8%), respectively.

Table 2. Weather conditions in growing seasons 2005-2007

Month	2005		2006		2007		Mean 1995-2005	
	Temperature [^{o}C]	Rainfall [mm]	Temperature [^{o}C]	Rainfall [mm]	Temperature [^{o}C]	Rainfall [mm]	Temperature [^{o}C]	Rainfall [mm]
Apr	8.0	23.8	7.7	66.0	8.5	17.6	8.2	29.3
May	12.7	86.1	12.4	58.8	13.8	73.1	13.4	53.2
Jun	14.8	30.2	17.1	22.7	18.2	105.5	16.2	48.4
Jul	18.6	43.2	21.0	46.1	18.0	104.7	18.3	77.9
Sep	16.5	43.1	17.0	112.9	17.8	42.1	18.4	59.5
Mean	14.1		15.1		15.2		14.9	
Total		226.4		306.5		343.0		268.3

Results and discussion

Grain yield height of spring wheat

In the present experiment, the average grain yield of spring wheat was 3.90 $t \cdot ha^{-1}$ (Fig. 2) and it was higher by 0.58 $t \cdot ha^{-1}$ than the yield obtained for the same cultivar in the study by Biskupski et al. (2004). Sułek and Podolska (2008), in turn, using nitrogen fertilisation under spring wheat cv. 'Nawra' at the rate of 90 $kg \cdot ha^{-1}$ (45 kg before sowing and 45 kg at stem elongation), obtained an average grain yield of 5.95 $t \cdot ha^{-1}$.

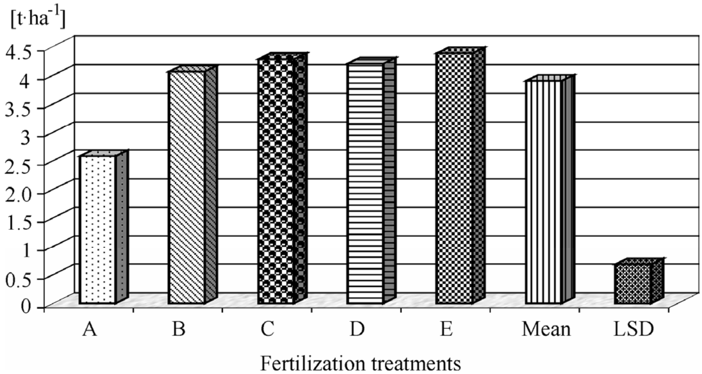

Fig. 2. Grain yield of spring wheat as affected by fertilisation treatment; A – control, B – 90 kg $N \cdot ha^{-1}$ (in-soil), C – 90 kg $N \cdot ha^{-1}$ (in-soil) + urea (foliar), D – 90 kg $N \cdot ha^{-1}$ (in-soil) + $MgSO_4$ (foliar), E – 90 kg $N \cdot ha^{-1}$ (in-soil) + urea (foliar) + $MgSO_4$ (foliar)

In-soil application of 90 kg $N \cdot ha^{-1}$ (B) and foliar fertilisation in all the variants (C, D, and E) resulted in a significant increase in grain yield in relation to the control treatment (A), which amounted to: 57.4%; 65.9%; 62.8% and 69.8%, respectively (Fig. 2). It also appeared that the most favourable variant of foliar application is to apply urea and magnesium sulphate(VI) in a joint measure, which was also proved in experiments by Czuba et al. (1999).

Chemical composition of spring wheat grain and its ionic balance

Spring wheat is a cereal used mostly for consumption. Therefore, apart from the yield, also the content of macroelements in grain, which are an important source of mineral substances in human diet and constitute a grain quality parameter, is essential for nutritional reasons. Macroelement content in cereal grain is characterized by a large variation depending on soil abundance of available nutrients, the weather conditions prevailing during growing season, the cereal species and cultivar as well as cultivation measures, of which fertilisation seems to be of primary importance (Matyka et al. 1993; Pisulewska et al. 1998; Kocoń 2005; Brzozowska 2006). It should be stressed that foliar fertilisation is one of the fastest and most effective method for providing plants with nutrients (Szewczuk and Michałojć 2003).

Under conditions of the present experiment, the contents of total phosphorus in spring wheat grain varied, and ranged from 4.48 to 4.70 $g \cdot kg^{-1}$ (Table 3). Significantly more phosphorus in relation to the control treatment was found in grain obtained from the treatments where foliar urea was applied, whereas the least, when the plants were fertilized with magnesium sulphate(VI). After joint application of urea and magnesium sulphate(VI) slightly less amounts of total phosphorus were found in grain, in relation to the control treatment, than after application of urea. However, the differences were not confirmed statistically.

Potassium contents in spring wheat grain ranged from 4.30 $g \cdot kg^{-1}$ to 4.73 $g \cdot kg^{-1}$. Of the treatments where only in-soil fertilisation was applied, potassium contents in grain were the highest (Table 3). It is worthy of note that average potassium content in grain decreased under the influence of foliar application, reaching the lowest value after urea application. In comparison with the control, this decrease amounted to 2.9%.

Foliar fertilisation accelerates plant development, and thus, the application of urea, which is known to have yield-forming activity as well as to support taking up other nutrients by plants, caused an increase in grain yield. As a result, the potassium content in yield decreased. A similar effect was obtained after joint application of urea and magnesium sulphate(VI).

After foliar urea application, a significant decrease of magnesium content was found in wheat grain. As compared with the control treatment, the decrease was on average 2.5%. Grain coming from the other tested fertilisation treatments contained also less magnesium than that collected from the treatment without fertilisation.

Table 3. Chemical composition of wheat grain as affected by fertilisation

Parameter [$g \cdot kg^{-1}$]	Fertilisation					Mean	LSD
	A	B	C	D	E		
P	4.49	4.54	4.70	4.48	4.62	4.56	0.168
K	4.43	4.73	4.30	4.43	4.40	4.46	0.209
Mg	1.22	1.19	1.13	1.17	1.20	1.18	0.070
Na	0.32	0.31	0.29	0.32	0.30	0.31	0.003
Ca	0.34	0.39	0.37	0.39	0.34	0.37	0.002

For explanations, see Fig. 2

The foliar application of urea solution caused also a significant decrease in sodium content in grain, which amounted to 9.4%, as compared with the control treatment (Table 3). Urea applied jointly with magnesium sulphate(VI) decreased sodium contents by 6.3%. A decrease in the content of this element in grain most likely resulted from the yield growth and occurrence of so-called effect of component thinning in yield (Table 3). Foliar magnesium sulphate(VI) application did not cause changes in sodium content in grain.

In the present study the average calcium content in wheat grain of all the fertilisation treatments amounted to 0.37 $g \cdot kg^{-1}$. A significant increase in the concentration of this element in grain was observed after in-soil fertilisation application – by 14.7% in relation to the control treatment, and in treatments where foliar application of urea and magnesium sulphate were performed – an increase by 8.8% and 14.7%, respectively. Combination of urea and magnesium sulphate applied together did not change calcium concentration in grain. In the study by Brzozowska (2006), foliar nitrogen application in triticale cultivation did not have a significant effect on calcium concentration in grain.

For nutritional reasons, in cereal crops intended for consumption and fodder, such as wheat, proper quantitative relations between ions may be of utmost importance. According to Metson (1984), optimal ionic relations in plants intended for feed should be as follows: K : Mg = 6 : 1, K : (Ca + Mg) = 1,6-2,2 : 1, and Ca : P = 2 : 1. It should be noted that these values can differ substantially for plants used mainly for consumption.

In the present study, exclusively in-soil fertilisation, and also with foliar urea application, resulted in a significant widening of the Mg : (K + Na) ration in wheat grain in relation to the control treatment, which amounted to 2.87 and 2.93, respectively (Table 4).

Table 4. Ionic relations in wheat grain as a result of fertilisation

Determined parameter	Fertilisation					Mean	LSD
	A	B	C	D	E		
Mg : (K + Na)	2.64	2.93	2.87	2.72	2.64	2.76	0.194
Ca : Mg	2.77	2.49	2.49	2.34	2.73	2.56	ns
K : (Ca + Mg)	0.63	0.61	0.63	0.64	0.63	0.63	ns
Ca : P	7.96	7.09	7.91	6.95	8.15	7.61	1.027
Mg : K	2.34	2.62	2.55	2.42	2.35	2.45	0.182
(Ca + Mg) : (K + Na)	1.81	1.85	1.80	1.79	1.81	1.81	ns
Na : K	9.47	10.31	9.98	9.48	11.07	10.06	ns

For explanations, see Fig. 2
ns – no significant difference

No effect on the Ca : Mg ratio, however, was observed of both in-soil and foliar fertilisation; its average value amounted to 2.56. According to Majcherczak et al. (2006), this parameter did not changed in grain of spring barley fertilized foliarly with microelements.

No changes in relation to the control treatment were also indicated in the present study in the K : (Ca + Mg) ratio, whose value in particular fertilisation treatments was close to the average from the study, which was equal to 0.63 (Table 4). Panak et al. (1986) state that the widening of this ionic relation may be caused by magnesium deficiency at the excess of potassium ions. This has a negative effect on ionic balance in plant and the ratio of the other ions, contributing to the worsening of grain chemical composition. Considerable widening of value of this ratio in grain was obtained by Majcherczak et al. (2006) by means of foliar boron fertilisation of spring barley.

Based on the present study it was stated that the Ca : P ration did not change remarkably under the influence of the experimental factor, as compared with the control treatment. However, a widening of its value was observed under the influence of foliar application of magnesium sulphate(VI) jointly with urea (8.15), as compared with the single application of magnesium sulphate (6.95). A higher value of this ration resulted from the effect of urea, which caused an increase by 3,1% of total phosphorus in grain in relation to the treatment fertilized only with magnesium sulphate(VI).

The study indicated that in grain collected from treatments only in-soil the ionic Mg : K ratio was considerably widened, as compared to the control treatment, and its value was 2.62 (Table 4). This was a consequence of a significant increase in potassium content in grain as a result of in-soil fertilisation, which amounted to 6.8%. The content of magnesium in grain of wheat fertilized only in-soil decreased by 2.5%.

Fertilisation applied did not cause changes in values of (Ca + Mg) : (Ka + Na) proportions, which ranged from 1.81 to 1.85. A significant increase in the ratio of monovalent to bivalent ion contents in winter barley grain as a result of nitrogen fertilisation was found by Barczak et al. (2005). In the study by Majcherczak et al.

(2006) a widening of the ratio of monovalent to bivalent cation sum in spring barley grain was obtained after foliar application of zinc, manganese or boron.

Ionic Na : K ratio did not change significantly under the influence of the fertilizers applied. Its values in wheat grain from particular fertilisation plots were varied and ranged from 9.47 in the control treatment to 11.07 after urea application jointly with magnesium sulphate(VI). Contribution of magnesium in maintaining the proper balance in plants between ions of sodium, potassium and calcium is stressed by Filipek (2001) and Jacobsen (1993).

Protein content in spring wheat grain and its biological value

In the present study, the average content of total protein in grain was 132 $g \cdot kg^{-1}$ (Fig. 3). Higher values of this quality parameter (ranging from 135 to 156 $g \cdot kg^{-1}$), in experiments with spring wheat, were obtained by Cacak-Pietrzak and Sułek (2007).

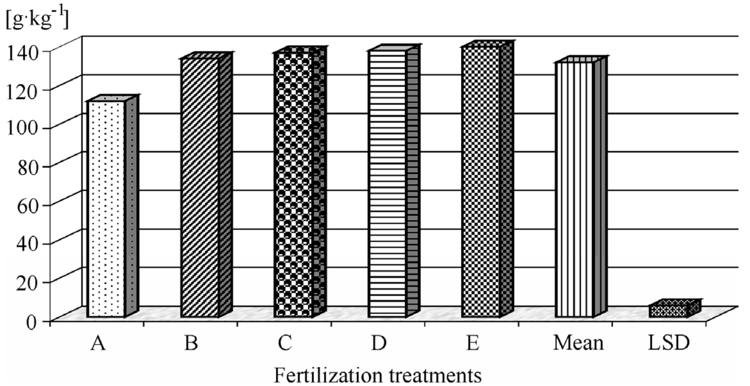

Fig. 3. Contents of total protein in spring wheat grain as affected by fertilisation. For explanations, see Fig. 2

According to Sztuder and Świerczewska (2002), besides specific varietal features, total protein content in spring wheat grain is determined also by foliar fertilizers applied. The highest effect of foliar fertilizers applied on the content of this component in wheat grain was indicated in the case of the cultivar 'Sigma', in which protein content ranged from 106 $g \cdot kg^{-1}$ in the treatment without foliar fertilisation to 138 $g \cdot kg^{-1}$ in the treatment where triple spraying with urea, magnesium sulphate and Polvit Z/J was applied. In the present study, all the variants of foliar fertilisation resulted in a significant increase in total protein content in grain, which in relation to the control treatment amounted to: 25 $g \cdot kg^{-1}$ (after urea application), 26 $g \cdot kg^{-1}$ (after $MgSO_4$ application) and 28 $g \cdot kg^{-1}$ (after the joint application of urea and $MgSO_4$; Fig. 3). However, the highest value of this parameter was obtained in treatments where nitrogen and magnesium were applied in a joint measure and they were significantly higher, as compared with the control treatment and with that fertilized with nitrogen only in-soil, by 25.0% and 4.5% respectively (Table 5).

As with a study by other authors (Ralcewicz and Knapowski 2004), significantly positive correlations were found between total protein content in grain and gluten content (r = 0.93), sedimentation index (r = 0.88) and bread volume (r = 0.94; Table 6).

Table 5. Amino acid content in spring wheat grain protein as affected by fertilisation [%, averages of three-year study]

Amino acid	Fertilisation						LSD
	A	B	C	D	E	Mean	α = 95%
Protein [g·kg^{-1}]	112	134	137	138	140	132	5.9
Asparagin acid	5.16	4.80	4.29	4.68	4.74	4.73	ns
Glutamin acid	28.43	27.82	25.34	28.37	27.28	27.45	ns
Serine	2.83	2.45	2.48	2.31	2.27	2.47	ns
Glycyne	1.94	2.02	1.88	2.06	1.80	1.94	ns
Alanine	3.02	2.58	2.37	2.52	2.33	2.56	0.35
Tyrosine	3.62	3.36	3.39	3.09	3.02	3.30	ns
Sum of endogenic	45.00	43.03	39.75	43.03	41.44	42.45	2.70
Lysine	3.06	2.55	2.49	2.87	2.52	2.70	0.38
Methionine	0.67	0.81	0.87	0.79	0.74	0.77	ns
Isoleucine	3.93	3.91	3.26	3.81	3.61	3.70	0.40
Leucine	6.53	5.82	5.17	5.98	5.95	5.89	0.48
Threonine	3.94	3.10	2.97	3.22	3.45	3.34	ns
Arginine	4.80	4.51	4.05	4.33	3.92	4.32	ns
Valine	5.03	4.71	4.19	4.75	4.47	4.63	0.35
Phenyloalanine	6.31	5.82	5.54	6.15	6.38	6.04	ns
Histidine	3.18	2.98	2.67	2.97	2.85	2.93	ns
Sum of exogenic	37.45	34.21	31.21	34.87	33.89	34.32	1.70
Total sum	82.45	77.24	70.96	77.90	75.33	76.77	4.06
Essential amino acid index	65.25	60.79	56.34	61.92	59.59	60.78	2.43
Chemical score for lysyne	45.60	37.95	37.15	42.80	37.50	40.20	5.79
Chemical score for methionine	18.45	22.35	24.05	21.85	20.60	21.46	ns

ns – no significant difference

Changes in total protein content in wheat grain indicated as a result of varying fertilisation were the consequence of changes in its amino acid composition (Table 5). In the present study, fertilisation applied caused a significant decrease in the total of amino acid content, including the sum of exogenous amino acids, in all treatments in relation to the control treatment. A decrease in amino acid proportion in protein under the influence of fertilisation resulted from a largely significant decrease in alanine, isoleucine, leucine, valine and lysine contents under this conditions. A negative correlation between the content of these amino acids and total nitrogen proportion in wheat grain (corresponding correlation coefficients were: $r = -0.968$, $r = -0.541$, $r = -0.697$, $r = -0.747$, $r = -0.753$) is worthy of note. Unfavourable changes in protein amino acid composition as a result of nitrogen fertilisation are indicated in many studies, also on other cereal species (Cwojdziński 1979; Barczak and Nowak 1998; Majcherczak et al. 2005). Such a direction of changes in protein quality is a consequence of changes in its fraction composition. Under the influence of nitrogen fertilisation, changes in proportions occur between the content of reserve proteins of grain endosperm (prolamins and glutelins), poor in lysine, and the amount of exogenous proteins of embryo and aleurone layer (albumins and globulins), rich in amino acids (Barczak 1995). It should be stressed that besides methionine, lysine is considered as an amino acid limiting the nutritional value of cereal protein (Gawęcki 2003).

In the present study for all the exogenous amino acids determined, the values of limiting amino acid indexes (CS) were calculated, which expresses the ratio of amino acid content in the tested protein to the content of a given amino acid in egg white, considered as the standard protein with the optimal nutritional value. The lowest values of these indexes in relation to the other amino acids were obtained for lysine and methionine (respectively, 40.2% and 21.5%).

It should be stressed, however, that although the values CS_{lysine} decreased significantly under the influence of the fertilisation applied in the study, the values $CS_{methionine}$ clearly increased, although the differences were not confirmed statistically. Another criterion of protein nutritional value, which takes into consideration its amino acid composition, is exogenous amino acid index (EAA-Index), defined as geometrical mean from the product of ratios of particular exogenous amino acid contents in the tested protein to the corresponding contents in the standard protein, translated into percentages. Fertilisation applied in the study caused a significant decrease in comparison with the control treatment of the EAA-Index value for each treatment, and particularly for treatments where nitrogen was applied only in-soil as well as in-soil and foliarly.

In treatments where besides nitrogen foliar magnesium sulphate(VI) was applied, only slight changes in amino acid composition of protein were found in relation to the corresponding variants fertilized only with nitrogen (B and C). Although the treatments differed significantly in the sum of exogenous amino acid contents (a difference of 2.69 $g \cdot kg^{-1}$ (8.6%)), but of the amino acids determined, statistically proved differences were found only for leucine (0.78 $g \cdot kg^{-1}$, 15.1%). No significant differences were found in the amino acid composition of wheat grain after in-soil nitrogen and foliar magnesium sulphate(VI) application, as compared with the treatment where nitrogen was applied only in-soil. Although magnesium is a part of chlorophyll and sulphur is a component of methionine and cysteine, and both components are activators of many enzymatic processes, playing an important role in protein synthesis (Kopcewicz and Lewak 2005), the present study did not confirm a considerable effect of magnesium sulphate(VI) application on protein quality. It may be concluded that the lack of explicit response to the presence of both elements in fertilisation was probably caused by the sufficient soil abundance of these components in relation to plant nutritional requirements. Many authors (Panak 1997; Jakubus and Toboła 2005; Szulc 2008) stresses that fact that a high effectiveness of sulphur and magnesium can be obtained only under conditions of their great deficiency in soil.

Technological parameters of spring wheat grain

An important evaluation parameter of wheat grain technological value is falling number, which characterizes enzymatic properties, particularly amylolytic activity. In the present experiment, as with in studies by other authors with spring wheat (Ralcewicz and Knapowski 2004; Sułek and Podolska 2008), the obtained average values of spring wheat falling number (above 300 s) indicate a low activity of alpha-amylase and do not disqualify the grain tested in respect of its usefulness for baking (Fig. 4). According to Sułek et al. (2006) and Cacak-Pietrzak and Sułek (2007), falling number value is mostly affected by genetic features of the cultivar and the weather conditions during plant grown and grain harvesting. Application of foliar fertilizers resulted in obtaining unproved statistically differences in values of this quality feature.

The amount and quality of gluten contained in wheat flour affect bread baking qualities. According to many authors, nitrogen fertilisation determines gluten content and can also have an effect on gluten quality (Wooding et al. 2000; Johansson et al. 2001; Podleśna and Cacak-Pietrzak 2006; Sułek and Podolska 2008). In the present experiment, foliar nitrogen fertilisation application at a rate of 90 kg·ha^{-1} resulted in a significant increase in the content of this component as compared with the gluten content obtained in the control and it was higher by 8.2% (Fig. 5). Also it has been stated that foliar application with solutions of urea, magnesium sulphate(VI) and urea and magnesium sulphate (VI) resulted in an increase in gluten content in spring wheat grain as compared with treatments A and B, although statistically significant only in relation to the control. Remarkable growth in gluten content under the influence of foliar fertilisation of spring wheat (by 17.6% as compared with the control) was found by Sztuder and Świerczewska (2002) and it was the highest in the case of cv. 'Sigma' after joint application of urea solution, magnesium sulphate and Polvit Z/J. Due to a high correlation between wet gluten content and sedimentation index proved in the earlier studies, gluten quality is determined by the value of this index (Ralcewicz and Knapowski 2004).

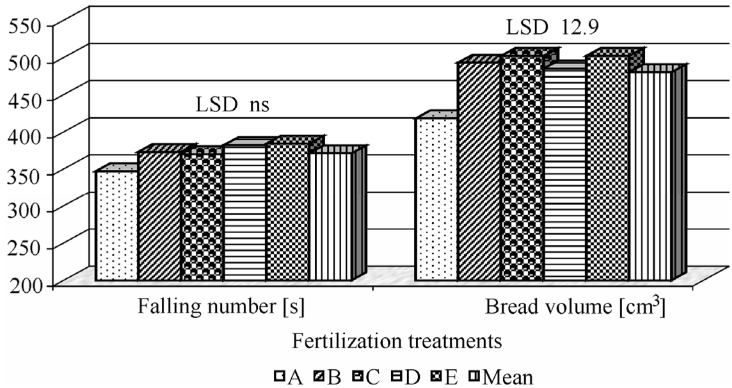

Fig. 4. Falling number and bread volume of spring wheat as affected by fertilisation. For explanations, see Fig. 2

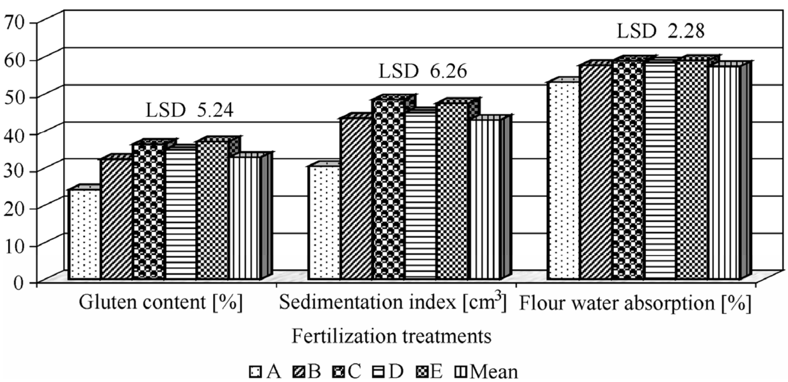

Fig. 5. Effect of fertilisation on contents of gluten, sedimentation index, and flour water absorption of spring wheat. For explanations, see Fig. 2

In studies with spring wheat carried out by Mazurek et al. (1999), Ralcewicz and Knapowski (2004), and Sułek and Podolska (2008), growing rates of nitrogen fertilisation had a positive effect on values of sedimentation index. Cacak-Pietrzak and Sułek (2007), in turn, stated that in all the tested cultivars of spring wheat (in 2006) an increase in nitrogen fertilisation level caused a decrease in the value of sedimentation number. In the present experiment, in-soil application of 90 kg N·ha^{-1} resulted in a significant increase in the value of the quality feature in question in relation to the control and the decrease amounted to 13 cm^3 (Fig. 5). Even higher values of sedimentation index were obtained after additional application of fertilisation combinations in foliar application. This particularly refers to treatments with foliar fertilisation in the form of urea and urea plus magnesium sulphate(VI) (significantly higher values as compared with the control by 18 cm^3 and 17 cm^3, respectively).

Sedimentation number was highly significantly positively correlated with total protein content and wet gluten (Table 6), which was also indicated in a study by Ralcewicz and Knapowski (2004). Relationships between the above baking features are also described by calculated and charted linear regression equations (Figs 6 and 7).

Table 6. Significant simple correlation coefficients between tested features of spring wheat

Parameter	(1)	(2)	(3)	(4)	(5)	(6)
(1) Grain yield	–	0.51	0.91	0.95	0.86	0.52
(2) Falling number	0.51	–	0.68	–	0.49	–
(3) Protein content	0.91	0.68	–	0.93	0.88	0.58
(4) Gluten content	0.95	–	0.93	–	0.90	0.55
(5) Sedimentation index	0.86	0.49	0.88	0.90	–	0.83
(6) Flour water absorption	0.52	–	0.58	0.55	0.83	–
(7) Bread volume	0.92	0.60	0.94	0.88	0.82	0.52

The quantity and quality of gluten and starch damage degree have an essential effect on flour water absorption (Sułek et al. 2002; Podleśna and Cacak-Pietrzak 2006). As with the study by Podleśna and Cacak-Pietrzak (2006), in the present experiment the in-soil nitrogen application (90 kg·ha^{-1}) resulted in an increase in flour water absorption value, and the increase was significantly higher by 4.5%. It is worthy of note that the value of the parameters in question was determined by the variant of foliar fertilisation applied. The highest flour water absorption was found in the treatment where urea and magnesium sulphate(VI) was applied (59.0%), and slightly lower in treatments C (58.9%) and D (58.4%; Fig. 5). Flour water absorption was significantly positively correlated with protein content, wet gluten content and sedimentation index (Table 6).

A direct quality index, which indicates the baking quality of wheat grain, is bread volume obtained from the test baking. As in other studies with spring wheat (Ralcewicz and Knapowski 2004; Podleśna and Cacak-Pietrzak 2006), in-soil nitrogen fertilisation applied in the experiment caused an increase in bread volume obtained from flour (Fig. 4). The increase was significant in relation to the control treatment (A) and amounted to 11.7%. However, bread volume values obtained from foliar application treatments jointly with nitrogen and magnesium (E) or with nitrogen only (C), were significantly higher, as compared with this value both obtained in the treatment without fertilisation (A) and in the treatment where only foliar magnesium was applied (D), and it was respectively 20.1% and 1.8%.

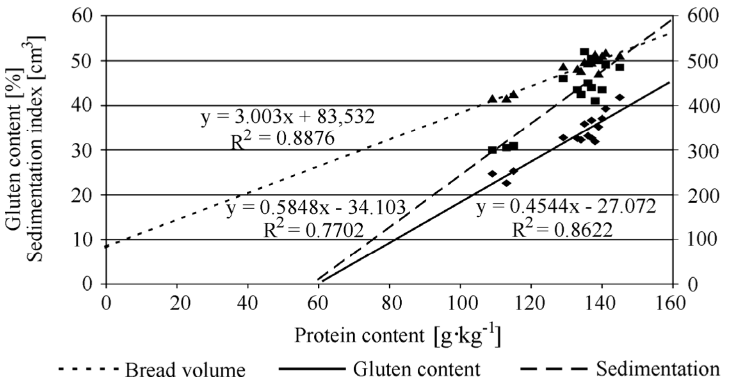

Fig. 6. Relationship between total content of protein and gluten, sedimentation index, and bread volume of spring wheat

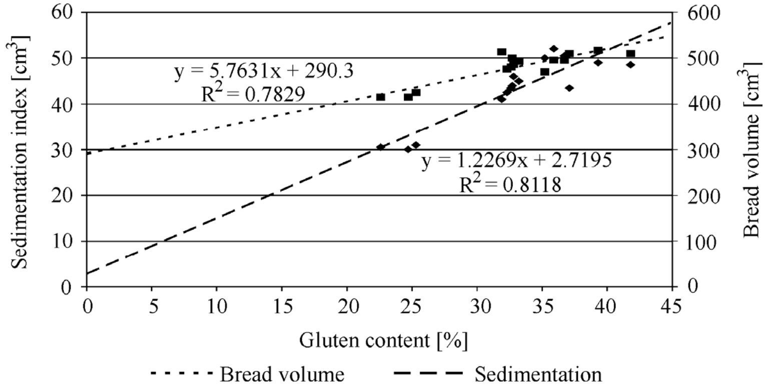

Fig. 7. Relationships between gluten content, sedimentation value, and bread volume of spring wheat

Bread volume was significantly positively correlated with the value of sedimentation index (r = 0.82; Table 6), which confirms the thesis that a higher proportion of high-particle glutenin increases bread volume (Verbruggen et al. 2001). Żmijewski et al. (1999), in turn, confirmed a significant positive correlation between bread volume and protein content, whereas they recorded a negative correlation for relationship between these feature and the falling number. In the present study, the quality feature in question was significantly positively correlated with all the baking parameters.

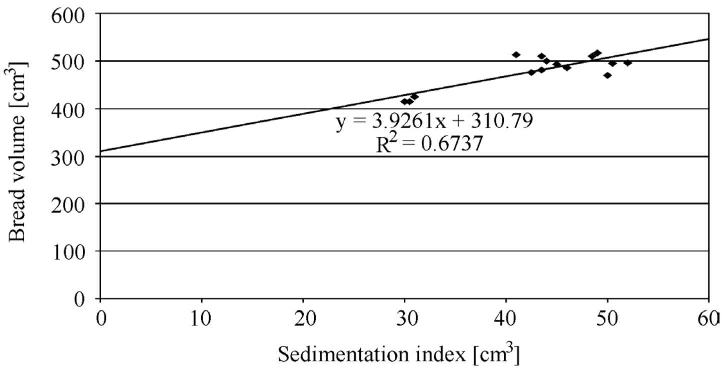

Fig. 8. Relationship between sedimentation index and bread volume of spring wheat

Relationships between bread volume and total protein content, wet gluten content and sedimentation value were described by linear regression equations, on the basis of which it can be calculated that with a growth of the above mentioned quality features e.g. by 5 units, volume of bread from 100 g flour can growth respectively by 15 cm^3, 27.8 cm^3 and 19.6 cm^3 (Figs 6-8).

Conclusions

1. Significantly highest grain yield of spring wheat cv. 'Zebra', as compared with the control, was observed after joint foliar application of urea and magnesium against a background of constant mineral fertilisation.
2. Contents of phosphorus and total potassium in wheat grain were comparable and significantly the highest as compared with the treatment without fertilisation, after foliar urea and in-soil nitrogen application, respectively. After urea application, however, the significantly lowest contents of magnesium and sodium were observed.
3. Fertilisation significantly determined the values of Mg : (K + Na), Mg : K, and Ca : P ratios. After in-soil or foliar nitrogen application in the form of urea against a background of constant mineral fertilisation, the values of both Mg : (K + Na) and Mg : K ratios were significantly wider in relation to values obtained in the control treatments.
4. Significantly highest content of total protein in spring wheat grain was found after joint foliar application of urea and magnesium, both in relation to contents obtained from the control treatment and after in-soil nitrogen application.
5. Applied fertilisation did not have a positive effect on biological value of protein, which is proved by values of indexes of exogenous amino acids and of the limiting amino acid for lysine.
6. Average significantly highest values of baking parameters in relation to the control were found after either foliar urea application or joint application of urea and magnesium against a background of constant mineral fertilisation.

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APPLICATION OF FUNGICIDES AND INSECTICIDES TO RED FESCUE (*Festuca rubra* L.) GROWN FOR SEED I. EFFECT ON YIELD

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Grasses grown for seed in Poland over the last few years (2005-2008) covered about 13 thousand ha (Main Inspectorate of Plant Health and Seed Inspection). One of the most essential species in reproduction is red fescue (*Festuca rubra* L.) the proportion of which accounts for about 22% of the seed plantation area of all the grasses. Red fescue boom is connected with the demand for the seed of lawn cultivars (Martyniak and Martyniak 2002), applicable for sodding of difficult areas such as slopes, roadsides (Goliński 2000), soil-less land improvement (Patrzałek 2003) or ash-slag dumps (Kitczak et al. 2003).

The basic condition of the cost-effectiveness of crop cultivation is the level of yielding, which depends on natural factors (e.g. rainfall, soil quality) and anthropogenic factors (e.g., the cultivar selection, level of fertilisation, growing experience) (Goliński 2000; Martyniak and Martyniak 2002). One of the factors which can guarantee the stability of seed yields and enhance their quality is also plant protection from agrophages (Czembor 2003).

Red fescue, similarly as other grasses, is commonly attacked by pathogens and pests. The threat varies depending on the subspecies, utilization method, weather or agrotechnical conditions (Kindler et al. 1991; Prończuk 1996, 2000; Czembor 2003; Prończuk et al. 2003; Lamparski and Szczepanek 2008; Pańka and Szczepanek 2008; Ropek and Kacorzyk 2008).

Pathogens cause wilting of plant parts, and even their dying, a decrease in the number of generative tillers, the seed number and weight (Czembor 2003). When facing a strong infection, yield losses can reach even 80% in the first year of use (Prończuk 2005). Pathogens occur also on kernels (Wiewióra and Prończuk 2000). Some of them can cause a decrease in the viability of seeds during storage (Musiał 1996). Research on the application of plant protection agents to growing grasses for seed are ambiguous (Czembor 2003). The application of fungicides in smooth meadow-grass (*Poa pratensis* L.) did not result in a significant increase in the seed yield (Cagas 1992). In the case of perennial ryegrass (*Lolium perenne* L.) a single application of fungicide prior to flowering increased the seed yield even by 21.5% as compared with no-treatment variant (Goliński 2003).

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Pests suck out sap or eat leaves, which leads to weakening the plants and limiting the assimilation area. Feeding on seed grasses can result in spike fusariosis, a decrease in the seed weight or a lack of seeds in spikes or panicles (Zawirska 1971). In the reports by Cagas (1987) the application of insecticides as well as burning of post-harvest residue in red fescue cultivation for seed limited the occurrence of inflorescences with spike fusariosis symptoms.

The degree of damage caused by diseases and pests and their effect on the plant productivity depends on the intensity of the occurrence and can be limited by the application of plant protection agents. Bearing that in mind, research has been taken up to evaluate the threat posed by pathogens (Pańka and Szczepanek 2009) and pests (Lamparski and Szczepanek 2009) of red fescue during a two-year period of full use and a possibility of increasing productivity, as well as the yield quality (present paper) by applying fungicides and insecticides.

Materials and methods

The present research was based on a strict field experiment, set up at Chrząstowo near Nakło, on the soil of class IV, of the very good rye complex, in completely randomised design, in four replicates. The plot size was 15 m^2. The research involved the use of lawn cultivar, 'Nimba', of red fescue (*Festuca rubra* L. ssp. *commutata*), which is one of the top lawn creations but the seed yield is much lower than this of other chewings cultivars of that species (Martyniak and Prończuk 2003). Fescue was sown in 2004 and 2005 and used for seed for two successive years, 2005-2006 and 2006-2007, respectively. Mixed sowing with spring barley cv. 'Justina', sown at the rate of 120 $kg \cdot ha^{-1}$ was applied. The full-protection treatment, when a threat posed by pathogens or pests was identified, was applied; during the vegetation period by spraying with adequate plant protection agents using the backpack sprayer. Over the sowing years, in September, azoxystrobin, a fungicide of the strobilurine group, was applied at the dose of 250 $g \cdot ha^{-1}$. Over the years of full use, two protective treatments were used: the first one was performed at the panicle emergence stage (the second decade of May), applying azoxystrobin at the dose of 250 $g \cdot ha^{-1}$ and deltamerthrin, an insecticide of the pyrethroid group, at the dose of 7.5 $g \cdot ha^{-1}$, while the second one at the end of flowering/beginning of grain filing (the second half of June), with fungicide containing prochloraz (imidazole) and propiconazole (triazole), at the doses of: 400 and 90 $g \cdot ha^{-1}$, respectively. In 2006 at the second date also lambda cyhalothrin of pyrethroid group at the dose of 6 $g \cdot ha^{-1}$ was applied. Over ripening, generative tillers at the row length corresponding to 0.25 m^2 and the number of spikelets and seeds in the sample of twenty panicle per plot were calculated. The leaf greenness index (the content of chlorophyll) was measured with the N-Testera test. The apparatus measures the difference in the absorption of light at the wavelength of 650 nm (maximum light absorption by chlorophyll a and b) and 940 nm (light retained by leaf tissues). The quotient of those differences is displayed in a form of the s-called SPAD (Soil-Plant Analyses Development) units (Fotyma 2000). The measurements were taken for 30 youngest, randomly selected leaves from each plot. The seed harvest was performed in the 1-2 decade of July. The germination test was made 5-6 months after harvest, based on 100 seeds in four replicates, following the method by the International Seed Testing Association (International Rules for Seed Testing 2009). To break the dormancy, KNO_3 was used. The present results concern the final germination evaluation (21 days after sowing). The statistical analysis was performed in the completely randomised design at p = 0.05. The analysis of variance for the percentage results was made after angular transformation.

Results and discussion

In the research area, the total rainfall is about 515 mm, of which most coincide in June, July and August (69, 71 and 58 mm, respectively). For an adequate growth and development of grasses grown for seed, weather conditions April through June are most important (Szczepanek 2005). Over the research years the rainfall and temperature distribution varied a lot (Fig. 1). In April and May 2005 rainfall, although not quite high, exposed to moderate temperatures were sufficient. In 2006 a heavy water deficit which appeared in early June inhibited growth, caused wilting of leaves, stalks and premature seed maturity. In 2007, as early as mid-March the average daily air temperature exceeded 5^{o}C, which resulted in an earlier (by about 2 weeks) start of vegetation as compared with 2005 and 2006. Water deficit occurred in April, especially in the 2nd and 3rd decade of that month, at the red fescue shooting phase.

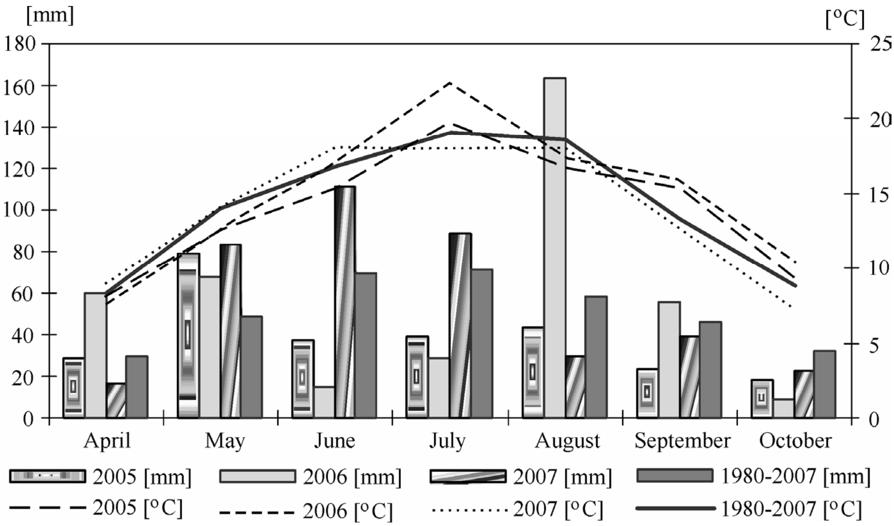

Fig. 1. Mean air temperature and total rainfall at Chrząstowo in the years 2005-2007

Both in the first and in the second year of full use, on average for the entire vegetation period, leaves of red fescue exposed to full chemical control with fungicides and insecticides demonstrated a higher value of greenness index, as compared with the no-treatments variant (Fig. 2). In the first seed harvest year a positive effect of protection was significant at the panicle emergence stage, in the second one – at the shooting phase. Such a plant condition was favourable for the creation of assimilates indispensable for seed filling and increased the yield (Fig. 3). An increase in the yield of perennial ryegrass seeds exposed to a few-time application of fungicides from the shooting phase to harvest is similarly accounted for by Hampton and Hebblethwaite (1984) who claim that the application of the preparations delayed the aging of photosynthetic-active tissues. As reported by Rolston et al. (2004), the application of fungicides (triazole, strobilurine) not only made the infection control possible but also increased maintaining the perennial ryegrass leaf greenness, which resulted in an increase in the seed yield by 20% in the case of fodder cultivars and 43% in lawn cultivars.

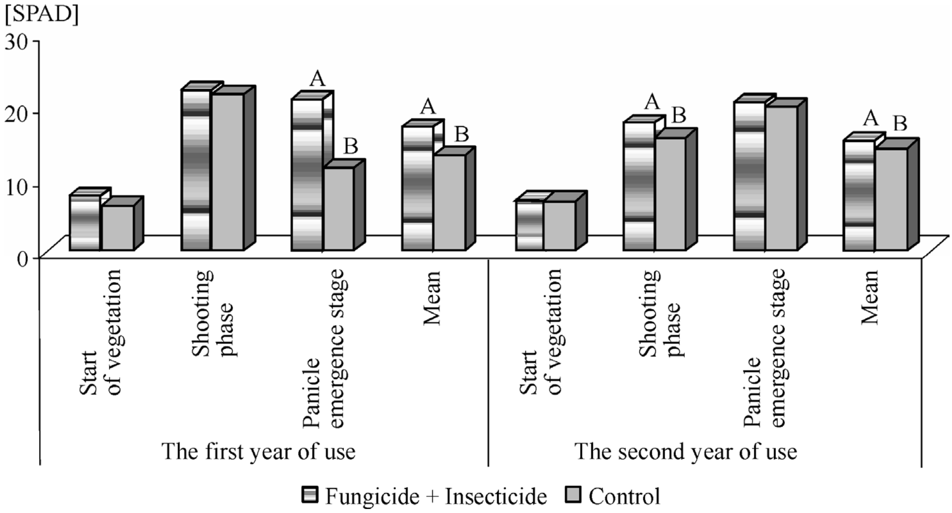

Fig. 2. Leaf greenness index of red fescue in the first and second year of use; means for 2005--2006 and 2006-2007. Means followed by different letters differ significantly at p = 0.05

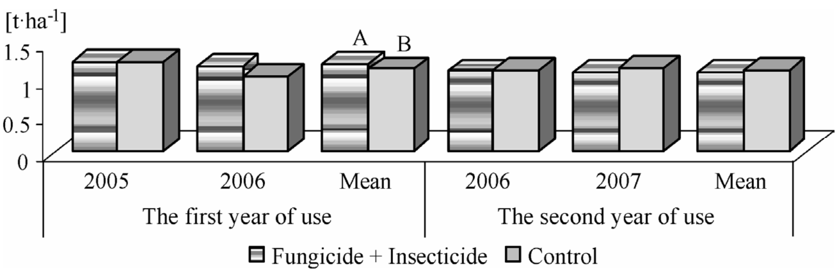

Fig. 3. Seed yield of red fescue in the first and second year of use. Means followed by different letters differ significantly at p = 0.05

The average level of yielding of the red fescue was high (mean for two years of use 832 kg·ha^{-1}). Martyniak and Martyniak (2002) claim that red fescue in Poland yields from 2.2 to 10.8 dt·ha^{-1} and they consider the yield exceeding 8 dt·ha^{-1} as high. On production plantations in Greater Poland growing that cultivar yields exceeding 4.1 dt·ha^{-1} were reported (Goliński 2000), and in the experiments located at Radzików only 4.7 dt·ha^{-1} (Martyniak and Prończuk 2003).

The effectiveness of the protection treatments applied in the present research was relatively low, which could have been due to an inconsiderable intensity of the occurrence of diseases in spring (Pańka and Szczepanek 2009), as well as of pests from panicle emergence stage to milk-dough stage of kernels (Lamparski and Szczepanek

2009). In the first year of full use, average for two series of experiments, the treatment of red fescue with fungicides and insecticides resulted in a significant increase in yield of 60.6 kg·ha^{-1} (Fig. 3). In the second year of harvest the treatments were also favourable (an increase in yield by 52.7 kg·ha^{-1}), but also the difference was non-significant. Welling (1987) showed an increase in the red fescue seed yield by 70 to 120 kg·ha^{-1} at the application of propiconazole at the shooting phase and three weeks later, which was connected with limiting the occurrence of leaf spot (*Drechslera* spp.).

Considering the costs of the tractor operation provided by Agricultural Counselling Centres and the prices of pesticides in the sales outlets, the cost of fungicide and insecticide throughout the growing cycle (the sowing year and two years of use) was about 750 PLN·ha^{-1}, therefore the break-even point of such treatments was at the price of seeds of PLN 6.60 per 1 kg. In the Kuyavia and Pomerania region the purchase prices are 30-40% lower, therefore, assuming the economic use of the seed yield only, the full protection is economically unjustifiable. A lack of economic justifiability of such protection variant is confirmed by a low value (60%) of profitability ratio (ratio of the value of increase in the yield to treatment costs). The reports by Goliński (2003) showed that the application of fungicides on perennial ryegrass seed plantation increased the yield by 56-165 kg·ha^{-1}, depending on the preparation used and the research year. Such an increase in yield guaranteed the profitability of a single treatment prior to flowering in the first year of full use.

An effect of protection against agrophages on the number of generative tillers neither in the first nor in the second year of use was found (data not presented). Prończuk (2000) reports on autumn infection of *F. rubra* with *Puccinia graminis* ssp. *graminicola* and *P. festucae* limiting the number of generative tillers. No such reaction in the present research can be accounted for by an inconsiderable intensity of the occurrence of rust (Pańka and Szczepanek 2009) during autumn formation of tillers capable of the perception of thermal stimulus in the sowing year or the first year of full use.

The application of full chemical protection did not affect the number of spikelets per panicle in the first year of full use; in the second year of harvest, average for both series and in 2007 it had a positive effect on that character of the morphological structure of inflorescence (Fig. 4).

The protection treatments had a favourable effect on the number of seeds per spikelet, both in the first and in the second year of full use, which was mostly thanks to the results reported in 2006 (Fig. 5). An increase in the effectiveness of seed setting in the full protection variant was one of the major factors increasing the red fescue seed yield. Similarly, Hampton and Hebblethwaite (1984), investigating perennial ryegrass, mostly refer an increase in the seed yield due to fungicide treatment to an increased number of seeds per spikelet.

The first seed harvest year was the only one in which an average for two series of experiments and in 2006 the thousand seed weight were greater in the variant of full chemical control (Fig. 6). Similarly, Goliński (2003) identified an increased plumpness of perennial ryegrass seeds following the application of the fungicide. Most probably maintaining high photosynthetic activity of leaves, with a high value of chlorophyll index (Fig. 2) made a greater accumulation of assimilates in seeds possible.

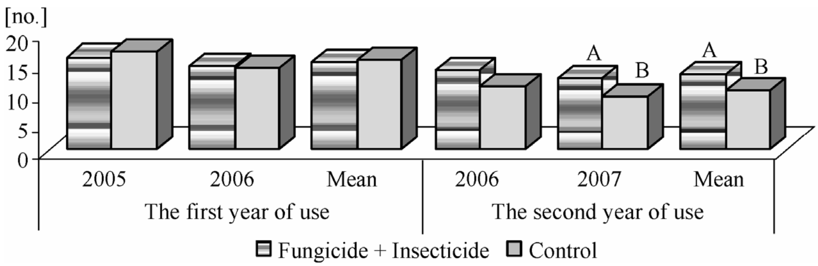

Fig. 4. Number of spikelets per panicle of red fescue in the first and second year of use. Means followed by different letters differ significantly at p = 0.05

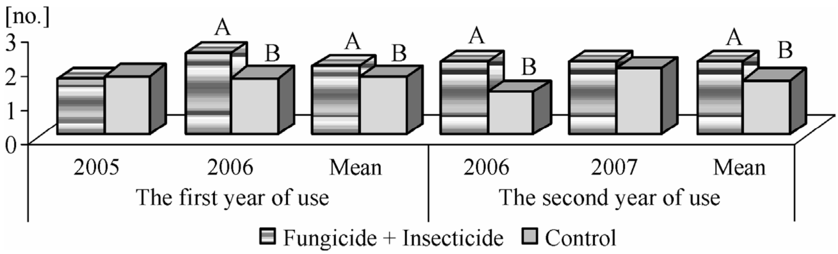

Fig. 5. Number of seeds per spikelet of red fescue in the first and second year of use. Means followed by different letters differ significantly at p = 0.05

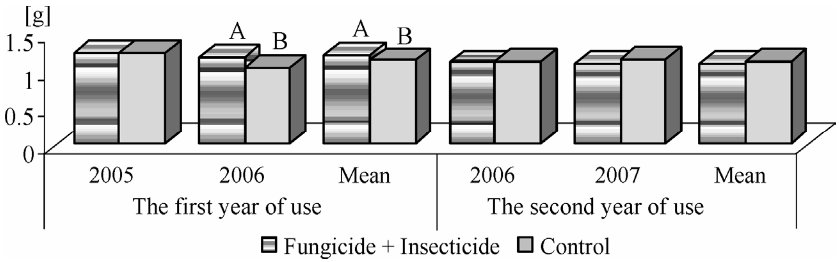

Fig. 6. Thousand seed weight of red fescue in the first and second year of use. Means followed by different letters differ significantly at p = 0.05

The seed germination test demonstrated a positive effect of the application of fungicides and insecticides on the proportion of normal seedlings in the seed yield from the first year of full use, on average for both series and in 2006 (Fig. 8). In the control, at lower number of such seedlings, an increase in the proportion of fresh seeds (swollen but producing no seedling) was observed (Table 1). Germination of such seeds could have been blocked due to embryo underdevelopment, or a higher concentration of phytoestrogens inhibiting germination, which corresponds to a lower thousand seed weight (Fig. 6). Larsen and Andreasen (2004) demonstrated a decrease in the germinability of red fescue at lower weight of kernels. Grzesiuk and Kulka (1981) claim that the immature seeds can get into deeper dormancy than the fully mature ones due to the increased accumulation of germination inhibitors. Similarly the infection of seeds with pathogens could have contributed to an increase in the proportion of fresh seeds in the control. The decrease in germinability of grasses of *Festuca* genus could be caused by *Fusarium* genus fungi (Ocamb and Alderman 2004), or *Gleotinia* (Prończuk 2000). Mebalds and Price (2008) showed that fungicides inhibited the occurrence of *Gleotinia temulenta* on perennial ryegrass, especially when applied over tillering and flowering. Goliński (2003) showed no effect of the application of fungicides on the germinability of perennial ryegrass. A single treatment must have been insufficient for the protection of seeds from seed infestation with pathogens.

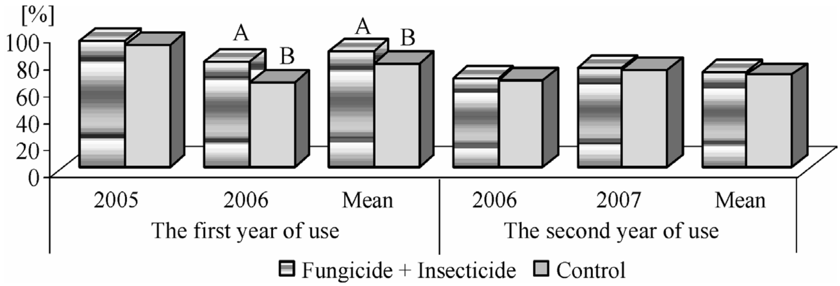

Fig. 7. Proportion of normal seedlings in the final evaluation of germination of the seeds of red fescue in the first and second year of use. Means followed by different letters differ significantly at p = 0.05

Red fescue in the variant of full protection from pathogens and pests in autumn in the first year of use, on average for both series and in 2005, produced a higher yield of dry matter of the autumn regrowth as compared with the control (Fig. 8). Similar, although non-significant was the reaction of fescue in the second year. The protection treatments limited the occurrence of diseases in autumn: rust, spot and, less considerably, powdery mildew (Pańka and Szczepanek 2009), which increased the plant regeneration potential after seed harvest. Prończuk (2000) reports on red fescue infection in autumn by *Puccinia* genus fungi strongly increasing the plant vigour. A positive effect of the application of fungicide with insecticide on the green forage yield was also reported by Lewis and Clements (1999) investigating *Lolium multiflorum*.

Table 1. Proportion of hard, fresh, abnormally germinating, and dead seeds in yield of red fescue [%]. Means followed by different letters differ significantly at p = 0.05

Treatment	Year of use					
	First			Second		
	2005	2006	Mean	2006	2007	Mean
	Hard					
Fungicide + Insecticide	0.3	0.5	0.4	0.5	2.3	1.4
Control	0.3	3.5	1.9	3.0	2.8	2.9
	Fresh					
Fungicide + Insecticide	0.3	17.0	8.6 A	32.8	15.1	24.0
Control	0.3	29.5	14.9 B	26.0	16.6	21.3
	Abnormally germinating					
Fungicide + Insecticide	1.5	4.5	3.0	2.5	1.6	2.0
Control	2.3	3.0	2.6	2.5	1.1	1.8
	Dead					
Fungicide + Insecticide	0.3	1.0	2.1	4.6	5.6	5.1
Control	4.3	6.5	5.4	3.0	6.0	4.5

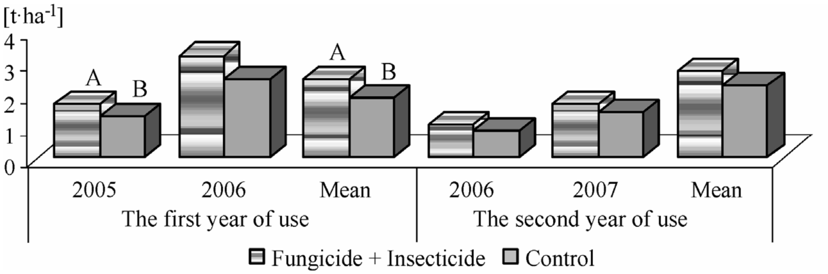

Fig. 8. Yield of dry matter of autumn regrowth of red fescue in the first and second year of use. Means followed by different letters differ significantly at $p = 0.05$

Conclusions

1. Full chemical control applied to red fescue cv. 'Nimba' against diseases and pests resulted in a significant increase in the seed yield (7.3%) and autumn regrowth (29%) in the first year of full use, as compared with the no-treatment variant. In the second year the effectiveness of protection is lower.
2. The application of protection treatments with fungicides and insecticides has a favourable effect on the index of leaf greenness of generative tillers and setting of seeds in spikelets in both harvest years.
3. In the first year of use, exposed to full chemical control of red fescue against agrophages, at a higher thousand seed weight, the proportion of normal seedlings increases and the proportion of fresh (swollen but non-germinating) seeds decreases.
4. An increase in the seed yield by 113 kg in the two-year period of use does not compensate the costs of full chemical control. Additional research of simplified protection systems will provide the grounds for optimization of the application of fungicides and insecticides in red fescue growing for seed.

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APPLICATION OF FUNGICIDES AND INSECTICIDES TO RED FESCUE (*Festuca rubra* L.) GROWN FOR SEED II. EFFECT ON DISEASES OCCURRENCE

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Red fescue, similarly as other grass species, can be infected by numerous pathogens during the vegetation period. Mikołajska (1960) found the occurrence of 71 fungal species on grasses in Poland; not all pose a major threat for plants. Those which, according to Kućmierz (1977), are potentially most dangerous represent 20 species; mostly, microorganisms which cause leaf-spot symptoms, e.g. *Bipolaris sorokiniana* and fungi belonging to genus *Drechslera*. European literature, however, lists only a few microorganisms which are considered most dangerous in the cultivation for animal feed and for seed: *D. anderseni*, *D. catenaria*, *D. dictyoides*, *D. poae*, and *D. siccans* (Wilkins 1972; Cook 1975; Labruyere 1980; Lewis 1992, 1994; Burhenne et al. 1994; Kutrzeba 1994). The most common diseases on leaves, despite spots, include also rusts. Grasses are infected by rust fungi of genus *Puccinia* and *Uromyces*. Often one grass species can be infected by a few fungal species of these genera. Red fescue, for example, is found to be infected with *Uromyces festucae*, *Puccinia coronata*, *P. festucae*, and *P. graminis* ssp. *graminicola* (Majewski 1977). The biggest losses, however, are most frequently caused by *P. festucae* and *P. graminis* ssp. *graminicola* (Czembor 2003; Prończuk 2005), especially *P. graminis* ssp. *graminicola* is considered to be one of the most dangerous pathogens in grass growing for seed. It infects mostly leaf sheaths, stems and inflorescences, forming spores in uredinia and telia, which results in drying of plant parts and even their wilting, reducing the number of generative stems and increased transpiration as a result of tearing of the epidermis by spore clusters. The intensity of occurrence and the disease development depend considerably on temperature, precipitation, humidity, level of inoculum, and even the number of days and hours when the leaf surface is dry. The average temperature of 10^{o}C recorded for successive 30 days enhances considerably the development of the pathogen. Such a period, if recorded in early spring, poses a major threat to grass seed plantations (Welty and Barker 1994). Similarly, the occurrence of powdery mildew (*Blumeria graminis*) can be dangerous for the plants if it coincides with shooting, tillering or flowering. The pathogen develops especially intensively when exposed to a lowered air circulation, low light intensity, high humidity, fertilisation and density, and at the

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temperature of about 18°C (O'Rourke 1975). Most often the disease is recorded in spring and in autumn, affecting the general plant condition and wintering. A decreased seed yield and its contamination with sclerotia is observed also when inflorescences are infected with *Claviceps purpurea*. The pathogen decreases the seed number and weight (Czembor 2003). Besides, honey dew abundant during flowering, containing conidial spores of the fungus, gets inflorescences stuck together and makes harvest difficult (Prończuk 2005). An additional unfavourable effect of the presence of *C. purpurea* in the plant can be the content of metabolites toxic for animals produced by this pathogen. A similar risk is found also when grasses are infected with *Fusarium* genus fungi and infestation with endophytic fungi of *Neotyphodium* and *Epichloë* genera, representing, similarly as the cause of ergot, family *Clavicipitaceae*. *Neotyphodium* and *Epichloë* are most often asymptomatic in the plant producing strongly toxic compounds, including lolitrem B, ergovaline and ergotamine (Schardl 2001). Ergovaline and ergotamine are often found in red fescue infested by *E. festucae*. Endophytic fungi, however, occur more often in the grasses of permanent grasslands and wild-growing, as compared with cultivable grasses (Dapprich et al. 1994; Lewis et al. 1997; Pańka and Sadowski 2002). The presence of endophytes can, on the other hand, have a positive effect on the plant growth and development and increase its resistance to infection with pathogens and pest feeding (Hesse et al. 2002; Bouton and Easton 2005; Pańka 2005).

These microorganisms occur seasonally, at specific plant development stages and depending on the weather pattern. Their pathogenicity depends on many factors, and the decrease in yield can range from a few even up to over 90% (Kućmierz 1977; Schultz et al. 1993; Prończuk 2005). However, stating the need to provide chemical control of the plantation is a problem. In some European countries or in North America chemical control is recommended, especially on seed plantations. On the other hand, the local occurrence of diseases or weather conditions unfavourable to the infection question the cost-effectiveness of protection practises (Labruyere 1980; Kalton et al. 1996).

With that in mind, research has been taken up to determine threats posed by pathogens and pests (Lamparski and Szczepanek 2009) to red fescue grown for seed when exposed to fungicides and insecticides treatments and their effect on yielding (Szczepanek 2009).

Materials and methods

The present research involved red fescue (*Festuca rubra* L. ssp. *commutata*) cv. 'Nimba', grown for seed. The field experiments were set up in completely randomised design, in 2004 and 2005 and used for two successive years. A detailed description of the conditions of setting up the experiment has been provided in the paper by Szczepanek (2009). Pesticides against diseases were applied when there was reported a threat posed by pathogens: in the year of sowing: autumn treatment in September with Amistar 250 SC **(**azoxystrobin – 250 $g \cdot dm^{-3}$), at the dose of 1.0 $dm^3 \cdot ha^{-1}$, whereas in the years of full use – two treatments: at the panicle emergence stage with Amistar 250 SC, at the dose of 1.0 $dm^3 \cdot ha^{-1}$ and at the end of flowering – with Bumper Super 490 EC (prochloraz – 400 $g \cdot dm^{-3}$, propiconazole – 90 $g \cdot dm^{-3}$) at the dose of 1.0 $dm^3 \cdot ha^{-1}$. The insecticides application pattern is described by Lamparski and Szczepanek (2009). Observations into the occurrence of disease symptoms on plants were made in the year of sowing once, in autumn, in the first year of use twice, in summer, during ripening, and in autumn, at the end of vegetation, while in the second year of use only in summer.

The plant infection was evaluated by using a modified scale by Birckenstaedt et al. (1994), where 0 stands for healthy leaves and 8 for leaves where disease symptoms were visible on over 69.3% of the leaf surface for rust and powdery mildew and 64.7% of the leaf surface for leaf spots. In each replication, 50 randomly sampled leaves were analysed. The degrees were converted into infection index (II) following the Townsend and Heuberger formula (Wenzel 1948), and then exposed to the analysis of variance for single-factor experiments in the completely randomised design. The significance of differences was determined based on the Tukey's confidence semi-intervals.

Results and discussion

The analysis of plant infection in the present experiment demonstrated mostly the presence of pathogens causing rust, spot and powdery mildew (Tables 1-3). Evaluating the plant wintering in spring in the first and second year of use there was found a sporadic occurrence of symptoms of infection with *Microdochium nivale*. Isolating microorganisms from wilting stems showed the presence of this pathogen and *Fusarium* fungi. Relatively most plant wilting symptoms were recorded in 2006. Prończuk (2000) also observed a variation in the occurrence of post-winter damage. It was a derivative of the susceptibility of the cultivar to infection by a complex of pathogens, effect of weather conditions of a given year as well as the age of plants.

Table 1. Occurrence of rusts, leaf spots, and powdery mildew [index of infection in %] in red fescue protected and unprotected with pesticides in the year of sowing (Chrząstowo 2004-2005)

Observation term	Observation year				Mean	
	2004		2005			
	Experimental combination					
	fungicide + insecticide	control	fungicide + insecticide	control	fungicide + insecticide	control
Autumn	Rusts					
	2.57 a*	7.27 b	2.22 a	5.99 b	2.39 a	6.63 b
	LSD 1.95		LSD 0.84		LSD 0.46	
	Leaf spots					
	3.13 a	8.82 b	2.06 a	5.85 b	2.59 a	7.33 b
	LSD 1.72		LSD 1.04		LSD 0.57	
	Powdery mildew					
	0.60 a	1.45 a	0.11 a	0.76 a	0.35 a	1.10 b
	LSD 1.07		LSD 0.65		LSD 0.36	

* values marked with the same letter in rows for each year and disease do not differ significantly at p = 0.05

The intensity of occurrence of those pathogens varied (Table 1). The weakest symptoms were recorded in red fescue in the year of sowing of both series. It was i.a. due to the shortest grass growth period without protective crop and thus the shortest exposition to an attack of pathogenic microorganisms. The intensity of occurrence of disease symptoms was not, therefore, high and in 2004 in the control combination reached the maximum of 8.82% for spots, 7.27% for rusts, and 1.45% for powdery mildew. A greater healthiness of grasses grown as companion crop for spring barley is confirmed by earlier perennial ryegrass reports (Pańka and Szczepanek 2008).

The infection index in 2005 was even lower than in 2004. The statistical analysis showed in both years a significant effect of the protection treatment on the occurrence of rusts and spots. There was noted no such effect in the case of powdery mildew, which must have been due to a very low intensity of *B. graminis* occurrence in plants not exceeding 1.45 and 0.76%, respectively, in 2004 and 2005. Symptoms at similarly low level were also recorded in the first year of full use of the second series (2006) for all the pathogens (Table 2). The year demonstrated water deficit in summer, which limited the development of diseases in red fescue. Only in the case of spot the statistical analysis showed a significant effect of fungicide treatment on limiting the disease development. The end of the vegetation period was, on the other hand, more favourable to the development of pathogens due to higher precipitation, which resulted in a higher degree of plant infection. Then there was observed a positive effect of fungicides, especially on limiting the occurrence of rust and spot. The first year of full use of the first series (2005) was relatively favourable to the development of diseases. In summer pathogens causing leaf spots were developing most intensively. The fungicides significantly protected the plants against their attack. Autumn observations identified a positive effect of chemical control on the plant health status, especially on the occurrence of rusts and spots.

Table 2. Occurrence of rusts, leaf spots, and powdery mildew [index of infection in %] in red fescue protected and unprotected with pesticides in the first year of use (Chrząstowo 2005-2006)

Observation term	Observation year				Mean	
	2005		2006			
	Experimental combination					
	fungicide + insecticide	control	fungicide + insecticide	control	fungicide + insecticide	control
Summer	Rusts					
	0.31 a*	2.21 a	0.0	0.65 a	0.16 a	1.43 b
	LSD 1.90		LSD 0.70		LSD 0.38	
	Leaf spots					
	3.06 a	13.20 b	1.31	4.55 b	2.18 a	8.87 b
	LSD 3.26		LSD 1.04		LSD 0.57	
	Powdery mildew					
	0.06 a	1.14 a	0.03	0.06 a	0.05 a	0.60 b
	LSD 1.16		LSD 0.15		LSD 0.08	
Autumn	Rusts					
	3.29 a	14.19 b	6.62	20.16 b	4.95 a	17.17 b
	LSD 4.28		LSD 3.87		LSD 2.11	
	Leaf					
	2.86 a	15.04 b	4.60	17.86 b	3.73 a	16.45 b
	LSD 3.10		LSD 3.19		LSD 1.74	
	Powdery mildew					
	0.86 a	3.20 a	1.47	5.53 a	1.17 a	4.36 b
	LSD 2.41		LSD 4.55		LSD 2.48	

* values marked with the same letter in rows for each year and disease do not differ significantly at p = 0.05

In the second year of use there was recorded usually higher plant infection in both series as compared with the first year (Table 3). A higher susceptibility to infection in successive years of use was also observed by Prończuk (2000); it causes a gradual blurring of differences across the experimental combinations. Definitely better conditions for development were found in pathogens in 2007 and so the summer evaluation revealed a significant effect of chemical control on the occurrence of all the three diseases analyzed. In 2006 the infection was lower and the protective effect of the fungicide occurred only in the case of spot.

Table 3. Occurrence of rusts, leaf spots and powdery mildew [index of infection in %] in red fescue protected and unprotected with pesticides in the second year of use (Chrząstowo 2006--2007)

Observation term	Observation year				Mean	
	2006		2007			
	Experimental combination					
	fungicide + insecticide	control	fungicide + insecticide	control	fungicide + insecticide	control
Summer	Rusts					
	1.32 a*	4.19 a	3.97 a	9.46 b	2.64 a	6.82 b
	LSD 3.20		LSD 3.72		LSD 2.03	
	Spots					
	2.29 a	8.89 b	2.49 a	22.56 b	2.39 a	15.73 b
	LSD 3.20		LSD 5.39		LSD 2.94	
	Powdery mildew					
	0.06 a	1.00 a	2.40 a	6.30 b	1.23 a	3.65 b
	LSD 1.05		LSD 3.45		LSD 1.88	

* values marked with the same letter in rows for each year and disease do not differ significantly at p = 0.05

In successive years of the experiment a relatively moderate occurrence of the disease analyzed was observed. The poorest disease symptoms were caused by *B. graminis*. A very low infection of red fescue with this pathogen was also reported by Prończuk (2000). Slightly more disease symptoms were recorded by the author in the case of leaf spots, especially during wet weather and most in the case of rust over summer and autumn. In the present research a greater intensity of the occurrence of spots and rusts in autumn was also noted. A reduced leaf blade area of meadow fescue is not favourable to infection with spores of pathogenic microorganisms. For that reason the species is usually less infected than the others. Some reports show a growing importance of rust fungi due to a stronger negative effect on yielding as compared with the pathogens causing spots (Welty and Barker 1994; Feuerstein 2000). Rust fungi, on the other hand, can deteriorate the quality of the green forage produced more considerably. Both *Fusarium* and *Drechslera* pathogens as well as *Bipolaris* pathogens can produce metabolites harmful for animals, e.g. trichothecenes (*Fusarium* spp.), helmintosporal and sterigmatocystin in the infected plants (*Bipolaris* spp., *Drechslera* spp.; Chełkowski 1985; Kwaśna et al. 1991). These pathogens transferred with kernels decrease their viability and can pose a threat in the initial period of development of young plants, resulting in their wilting (Musiał 1996; Wiewióra and Prończuk 2000).

Analysing the mean values for the year of sowing and successive years of use, one can state a significant positive effect of the fungicide treatments on the health status of red fescue grown for seed. The plants in chemical-control combinations used to be less infected by fungal pathogens, causes of rusts, spots and powdery mildew, which was reflected in their better condition, which had a special effect on an increase in the seed yield and the number per spikelet (Szczepanek 2009). A significant variation was reported by the author for the mean yielding values in the first year of use of both series, and for the number of seed per spikelet in both years of full use. An increase in the perennial ryegrass seed yield following the application of fungicide was also observed by Goliński (2003). A positive effect of fungicides on plants can be not only due to protection against pathogens but also a positive effect on their growth and development. Fungicides from the groups being derivatives of strobilurine (Amistar 250 EC) are known thanks to their effect on biochemical processes in cells, especially water economy which allows the plants for keeping the leaf surface green longer, which has a direct effect on the intensification of the process of photosynthesis, and thus assimilate accumulation. It is confirmed by the analysis of the green leaf area index performed by Szczepanek (2009) who reports on its higher level in the combinations with fungicide protection. Besides, a positive effect of strobilurin protection is expressed with a better plant growth and development, which results in their higher resistance to biotic and abiotic stress factors which occur in later growth phases. Szczepanek (2009) observed an increase in the dry matter of autumn regrowth in the combinations with fungicidal protection. Plant infection in these combinations in autumn was also lower.

Conclusions

Red fescue cv. ‘Nimba’, was mainly infected by pathogens causing leaf spots, rusts and powdery mildew. The intensity of occurrence of *Blumeria graminis* was very low at all the observation terms. In the plants there were recorded stronger spots and rusts symptoms, especially in the case of autumn infection evaluation. The chemical control applied enhanced the health status of plants, which was confirmed in most cases by the statistical analysis.

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APPLICATION OF FUNGICIDES AND INSECTICIDES TO RED FESCUE (*Festuca rubra* L.) GROWN FOR SEED III. EFFECT ON THE OCCURRENCE OF PESTS

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Red fescue (*Festuca rubra* L.) is one of the most common grasses all across Poland. There are varied resistances to difficult habitat conditions: low and high air temperature, droughts, and low nutrient richness of soil (Kozłowski et al. 1998). This species is especially applicable to lawn mixtures, allocated to sports fields, roadsides, difficult areas covered with grass (Goliński 2000). As one of the top fodder grasses, red fescue is attacked by different pests. The most important part of the grass fauna is the class of insects. Apart from them, there are: *Nematoda*, *Acarina*, *Gastropoda*, and *Vertebrata* (Mühle 1975). The size and quality of the seed yield are especially negatively affected by *Aphididae* and *Thysanoptera* which occur over tillering (Władyko and Żurańska 1991; Żurańska et al. 1994; Kąkol et al. 1999). The abundance of the pest population is connected with the intensity of fertilisation of grass plants (Jaworska et al. 1999). The occurrence of phytophagous insects with the hemipteroidal mouthpart in the case of seed cultivation of perennial ryegrass depends on the sowing method and the period of use, and in red fescue – on the level of nitrogen fertilization (Lamparski and Szczepanek 2004, 2006, 2008).

The aim of the present paper was to evaluate the effect of chemical plant protection on the occurrence of phytophagous insects on red fescue grown for seed.

Materials and methods

In 2004 and 2005 (series 1 and 2, respectively) an exact field experiment was set up which involved lawns of cultivar 'Nimba' of red fescue (*Festuca rubra* L. ssp. *commutata*) grown for seed. It covered, for each series, the year of sowing and two years of full use. In the control (C) neither diseases nor pests were controlled. The full control treatment (F + I), in the case of the identified threat posed by pathogens or pests, adequate plant protection agents were sprayed. In the years of use, 2005, 2006, and 2007, insecticides (of the pyrethroid group) were applied at the panicle emergence stage (the second decade of May), using Decis 2.5 EC ($0.3\ dm^3 \cdot ha^{-1}$), whereas in 2006

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also at the phase of the end of flowering and the beginning of grain filling (the 2nd half of June), Karate Zeon 050 CS (0.12 $dm^3 \cdot ha^{-1}$). The application of insecticides was combined with the application of fungicides.

Insects were caught using the scooping method, starting from the panicle emergence stage, through flowering until the milk-dough stage. In each plot, 15 m^2 in size, ten strikes with the entomological scoop were made. The number of the insects caught was determined as density. The entomological material was determined with the use of the keys: Müller (1976), Korcz (1994), Zawirska (1994), Nowacka (1996).

The present results were verified with the analysis of variance for single-factor experiments in the completely randomised design. To compare the mean values, the Tukey's test was used. Due to a low abundance of insects representing the following orders: *Coleoptera*, *Diptera*, *Hymenoptera*, *Lepidoptera*, *Neuroptera*, *Orthoptera*, they have not been discussed in detail in this paper, whereas the 'insects' category includes all of the insects caught.

Results and discussion

The occurrence of insects on red fescue grown for seed was poor; in the second year of full use it was 13% higher, as compared with the first one (Fig. 1). In the first and second year, the density of insects on the plot was lowest at the full red fescue panicle emergence stage and it was getting higher over its flowering and ripeness (Figs. 2 and 3). The protection effectiveness in the first year of harvest was inconsiderable; limiting of the insect density was statistically verified only in the second series of the experiment (in 2006; Fig. 1). It was due to a significant decrease in the number of insects which occur on red fescue at the milk-dough stage, after the second treatment which involved insecticide (Fig. 2). In the second year a favourable effect of chemical control was significant in both series and at each development stage researched (Figs. 1 and 3).

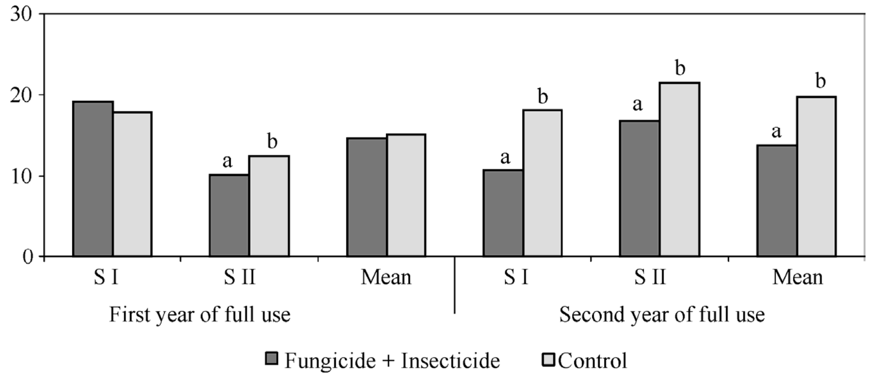

Fig. 1. Density of insects on red fescue grown for seed in the first and in the second year of full use (mean for the vegetation period) [individuals per plot]. Means followed by different letters differ significantly at p = 0.05 within the series

As for the abundance, *Thysanoptera* accounted for slightly over 25% of the insects which occurs on red fescue. In the first year of full use, irrespective of the development stage of the plant and the experimental treatment, there occurred fewer of them, as compared with the second year. The lowest number of that group was caught at the full red fescue panicle emergence stage and most over flowering in the first year or milk-dough stage in the second year of use. The protection treatments limited *Thysanoptera* infestation only in the second year, over flowering and ripeness stages.

Fauna of *Thysanoptera* included insects representing *Thripidae* and *Phleothripidae* families. In the first year of full use insects of these families occurred at similar intensity and the insecticides applied did not limit their density, whereas in the second year there were more *Phleothripidae* and their control effectiveness was slightly higher than *Thripidae* (Table 1).

A vast majority of *Thysanoptera* are phytophagous insects of crops. As a result of their feeding, there occur silver-white spots on the stems, which leads to plant wilting and withering (Miętkiewski et al. 1984). Besides sack-sucking from still soft kernels results in a decrease in their weight. Feeding of *Thysanoptera* can also cause white spike in grasses (Kukowski 1986; Jaworska et al. 1998). They are an important part of harmful fauna of many monocotyledonous plants. On the perennial ryegrass seed plantation in the first year of full use they were most abundant insects, and their maximum density was observed in the second half of June (Lamparski and Szczepanek 2004). Many authors claim that the abundance of these insects depends on weather conditions (Władyko and Żurańska 1991; Lamparski and Szczepanek 2004).

In the present research *Homoptera* occurred in red fescue at slightly higher intensity, as compared with *Thysanoptera* (Table 2). The density of these insects in the first and second year of full use was similar. In both years of yielding, most of these insects occurred at the milk-dough stage of fescue. The chemical protection with the use of insecticides limited the abundance of *Homoptera* effectively at all the development stages, in both harvest years, which resulted from similar effectiveness of the treatments in the control of both *Aphididae* and *Cicadellidae*.

Homoptera are considered to be top monocotyledons pests. Their larvae and adult individuals pierce leaves and suck the sap, producing yellowish or reddish spots, the plant leaves get twined (Nowacka 1996; Müller 1976; Miczulski 1994; Prestidge 1989). The most important representatives of this order are *Cicadellidae* which represents warm-habitat species, and thus its more abundant occurrence and harmfulness, more intensively recorded in dry years of high temperature (Nowacka 1996). Leszczyński et al. (1987) as well as Żurańska et al. (1994) report that in cereals and on seed grasses it is *Sitobion avenae* (F.) H.R.L. which is most frequent; up to the phase of cutting infests mainly flag leaves and the maximum of its intensity coincides with milk stage. *Rhopalosiphum padi* L. is less frequent, occurring mainly on lower leaves, leaf sheaths and stems and the maximum abundance of the species is the period of tillering and flowering. On perennial ryegrass and red fescue fauna of *Homoptera* was represented by *Aphididae*, *Cicadellidae*, and *Delphacidae* (Lamparski and Szczepanek 2004, 2006, 2008). The density of *Aphididae* and *Cicadellidae* on these grass species, both in the first and in the second year of full use was similar, and inconsiderable variations resulted from more or less favourable weather conditions. The highest abundance of pests was identified over the period of full tillering and seed ripeness. *Homoptera* more eagerly fed on well nourished and lushly growing and thus more fertile generative stems of plants. Żurańska et al. (1994) confirm that the occurrence of these pests was most affected by weather conditions, especially at the beginning of the vegetation period.

Table 1. Density of *Thysanoptera* on red fescue grown for seed [individuals per plot]

Insect group	Year of use	Treatment	Development stage											
			Full panicle emergence stage			Flowering			Milk-dough stage			Mean		
			Series											
			I	II	Mean	I	II	Mean	I	II	Mean	I	II	Mean
Thripidae	1	F + I	0.50	0.00	0.25	1.50	2.50	2.00	6.75	1.75	4.25	2.92	1.42	2.17
		C	0.00	0.25	0.13	0.50	1.50	1.00	2.00	4.00	3.00	0.85	1.92	1.38
		$LSD_{0.05}$	0.71	0.61	0.33	0.99	0.99	0.54	3.06	1.17	0.64	0.98	0.55	0.30
	2	F + I	0.00	0.50	0.25	0.00	1.25	0.63	0.00	4.50	2.25	0.00	2.08	1.04
		C	0.25	1.75	1.00	0.75	1.50	1.13	0.25	4.75	2.50	0.42	2.68	1.55
		$LSD_{0.05}$	0.61	0.93	0.51	0.61	0.93	0.51	0.61	2.21	1.20	0.51	0.92	0.50
Phlaeothripidae	1	F + I	0.75	1.50	1.13	1.25	8.00	4.63	0.50	0.00	0.25	0.83	3.17	2.00
		C	0.50	0.00	0.25	0.00	8.25	4.13	0.00	0.25	0.13	0.15	2.84	1.49
		$LSD_{0.05}$	1.37	0.71	0.75	0.61	1.17	0.33	0.81	0.61	0.39	0.57	0.66	0.31
	2	F + I	0.00	0.75	0.38	5.50	0.00	2.75	2.50	0.50	1.50	2.67	0.40	1.53
		C	0.25	0.50	0.38	7.00	0.50	3.75	7.25	0.00	3.63	4.92	0.33	2.62
		$LSD_{0.05}$	0.61	1.37	0.75	1.22	0.71	0.39	1.97	0.71	0.39	0.78	0.63	0.34
Thysanoptera	1	F + I	1.25	1.50	1.38	3.25	10.50	6.88	8.50	1.75	5.13	4.33	4.59	4.46
		C	0.50	0.25	0.38	1.00	9.75	5.38	2.75	4.25	3.50	1.40	4.75	3.08
		$LSD_{0.05}$	1.37	0.93	0.51	1.17	1.37	0.75	1.69	1.66	0.90	0.95	1.09	0.60
	2	F + I	5.50	1.25	3.38	5.50	2.00	3.75	2.50	6.25	4.38	4.50	3.18	3.84
		C	4.25	2.25	3.25	8.00	3.50	5.75	8.00	6.25	7.13	6.75	4.00	5.38
		$LSD_{0.05}$	0.93	1.32	0.72	1.58	1.86	1.02	2.74	2.60	1.41	0.81	1.50	0.82

Table 2. Density of *Homoptera* on red fescue grown for seed [individuals per plot]

Insect group	Year of use	Treatment	Development stage											
			Full panicle emergence stage			Flowering			Milk-dough stage			Mean		
			Series											
			I	II	Mean	I	II	Mean	I	II	Mean	I	II	Mean
Aphididae	1	F + I	0.75	0.00	0.38	1.25	0.00	0.63	3.50	0.00	1.75	1.83	0.00	0.92
		C	1.00	0.25	0.63	1.75	0.50	1.13	5.00	0.50	2.75	2.58	0.42	1.50
		$LSD_{0.05}$	1.54	0.61	0.84	1.32	0.71	0.72	1.87	0.71	0.39	1.05	0.21	0.11
	2	F + I	0.00	0.75	0.38	0.00	1.50	0.75	0.00	3.00	1.50	0.00	1.73	0.86
		C	0.50	1.00	0.75	0.50	1.75	1.13	0.25	5.25	2.75	0.42	2.68	1.55
		$LSD_{0.05}$	0.71	1.54	0.84	0.71	1.69	0.92	0.61	2.09	1.14	0.39	1.23	0.67
Cicadellidae	1	F + I	3.25	0.00	1.63	2.50	0.50	1.50	7.25	1.00	4.13	4.33	0.50	2.41
		C	3.00	0.25	1.63	6.50	0.00	3.25	9.00	2.50	5.75	6.18	0.92	3.55
		$LSD_{0.05}$	1.84	0.61	1.00	2.23	0.71	1.22	2.89	1.59	1.58	1.14	0.74	0.62
	2	F + I	0.00	3.25	1.63	0.00	2.50	1.25	0.50	7.25	3.88	0.17	4.33	2.25
		C	0.25	5.25	2.75	2.25	6.50	4.38	1.75	7.75	4.75	1.42	6.50	3.96
		$LSD_{0.05}$	0.61	1.93	1.05	1.17	2.23	1.22	0.93	2.78	1.52	0.56	1.39	0.76
Homoptera	1	F + I	4.75	1.50	3.13	5.75	0.50	3.13	12.75	1.00	6.88	7.58	1.00	4.29
		C	4.00	0.50	2.25	8.25	1.75	5.00	14.00	3.00	8.50	8.75	1.75	5.25
		$LSD_{0.05}$	3.22	1.41	0.77	2.60	1.69	0.92	3.92	1.99	1.09	1.85	0.77	0.42
	2	F + I	0.75	4.75	2.75	0.50	6.00	3.25	0.50	11.75	6.13	0.58	7.50	4.04
		C	2.50	6.25	4.38	2.75	8.25	5.50	2.00	13.00	7.50	2.42	9.18	5.80
		$LSD_{0.05}$	1.69	3.28	1.78	1.97	3.06	1.67	1.22	2.89	1.58	1.09	2.09	1.14

Table 3. Density of *Heteroptera* on red fescue grown for seed [individuals per plot]

Insect group	Year of use	Treatment	Development stage											
			Full panicle emergence stage			Flowering			Milk-dough stage			Mean		
			Series											
			I	II	Mean	I	II	Mean	I	II	Mean	I	II	Mean
Miridae	1	F + I	0.00	0.25	0.13	4.00	1.75	2.88	5.75	1.25	3.50	3.25	1.17	2.21
		C	0.25	0.00	0.13	4.00	1.50	2.75	7.25	2.75	5.00	3.75	1.42	2.58
		$LSD_{0.05}$	0.61	0.61	0.33	2.64	0.93	0.51	2.18	1.93	1.05	0.72	0.93	0.51
	2	F + I	0.00	0.00	0.00	3.75	4.00	3.88	0.50	6.50	3.50	1.42	3.53	2.47
		C	0.50	0.50	0.50	1.50	4.00	2.75	2.50	8.25	5.38	1.50	4.25	2.87
		$LSD_{0.05}$	0.71	0.71	0.39	1.97	2.64	1.44	1.00	3.44	1.88	0.81	0.97	0.53
Pentatomidae	1	F + I	0.00	0.00	0.00	1.75	3.50	2.63	0.50	2.50	1.50	0.75	2.00	1.38
		C	0.75	0.25	0.50	4.00	3.75	3.88	0.00	4.25	2.13	1.58	2.75	2.16
		$LSD_{0.05}$	0.61	0.61	0.33	2.09	0.93	0.51	0.71	0.93	0.51	0.57	0.39	0.21
	2	F + I	1.50	0.00	0.75	6.50	1.75	4.13	0.75	0.00	0.38	2.92	0.58	1.75
		C	2.50	2.25	2.38	0.75	3.75	7.25	2.00	0.50	1.25	5.08	2.15	3.62
		$LSD_{0.05}$	1.41	1.17	0.64	1.97	1.93	1.05	1.54	1.22	0.67	1.09	0.65	0.36
Heteroptera	1	F + I	0.25	0.50	0.38	6.00	5.75	5.88	7.00	3.75	5.38	4.42	3.33	3.88
		C	0.75	0.25	0.50	8.00	5.25	6.63	7.25	7.00	7.13	5.33	4.17	4.75
		$LSD_{0.05}$	0.86	0.93	0.51	4.12	1.32	0.72	3.22	1.84	1.00	1.20	0.97	0.53
	2	F + I	1.50	0.25	0.88	0.75	6.00	8.38	1.25	6.75	4.00	4.50	4.35	4.42
		C	3.00	2.75	2.88	2.25	7.75	10.00	4.50	8.75	6.63	6.59	6.40	6.49
		$LSD_{0.05}$	1.87	1.32	0.72	1.93	3.79	2.06	2.21	3.12	1.70	1.45	1.23	0.67

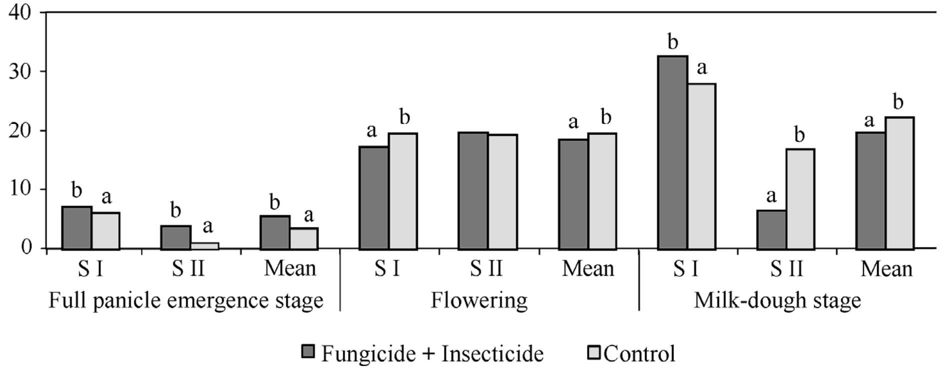

Fig. 2. Density of insects on red fescue grown for seed in the first year of full use [individuals per
plot]. Means followed by different letters differ significantly at p = 0.05 within the series

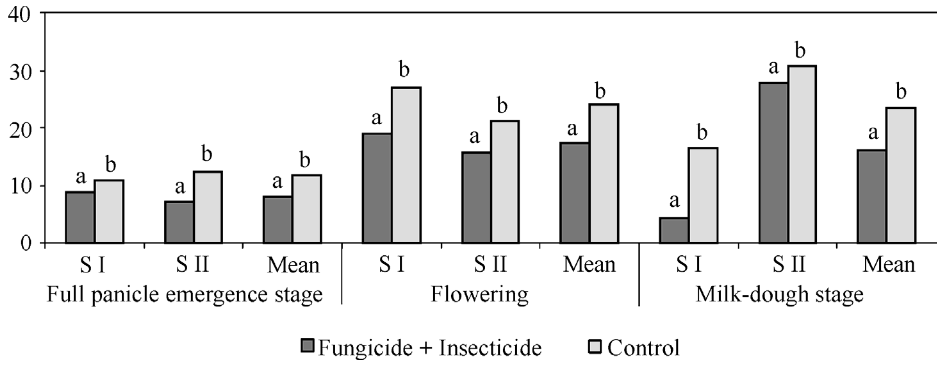

Fig. 3. Density of insects on red fescue grown for seed in the second year of full use [individuals per plot]. Means followed by different letters differ significantly at p = 0.05 within the series

Based on the present research, it was noted that *Heteroptera* occurred on red fescue at a similar intensity, as compared with *Homoptera* (Table 3). In the first year of full use, irrespective of the development stage researched in red fescue, they were slightly less numerous than in the second year. In both years, most of these insects infested red fescue over flowering. In the variant of full chemical control, there were mostly less abundant than in the control. The *Heteroptera* fauna was composed of insects of *Miridae* and *Pentatomidae* families. In the first and second year of full use the chemical control applied limited the abundance of *Pentatomidae* at all the development stages in red fescue, whereas *Miridae* – mainly at the milk-dough stage.

Heteroptera are common all across Poland (Korcz 1994). Both their larvae and adult insects damage many crop species (Miczulski 1994; Lamparski et al. 2007, 2008). In the places of piercing, the tissue dies and the plants are deformed, wrinkled and twisted (Korcz 1989, 1994; Soika and Łabanowski 1990). Feeding of these insects from tillering, according to Korcz (1994), can lead to fescue leaf wilting. Lamparski and Szczepanek (2008) report that of the *Heteroptera* caught, the most abundant infestation was recorded for pests of *Miridae* and *Pentatomidae* families. An especially high intensity of *Pentatomidae* representatives was recorded in the second year of red fescue growing for seed. In perennial ryegrass, on the other hand, *Lygus rugulipennis* Popp. appeared in the first decade of June, namely over full tillering and at the beginning of flowering of the plant (Lamparski and Szczepanek 2004). In the second year of ryegrass growing there were noted considerably more individuals of that species than in the first year, due to conditions more favourable for the insect development; less rainfall in the first decade of June. Hannunen and Ekbom (2001) report on that pest starting feeding over tillering of monocotyledonous plants. Other *Heteroptera* which occur on perennial ryegrass, including *Aelia acuminata* L. and *Notostira erratica* L. were most numerous at the plant seed ripeness (Lamparski and Szczepanek 2004).

Conclusions

1. Insects infest red fescue grown for seed from flowering to milk-dough stage and they are phytophagous insects with the hemipteroidal mouthpart, like *Homoptera* and *Heteroptera* as well as *Thysanoptera*.
2. The density of insects and their control effectiveness are greater in the second seed harvest year than in the first one.
3. In both years of full use insecticides applied at the red fescue panicle emergence stage are successful in limiting the number of *Hemiptera* pests. The control of *Thysanoptera* is effective only in the second year of yielding.

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EFFECT OF THE PHOTOPERIOD ON GROWTH AND FLOWERING OF *Ajania pacifica* (Nakai) Bremer ET HUMPHRIES IN THE GLASSHOUSE

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An interesting alternative for chrysanthemum (*Dendranthema* x *grandiflora*) can be pacific ajania (*Ajania pacifica*), referred to as its close relative of the same family, Asteraceae. Quite recently it has been known as *Dendranthema pacificum*, and earlier *Chrysanthemum pacificum*. Their genetic closeness is demonstrated by the results of research into producing interspecific hybrids (Fukai et al. 2000; Roh and Ikeda 2003). The plant has originated from central and eastern Asia. It has been available on the Polish market for a relatively short time but it has already attracted some interest. The inflorescence of the most popular cultivars, e.g. 'Silver and Gold', 'Yellow Splash', 'Mimosa Gold', 'Sarah' or 'Bea', is yellow in colour. The cultivars differ in the vigour, habitat and leaf colour intensity. There are also known plants of two-colour inflorescences; yellow ray florets and the surrounding white ('Bess') or pink ('Pink Ice', 'Mimosa Pink') ligulate florets.

It seems that through a close relationship, pacific ajania can be treated similarly as chrysanthemum, applying a similar growing technology. Just like chrysanthemum, it is a short-day plant. Thanks to the controlled cultivation, flowering of this type of plants is possible, regardless of the season at the predetermined date, by shortening the day length during naturally long days or by prolonging the day with artificial light when the days are short but also by maintaining the adequate temperature.

The research into the possibility of spring flowering in chrysanthemum under the conditions of natural uncontrolled photoperiod was originated in Sweden (Larsen 1981a, b). The experiments reported by Zalewska (1986/87a) confirmed that such cultivation is real also in Poland's conditions. Further research by that author demonstrated that the applicability of a dozen or so standard and spray chrysanthemum cultivars as well as a few of Sombrero group to the spring-flowering without darkening (Zalewska 1986/87b; Zalewska and Żabicka 2003). Eliminating this treatment allows a simultaneous glasshouse growing of other photoperiod-independent species, and in the case of hand darkening – it decreased the production costs significantly. All that suggests that pacific ajania could well enhance the assortment of perennials offered in spring as a plant produced also without darkening. The applicable literature does not, however, seem to offer information on this species. The results of chrysanthemum

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research carried out earlier encouraged further research into the effects of spring-flowering of pacific ajania both when exposed to the natural and the controlled photoperiod.

Materials and methods

The research was performed in 2007 in the glasshouse of the Department of Ornamental Plants and Vegetables Crops, University of Technology and Life Sciences in Bydgoszcz. The experiment involved pacific ajania 'Silver an Gold'. Commonly it is referred to as silver and gold chrysanthemum, which comes from beautiful original foliage. The upper dark-green side of the leaf is circled by silver-white edge of hair, while the bottom part is entirely covered with tomentum similar in colour, which makes it exceptionally decorative. Its advantage is also the leaf shape, slightly resembling the oak leaf and very abundant foliage and bushy habitat. 'Silver and Gold' produces small yellow inflorescences, filled only with ray florets. Very numerous inflorescence buds, located on rigid straight stems get swollen, however, quite slowly (even 4-5 weeks), and so under unfavourable weather conditions, the plants grown in the garden will no longer manage to break. However, before breaking, they are decorative enough not to be disqualified as attractive lawn flower-bed perennials (Zalewska 2005).

The first stage, which involved the vegetative plant growth phase, was carried out in the long-day glasshouse (nursery). Cutting was performed every two weeks, at four dates: January 4 and 18 and February 1 and 15, 2007. Each time 150 shoot cuttings, 5-6 cm in length, were sampled and placed in paper-pots 3 cm in diameter, applying rooting agent A (containing 0.3% of Indole-3-butyric acid). Next the cuttings were placed into plastic pallets, adjusted to paper-pots. The vegetative phase of cutting growth together with their rooting took 4 weeks; the plants were exposed to extra light under prolonged day (to 16 hours per day; in January 4 p.m. to 11 p.m., in February from 5 p.m. to 11 p.m. and in March from 6 p.m. to 10 p.m. During the plant growth in the glasshouse of long day, the mean air/medium temperature was 18.5/20.1°C, respectively, and the relative air humidity – 53.4%. Then the plants were replanted into a permanent place, to the short-day glasshouse, to correspond to the cutting dates: February 1 and 15 and March 1 and 15. Each time 120 cuttings similar in length were sampled and divided into two groups, 60 cuttings each, to be grown under natural and controlled photoperiod (at a day shortened by darkening to 10 hours). They were planted into pots 9 cm in diameter into the chrysanthemum – growing medium (manufacturer: 'Hollas' of Pasłęk) of pH 6.5. This is how the second experiment stage started – generative plant growth phase, about 12 weeks long until the start of flowering. Plants grown under controlled photoperiod, being the control combination, started to get darkened first on March 1. This treatment was applied every day 6 p.m. to 8 a.m., except for Saturdays, with the use of black foil, and got completed when most plants reached the beginning of flowering stage. During plant growth in the short-day glasshouse the mean air/medium temperature was, respectively, 22.7/19.4°C and relative air humidity – 70.8%.

Agrotechnical and cultivation practises were compliant with the chrysanthemum technology guidelines. The plants growing as exposed to natural photoperiod at none of the dates produced inflorescence buds, and thus they did not flower. In the darkened plants, the following were noted: the inflorescence bud emergence date (when it was well visible with the naked eye), and the beginning of flowering (when half of the buds on the plant were open and the first stained ray florets were visible). The mean date of the inflorescence bud emergence and flowering was determined based on the weighted mean. There was also calculated the number of days after planting onto the permanent place until the inflorescence bud appeared (microscopic development) and the number of days after the emergence of the bud to the beginning of flowering (macroscopic development). Similarly, the period of growing in the short-day glasshouse (from planting into pots to the end of growing) and the percentage of flowering plants was calculated. Reaching the stage of the beginning of flowering was connected with the end of darkening and with the measurement of 30 plants in each combination (most homogenous in size). In the darkened plants there was noted the plant height, measuring it from the top edge of the pot to the very top inflorescence, whereas the plant width was the mean value of the double measurement in the widest points, the corymb length – from the lowest located inflorescence pedicles to its top and the corymb width which was composed of the mean value of the double measurement in the widest points. The number of corymb pedicles and the number of inflorescences was also determined. In the plants growing exposed to natural photoperiod, the height and width as well as the number of lateral branches were the only values measured. The plant height was determined by measuring it from the top edge of the pot to the top of the plant, the width was composed of the mean value of a double measurement in the widest points. The results were statistically verified with the analysis of variance, and the mean values were compared by applying the Tukey's test at the level of significance of $p = 0.05$. Since the darkened plants did not flower, the parameters recorded at respective periods were separately compared for each photoperiod. The calculations were performed using FR-ANALWAR software, based on Microsoft Excel.

Results

The plants grown under controlled photoperiod flowered in 100%, at each date of starting the cultivation, whereas those which were growing exposed to the natural day length did not set any buds at all (Fig. 1).

Fig. 1. Plants grown under controlled photoperiod (on the left) and natural photoperiod (on the right)

The buds in the plants grown under controlled photoperiod started to appear at the end of April; earliest in the group of plants planted onto the permanent place at date I (February 1), and latest in those planted out at date IV (March 15). As for flowering, it was the same; the plants planted onto the permanent place on February 1 were flowering as early as from the beginning of June, while those planted out on March 15 – only in the second half of this month. At the same time, the later the date of planting onto the permanent place, the shorter the period of microscopic development of the inflorescence bud (by an average of nine days). The buds were developing longest, more than 12 weeks, in the plants planted most early, while shortest, eight weeks, in those planted at the latest date. The macroscopic bud development was shortest, five weeks, in the plants planted onto a permanent place at the beginning of February, while longest, six weeks, in those planted at the beginning of March. The date of starting the cultivation had a significant effect on its duration. The longest period of cultivation was recorded in the plants planted on February 1, while the shortest in the plants the growing of which started on March 15. The later the planting date, the shorter the growing period. The plants planted at date I took as much as 125 days to flower, almost a month more than those planted at date IV. The ones the growing of which started February 15 and March 1 were growing at a similar rate (Table 1).

Table 1. Inflorescence bud development stages and the duration of cultivation of plants in the short-day glasshouse under controlled conditions

Beginning of cultivation	Inflorescence bud				Duration of cultivation [days]
	Emergence [date]	Microscopic development [days]	Beginning of flowering [date]	Macroscopic development [days]	
I (February 1)	27.04	86.27 d*	05.06	38.43 a	124.73 c
II (February 15)	30.04	75.47 c	09.06	39.17 ab	114.63 b
III (March 1)	06.05	66.93 b	15.06	42.20 b	109.13 b
IV (March 15)	12.05	57.70 a	20.06	39.20 ab	96.90 a

*means values in columns marked with the same letters do not differ significantly at p = 0.05 (Tukey's test)

The start date of cultivation had a significant effect on the length and width of the corymb (Table 2). The longest corymbs were produced by plants planted earliest. Their mean length was 15.5 cm and they were significantly longer than those grown at later dates. The plants planted onto a permanent place on March 1 formed the shortest and the narrowest corymbs (Table 2).

Table 2. Corymb length and width in plants grown in the short-date glasshouse under controlled conditions

Beginning of cultivation	Corymb	
	Length [cm]	Width [cm]
I (February 1)	15.52 a*	16.62 a
II (February 15)	13.58 b	16.56 a
III (March 1)	10.34 d	12.66 b
IV (March 15)	12.01 c	15.12 a

*means values in the columns marked with the same letters do not differ significantly at p = 0.05 (Tukey's test)

The date of starting cultivation also affected the number of pedicles and inflorescences per corymb in darkened plants. The lowest number of pedicles was produced by plants planted at date IV, while the lowest number of inflorescences was observed in the plants planted onto the permanent place at date III (Table 3).

Table 3. Mean number of pedicles per corymb and inflorescence in plants grown in the short-day glasshouse under controlled conditions

Beginning of cultivation	Corymb	
	Number of pedicles	Number of inflorescences
I (February 1)	27.60 a*	261.60 a
II (February 15)	26.07 ab	255.87 ab
III (March 1)	24.60 b	196.60 c
IV (March 15)	21.93 c	213.23 bc

* means values in the columns marked with the same letters do not differ significantly at $p = 0.05$ (Tukey's test)

The planting date affected the height and width of darkened plants. The ones the growing of which started on February 1 were the tallest and the widest. The plants planted in March differed neither in the height nor the width (Figs 2 and 3).

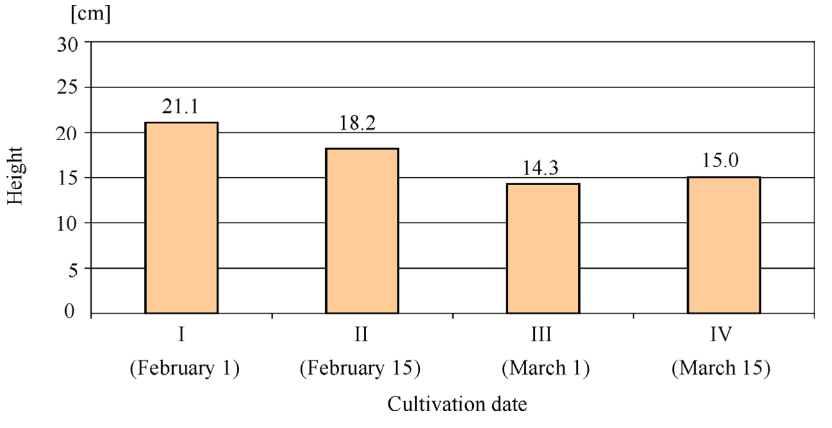

Fig. 2. Height of plants grown in the short-day glasshouse under controlled conditions depending on the cultivation date; $LSD_{0.05} = 2.09$

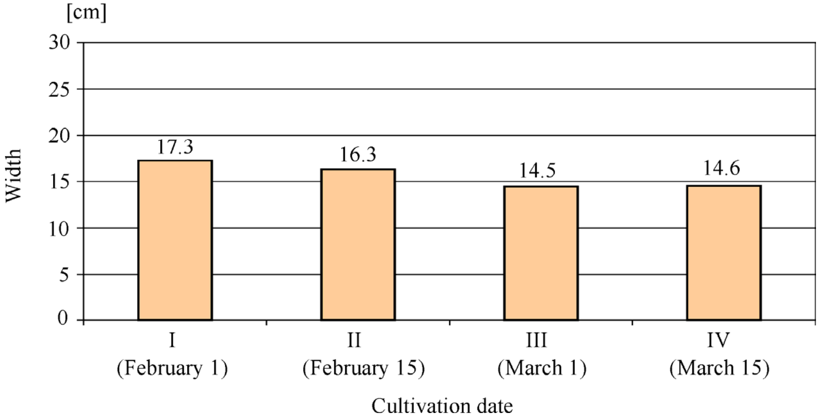

Fig. 3. Width of plants grown in the short-day glasshouse under controlled conditions, depending on the cultivation date; $LSD_{0.05} = 0.95$

The date of planting onto permanent place also had the effect on the height of the undarkened plants. Unlike the darkened plants, those the cultivation of which started February 1 were shortest. The plants planted out in the second half of February and in March reached a similar height (Fig. 4). The cultivation start date, however, did not affect the width of the undarkened plants (Fig. 5).

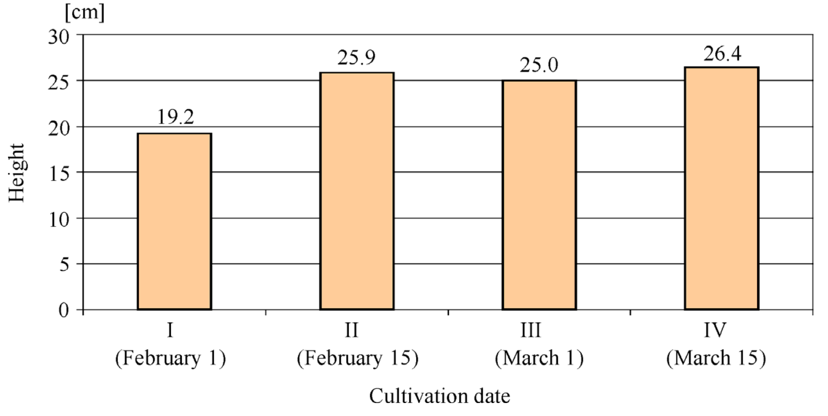

Fig. 4. Height of plants grown in the short-day glasshouse under natural conditions, depending on the cultivation date; $LSD_{0.05} = 2.09$

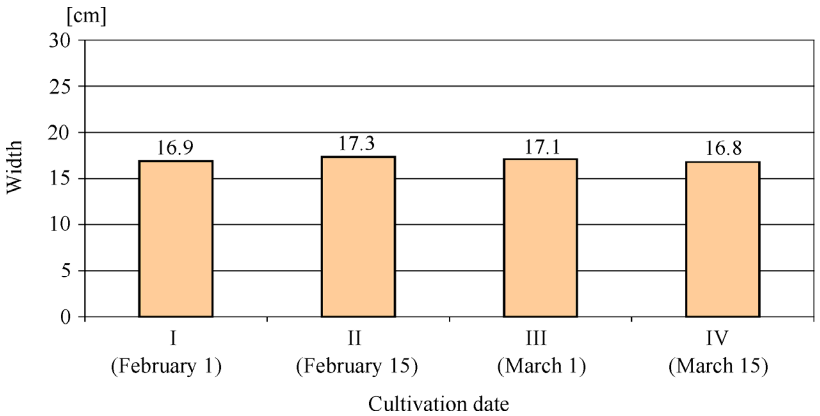

Fig. 5. Width of plants grown in the short-day glasshouse under natural conditions, depending on the cultivation date; $LSD_{0.05} = 0.95$

The cultivation start date under natural photoperiod conditions, without darkening, also affected the number of lateral branches; their lowest number was observed in the plants planted at date IV. The plants the growing of which started at earlier dates, however, produced a similar number of branches (Table 4).

Table 4. Number of lateral branches in the plants grown in the short-day glasshouse, under natural conditions

Beginning of cultivation	Number of lateral branches
I (February 1)	20.33 a*
II (February 15)	20.03 a
III (March 1)	19.30 a
IV (March 15)	15.57 b

* means values in columns marked with the same letters do not differ significantly at p = 0.05 (Tukey's test)

Discussion

In the present experiment pacific ajania 'Silver and Gold', grown under the conditions of photoperiod uncontrolled by plant darkening, did not flower. One shall note here that the research reported by Zalewska (1986/87b) demonstrated that not every chrysanthemum cultivar was applicable to the spring-flowering under natural photoperiod, which suggests a possibility of cultivar-specificity also within the species of pacific ajania. The length of chrysanthemum cuttings upon planting onto a permanent place (after a 4-week growth in long-day glasshouse) was on average 11.5 cm, while the length of pacific ajania cuttings after the same growing period under long-day conditions was only 8 cm. In both cases there were sampled shoot cuttings similar in length (5-6 cm). All that suggests that the rate of vegetative growth in pacific ajania is much lower than in chrysanthemum. The photoperiodic stimulus acceptor is the leaf and so in the plants dependent on the day length it determines flowering. According to Cockshull (1976), chrysanthemum flowering depends considerably on the number of leaves. Only once the adequate number of leaves is produced, the plants are becoming capable of flowering, even under long-day conditions. However, it was not confirmed by the research carried out in pacific ajania. All the plants grown in the short-day glasshouse (both under natural and controlled photoperiod) at the first stage of cultivation were growing for four weeks under the same conditions (in the long-day glasshouse), thus reaching the same length, and as a result, presumably the number of leaves. Apart from the light intensity, both in the case of chrysanthemum and pacific ajania, the processes of growth and development are controlled by the photoperiod, namely the daily period of light exposure, but the control mechanism, controlled by the photoperiod operates as coupled with temperature. According to Larsen (1981a), a higher temperature around darkened chrysanthemum (by about 2°C, due to black material covering) can cause earlier flowering. In the present experiment in the long-day glasshouse, all the plants were growing under the same temperature, later, however, in the short-day glasshouse, starting from March 1, the ones which were darkened for 14 hours from 6 p.m. were growing exposed to higher temperature. Even though no temperature measurements were taken under foil which covered the plants, it seems that that fact could have resulted in no-bud-setting in pacific ajania, grown under natural day length. According to Cockshull (1976), the initiation of flowers under long-day conditions is inevitable, connected with the aging of apical meristems, and the flowering time is genetically determined. Zalewska (1986/87a) claims that the most favourable date to start chrysanthemum cultivation in the glasshouse in spring, without darkening, is for Central Europe the first half of February since the plant quality is not inferior and it is even superior to the quality of those grown under controlled photoperiod, reaching full flowering only a few days later. Starting the cultivation as late as in March, however, delays flowering considerably. According to Jerzy (2000), in Poland, in February and in March the day is still relatively short (10-12 hours), which enhances the initiation of the inflorescence bud in many chrysanthemum cultivars and despite the days becoming longer and longer, once the inflorescence bud development has started, it continues adequately, which results in developing normally formed inflorescence. Besides, the reports by Cockshull and Hughes (1972) demonstrate that in the process of flower initiation in chrysanthemum the first two weeks of short days are most important. This information has not been confirmed by research which involved pacific ajania, genetically-close to chrysanthemum. In the present experiment, exposed to the natural photoperiod, inflorescences were not produced even by those plants which were planted on February 1 and 15, growing at the natural short day (9.5-10 hours), four and two weeks, respectively. One can therefore assume that in the case of pacific ajania, the number of short days was insufficient to initiate inflorescences in the period researched. The unexpected lack of flowering in pacific ajania could have been due to the climatic conditions of the environment the plant has originated from. Even though pacific ajania appeared to be inapplicable to spring-flowering-oriented growing in the glasshouse, under natural photoperiodic conditions, starting from February 1 to March 1, the quality of plants produced at a day shortened by darkening, especially those planted onto a permanent place on February 15 encourages further research in that field, also based on other cultivars of that species. Currently pacific ajania is available on the Polish market sporadically, while chrysanthemum, close to it, has won a year-round popularity. It seems that it would be well justifiable to get Polish chrysanthemum producers interested also in its cultivation and the similarity to chrysanthemum can, in that case, constitute an effective incentive.

Conclusions

1. An inapplicability of *Ajania pacifica* 'Silver and Gold', to the spring-flowering, when exposed to natural day length, without darkening was stated. At none of the four dates of cultivation did the plants set inflorescence buds, while under controlled photoperiod, irrespective of the cultivation date, the plants were flowering.
2. The most favourable date of starting controlled cultivation was mid February. The plants produced were flowering abundantly; they were relatively short, proportional, with a compact habitat, which will, in the future, facilitate limiting the application of retardants. An earlier date significantly prolonged the growing period, while the later one deteriorated the quality of flowering plants considerably.

Acknowledgements

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ECONOMIC AND SOCIAL REQUIREMENTS FOR DEVELOPMENT OF AGRICULTURAL PRODUCTION AND OF RURAL AREAS IN THE KUYAVIAN-POMERANIAN PROVINCE

ENTERPRISE AND ALTERNATIVE SOURCES OF INCOME ON FARMS WITH THE INOWROCŁAW COMMUNE AS AN EXAMPLE

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The development of the countryside and agriculture in Poland has assumed a new dimension after the integration with the European Union in 2004 which was yet another stage of transformations originated in 1989. Winning a considerably greater economic freedom, especially opening of the foodstuffs markets within the Community, resulted in a need of changes in the approaches of many farmers. Competing with greater and economically stronger farms in the countries operating within the EU longer encourages enterprise behaviours and searching for alternative income on farms to a greater extent.

The enterprise behaviours are a prerequisite for the economic and social development of the rural areas and determine the multi-functional development of the countryside (Duczkowska-Małysz 1998). Enterprise is expressed in actions which require an individual to be active, responsible for changes and committed (Krzyminiewska 2006). It is thanks to the enterprise of the population, mainly active in non-agricultural fields, that the rural areas can develop effectively. The non-agricultural activity is especially favourable in Polish conditions since the qualities of the domestic agriculture are a high level of agrarian break-up and a considerable share of population connected to agriculture as the source of income. In such situation it is difficult to achieve a considerable increase in the income of farmer families and the development of rural areas without developing non-agricultural forms of enterprise. To achieve such objectives, it is indispensable for the farmers themselves and their families to be ready to change the attitudes.

Besides the ability for adaptation in changing conditions around or involvement, one shall consider many factors stimulating the development of rural enterprise, including the education background in a given region, population age structure, skills and attitudes of rural population or cultural heritage in the rural areas (Zając and Kata 2006). The development of non-agricultural enterprise is also considerably affected by the barriers perceived by the rural population. The most frequently mentioned limitations are high tax rates and high labour costs as well as high credit interest rates (Miś 2006).

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Rural areas in Poland show a high regional variation due to both historical development differences and natural conditions (Zawisza and Kochanowska 2003). Depending on the natural, social and economic conditions of a given commune, the enterprise of the population can be expressed in agricultural economies-of-scale production enterprise, in non-agricultural enterprise directly connected with agriculture and in non-agricultural enterprise not directly connected with agriculture (Mielcarek 2006).

The aim of the present research was to evaluate the development potential of different enterprise forms, especially non-agricultural enterprise, as income sources alternative to agriculture in the Inowrocław commune. It is a commune, referred to as municipality, located in the Kuyavian-Pomeranian Province, the Inowrocław County. The commune area is 171.05 km^2, which accounts for 13.96% of the county's area. The population density is 65.8 people per 1 km^2. The commune includes fifty locations, organized in twenty-seven *solectvos*, being a subdivision of the commune. The Inowrocław commune neighbours with seven other communes: Rojewo, Gniewkowo, Dąbrowa Biskupia, Kruszwica, Strzelno, Janikowo, Pakość. The commune capital and the capital of the entire county is Inowrocław. The first mention of Inowrocław dates back to 1185. The city was established based on a large market place and the salt-works in close vicinity. Inowrocław was granted the town status in 1238. The mainstay economy in the Inowrocław commune is agriculture. The commune enjoys some of the top land in the county. It is also one of the biggest communes in the county as far as the agricultural acreage is concerned. The agricultural acreage is 11,226 ha, of which arable land covers 10 300 ha, meadows and pasture land – 847 ha, whereas orchards – 79 ha. The commune has fertile soils of the first and second soil valuation class, which account for 64% of arable land, while soils of the third and fourth class – for 28%, and soils of the fifth and sixth class – only 8%.

Farms and respondents in the population under study

The study included a group of 136 respondents operating farms in the Inowrocław commune. With this sample representation, the results were analyzed at the probability of 95%, and the measurement error was 6%. The farms that were qualified to participate in the study were selected at random and represented 3 groups: (i) farms with agricultural enterprise only, (ii) farms with agricultural and non-agricultural enterprise, (iii) farms with non-agricultural enterprise mostly. The study was carried out in August and September 2008 with the opinion poll method. The questionnaire consisted of 20 questions, including: 7 closed questions, 8 semi-open ended questions and 5 classification questions.

The respondents were mostly men, who accounted for 55.1% of the individuals covered by the study (75 people). A smaller group of the population researched was made up of women, who accounted for 44.9% of the respondents (61 people). The respondents were mostly within the age range of 40-49 (38.2% of the respondents) and of 50-59 (23.5% of the respondents). A slightly smaller group were the persons aged 30-39 (22.1%). Individuals below 29 accounted for 9.6% of all the respondents. The smallest group was made up by persons over 60 (6.6%). Most respondents declared to have completed secondary education (42.6%), a slightly smaller group were the vocational school graduates (40.5%). Holders of higher education degrees accounted for 14.0% of the respondents, while primary school education was reported by 2.9% only.

Of all the respondents, the biggest group was made up by persons with a farm of 16-30 ha (25.7%). Slightly fewer respondents had farms of 11-15 ha (23.5%). The farm from 5 to 10 ha was reported by 17.7% of the respondents. The farm from 31 to 50 ha was owned by 16.2% of the respondents. The farm smaller than 5 ha was declared by 11.8 % of the respondents. The biggest farms, from 51 to 100 ha, were owned by 4.4% of the respondents, while only 0.7% of the respondents declared to have a farm over 100 ha.

To answer the question about the number of family members in the household, most respondents said that it ranged from three to five people (60.3%). From six to eight family members were reported by 26.5% of the respondents, below three family members – by 13.2% of the respondents. None of the respondents reported nine or more family members.

Enterprise of farmers under study

Persons running a farm usually take up enterprise within their reach, mostly determined by vocational and professional background, economic potential and financial resources, labour resources and free time available as well as by enterprise attitudes.

The decision on starting a non-agricultural enterprise is much affected by how long the respondents have carried out their agricultural activity. Of all the respondents, most people (31.6%) have operated agricultural enterprise 16 to 25 years. Slightly fewer respondents (29.4%) replied that they had operated agricultural enterprise 6 to 15 years. Fewer respondents answered that they had carried out agricultural activity 26 to 35 years (17.7%). The respondents who carried out their agricultural activity for a short time accounted for 14.7% of the respondents. The lowest number of respondents (6.6%) declared that they had run agricultural enterprise more than 35 years (Fig. 1).

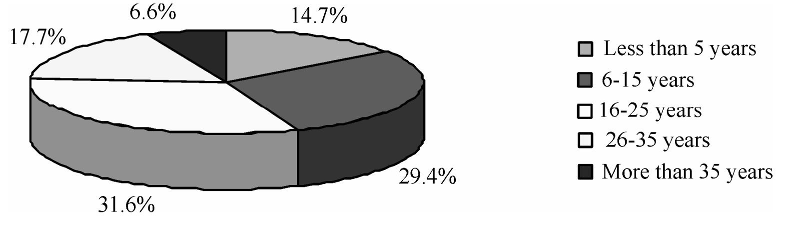


Fig. 1. Agricultural enterprise operation period

Taking the key development decisions is usually determined by the resources on the farm as well as ambitions and expectations. The respondents were asked about their intentions concerning the farm. The question concerned the planned farm size. Most of them (44.1%) answered that they were planning to increase their farm acreage by purchasing land. Slightly fewer respondents (32.4%) declared that they intended to keep the farm size as it was. A smaller part of the respondents (11.0%) planned to increase the farm acreage by lease. A relatively small group of respondents intended to decrease their farm size. Only 7.4% of the respondents planned to decrease their farm size by leasing out land. Decreasing the farm acreage by selling land was the plan of 2.9% of the respondents, while 2.1% intended to sell the entire farm (Fig. 2).

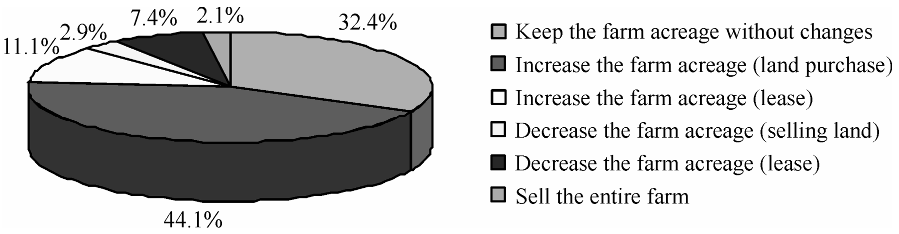


Fig. 2. Intentions of respondents concerning the changes in the farm acreage

Upon taking a decision on starting the non-agricultural enterprise, the amount of income generated on the farm is essential. Insufficient agricultural income can constitute an important motivation for searching for new possibilities of earning income. Most respondents (37.5%) expressed their relative dissatisfaction and answered that their income was rather insufficient. Fewer respondents (25.0%) stated otherwise, staying that their income was rather sufficient. Slightly fewer respondents (21.3%) definitely declared their dissatisfaction with their income, while 16.2% of the respondents claimed that their income from the farm was satisfactory (Fig. 3). Of all the respondents who declared that their income was sufficient, most were owners of the farm bigger than 16 ha. The respondents who were dissatisfied with their income were mostly farmers with up to 30 ha acreage. The most divided in their opinions about their income were the respondents with farms 16-30 ha.

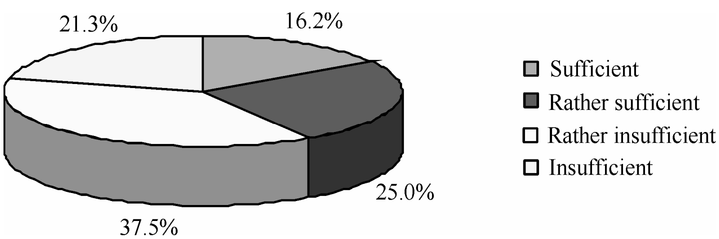


Fig. 3. Agricultural income in the opinion of the respondents

In the development of the enterprise what is important is the motivation which encourages enterprise attitudes. The study, therefore, included questions about the possibility of increasing the present income from the farm. Most respondents replied that they could rather see a possibility of increasing their income (24.3%). However, the same number of respondents claimed that they could not give a definite answer to that question. Slightly fewer respondents (21.2%) replied that they could not quite see a possibility of increasing their farm income. About 1/5 of the respondents (18.4%) replied that they definitely could not see such a possibility, while only 11.8% claimed that they definitely could see a possibility of increasing their farm income (Fig. 4).

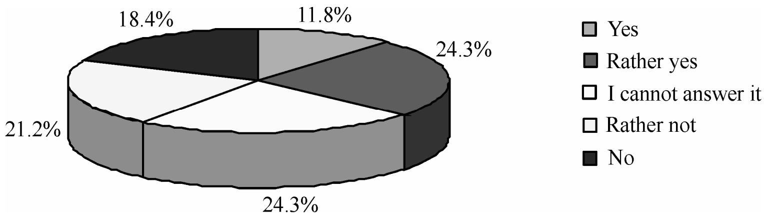
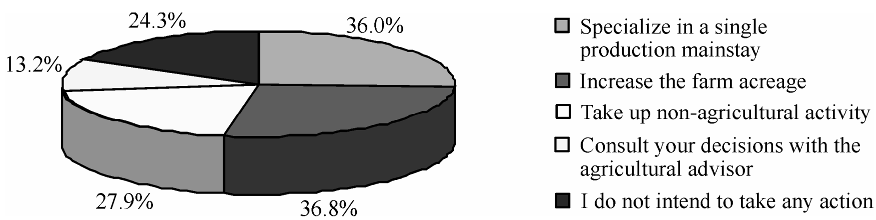


Fig. 4. Perceiving a possibility of increasing their farm income by the farmers

The relationship between the age, and perceiving the possibility of increasing the farm income demonstrates that the respondents aged up to 40 more often perceived such chances than the older people. The relationship between the gender and perceiving the possibilities of increasing the farm income demonstrates that most women (26.2%) claimed that they did not see any such possibilities. Slightly fewer of them (23.0%) stated that they could not answer the question. Fewer women (21.3%) answered that they could not rather see any such possibilities. Fewer respondents (16.4%) answered that they could rather see a possibility of increasing the farm income, while only 13.1% replied that they could definitely see such possibilities. Of all the men, most (30.7%) stated that they could rather see possibilities of increasing agricultural farm income. Slightly fewer (25.3%) could not answer that question. Fewer men (21.3%) claimed that they could not rather see any such possibilities. Only 12.0% of men replied that they definitely could not see any such possibilities, whereas 10.7% reported to see possibilities of increasing their agricultural farm income.

Another problem concerned the activities the respondents intended to take up to increase agricultural farm income in the future. Most respondents (36.8%) replied that they intended to increase their farm income by increasing its acreage. Slightly fewer respondents (36.0%) answered that they would like to get specialised in a single mainstay. Almost 1/3 of the respondents (27.9%) claimed that they intended to launch non-agricultural activity. A considerably large group answered that they did not intend to take up any activities to increase the farm income. Only 13.2% of the respondents replied that they wanted to consult their decisions with the agricultural advisor (Fig. 5).

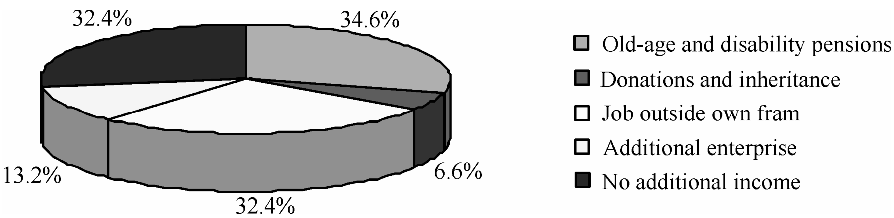


The respondents could mark more than one answer

Fig. 5. Actions the respondents intend to take to increase the farm income

Of all the respondents who, in order to increase their agricultural farm income intended to get specialised in a single production mainstay, most people were owners of the farm of 16-30 ha in acreage (30.6%). Slightly fewer people had farms smaller than 5 ha (20.4%). The lowest number of respondents who would decide to specialize in a production mainstay were the people with the farm acreage of 101-300 ha (2.0%). Of all the individuals who intended to increase the farm acreage, most were those who had the farm 16-30 ha in acreage (42.0%). Of all the respondents, the lowest number of those who were going to increase the farm acreage were the people with the farm acreage of 5-10 ha (4.0%) and 101-300 ha (2.0%). Of all the respondents who, in order to increase the income, planned to launch a non-agricultural enterprise, most represented were the owners of the farm 31-50 ha in acreage (26.3%). There were slightly fewer respondents with the farm acreage of 16-30 ha (23.7%) and 5-10 ha (23.7%), whereas the owners with farms below 5 ha and 11-15 ha (13.2%) were the least numerous group of respondents (13.2%). Of all the respondents who intended to consult their decisions with the agricultural advisor, most were the owners of farms 5-10 ha (50.0%), while the least numerous group – those with the farm acreage of 11-15 ha (11.1%). Of all the respondents who did not plan to take up any actions to increase the income, most people were the owners of farms 11-15 ha in acreage (48.5%), while the least represented were those with the farm acreage below 5 ha (9.1%), 16-30 ha (9.1%) and 31-50 ha (9.1%).

The respondents were also asked what additional non-agricultural income the farm had had so far. Most respondents (34.6%) replied that the additional household income had been generated by old-age and disability pensions. Slightly fewer respondents (32.4%) declared that their alternative household income source was a job as a hired employee. The same number of respondents (32.4%) replied that they did not have any additional income. Only 13.2% replied that they carried out additional enterprise and only 6.6% of the respondents claimed that the additional income of their household was generated by donations and inheritance (Fig. 6).

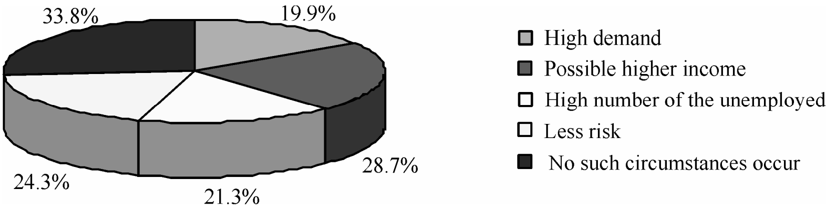


The respondents could mark more than one answer

Fig. 6. Additional income to the agricultural farm income of the respondents

Factors stimulating the non-agricultural enterprise in the opinion of the farmers

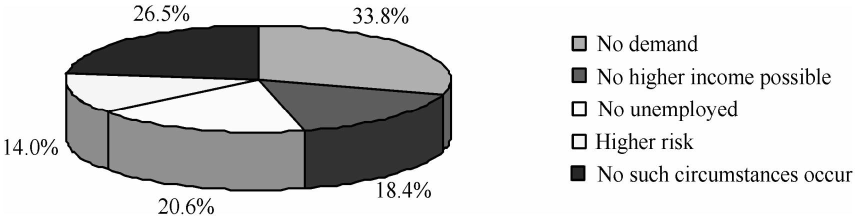
To launch the non-agricultural enterprise, realizing the possibilities and barriers which the respondents can face is essential. The respondents, asked about the circumstances which would facilitate running or launching non-agricultural enterprise, most often stated (33.8%) that there existed no such circumstances which would facilitate running or launching non-agricultural enterprise. Slightly fewer respondents (28.7%) claimed that it was possible to generate higher income than the agricultural enterprise income. Fewer respondents (24.3%) replied that the non-agricultural enterprise was less risky than the agricultural one. Even fewer respondents (21.3%) answered that there was a high number of the unemployed in the area who could be employed, while 19.9% of the respondents claimed that there was high demand for non-agricultural services and production (Fig. 7).



The respondents could mark more than one answer

Fig. 7. Factors facilitating running or launching non-agricultural enterprise

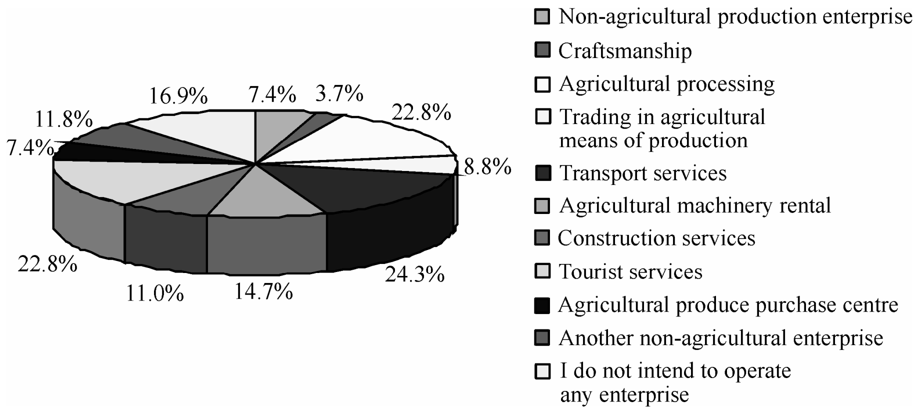
An important factor discouraging from taking up activity to search for new sources of income can be different barriers and factors making running or launching non-agricultural enterprise difficult. Most respondents (33.8%) replied that the factor making running or launching non-agricultural enterprise difficult was no demand for non-agricultural services or production. A considerable part of the respondents (26.5%), however, claimed that there were no circumstances making such operation or launch difficult. Fewer respondents (20.6%) claimed that the factor making the operation or launch of non-agricultural enterprise difficult was a lack of the unemployed who could be hired. Slightly fewer respondents (18.4%) replied that it was not possible to generate higher income from the non-agricultural than from the agricultural enterprise. Only 14.0% of the respondents claimed that the non-agricultural enterprise was more risky than the agricultural enterprise (Fig. 8).



The respondents could mark more than one answer

Fig. 8. Factors making running or launching non-agricultural enterprise difficult

Taking up a decision about the kind of enterprise is considerably affected by external factors around but also disposition and qualities of the farmers. Similarly much depends on education, age and economic potential but also own original ideas are essential, determining the directions of the actions. New possibilities are also offered by EU payments. The respondents were asked what kind of non-agricultural enterprise they would choose in the future. Most often the respondents answered (24.3%) that they would choose transport services. Slightly fewer respondents (22.8%) would go for agricultural processing. The same number of respondents (22.8%) answered that they would decide for tourist services (room rental, etc.). Only 16.9% of the respondents claimed that they did not intend to run any non-agricultural enterprise in the future. Fewer respondents (14.7%) would launch agricultural machinery, equipment and tool rental. Even fewer (11.8%) of the respondents would choose yet another non-agricultural activity. However, none has specified the kind of enterprise. Only 11.0% of the respondents replied that they would run construction services, and even fewer respondents (8.8%) would launch trading of agricultural means of production, clothing or foodstuffs. The agricultural produce purchase centre would be selected by only 7.4% of the respondents and the same number would launch non-agricultural production enterprise, whereas only 3.7% would go for craft enterprise (Fig. 9).



The respondents could mark more than one answer

Fig. 9. Kind of non-agricultural enterprise the respondents would choose

Non-agricultural enterprise among the respondents in the Inowrocław commune

Of all the respondents covered by the survey, 68.4% did not run any non-agricultural enterprise, whereas 31.6% declared that they had been running a non-agricultural enterprise. The analysis of the relationship between the farm acreage and the decision about launching non-agricultural enterprise shows that most respondents (27.9%) who generated non-agricultural income had farms from 11 to 15 ha. Slightly fewer of them (25.6%) had farms below 5 ha. Fewer respondents (23.3%) who dealt with the non-agricultural activity had farms 16 to 30 ha. The farms from 5 to 10 ha were owned by 16.3% of the respondents with additional non-agricultural enterprise. Only 7.0% of the respondents with non-agricultural enterprise had farms from 31 to 50 ha. Of the respondents who did not launch any non-agricultural activity, most (26.9%) had farms from 16 to 30 ha. Slightly fewer respondents (21.5%) were the owners of farms from 11 to 15 ha. Farms from 31 to 50 ha were owned by 20.4% of the respondents who did not run any enterprise alternative to the agricultural one. The farms from 5 to 10 ha were owned by 18.3% of the respondents, while those from 51 to 100 ha – 6.5% of the respondents who did not run any non-agricultural enterprise. The farms below 5 ha were owned by 5.4% of the respondents who did not declare any other sources of income than the farm. The farm from 101 to 300 ha was reported by one respondent (1.1%) who did not run any non-agricultural enterprise.

The comparison of the relationship between the age and running non-agricultural enterprise shows that of all the respondents who were running non-agricultural enterprise, most (48.8%) were aged 40-49, slightly fewer (27.9%) respondents with non-agricultural enterprise were aged 50-59. The respondents running non-agricultural activity at the age below 29 were less numerous (16.3%), while those with the non-agricultural enterprise aged over 60 accounted for 7.0%. Of all the respondents aged 30-39, there was nobody who would run non-agricultural enterprise, whereas of all the respondents without the non-agricultural enterprise, most (33.3%) were aged 40-49. Slightly fewer respondents (32.3%) with agricultural enterprise only were aged 30-39. Fewer respondents (21.5%) who dealt only with agricultural activity were aged 50-59. Only 6.5% of the respondents with no agricultural enterprise were over 60 and below 29.

Of all the respondents, 31.6% declared that they were running non-agricultural enterprise. The replies demonstrate that most of the farmers researched have launched their non-agricultural enterprise over the last 15 years. Most respondents (39.5%) answered that they had been running non-agricultural enterprise for 6 to 15 years. Slightly fewer respondents (34.9%) claimed to have been operating the non-agricultural enterprise shorter than 5 years. Slightly fewer respondents (25.6%) declared to have been operating the non-agricultural activity for 16 to 25 years. None of the respondents replied that he had been operating non-agricultural enterprise longer than 26 years (Fig. 10).

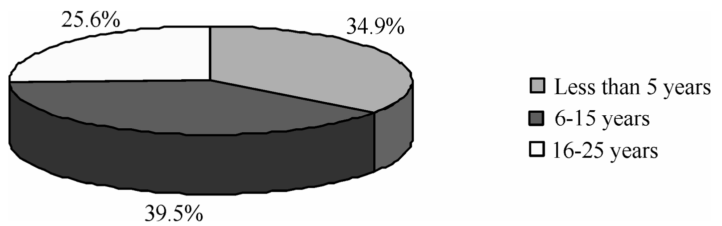


Fig. 10. Non-agricultural enterprise operation period

The respondents were also asked what kind of enterprise they were running. Most of the respondents (32.6%) replied that they were operating non-agricultural enterprise other than those suggested; e.g. pharmacy, bakery, grocer's shop. Slightly fewer respondents (27.9%) claimed that they were running a non-agricultural production enterprise. The agricultural produce purchase centre was managed by 18.6% of the respondents, while fewer (11.6%) replied that they dealt with agricultural processing. Only 7.0% declared that they were dealing with craftsmanship, the same number – with transport services (7.0%) and with the trade of means of agricultural production, foodstuffs or clothing (7.0%). Only 4.7% of the respondents answered that they were rendering construction services. None declared to have been running agricultural machinery rental or tourist services.

Of all the respondents with non-agricultural enterprise, most were of secondary or higher education background. The respondents of primary school education background dealt only with non-agricultural production activity (100.0%). Among vocational school graduates, most also dealt with non-agricultural production enterprises (38.5%), and slightly fewer (23.1%) were operating agricultural produce purchase centre or foodstuffs processing. Only 15.4% rendered construction services. Of all the respondents of secondary education background, most (29.4%) were operating agricultural produce purchase centre and slightly fewer respondents answered that they were running other non-agricultural enterprise (23.5%). Fewer respondents (17.6%) declared that they were dealing with trade or rendering transport services. Only 11.8% of the respondents were offering agricultural processing. As for the respondents with a higher education degree, most (58.8%) replied that they were operating another non-agricultural enterprise. Only 23.5% people were dealing with non-agricultural production activity, while 17.6% – with craftsmanship.

The persons researched with non-agricultural activity included 26 women and 24 men. Most women (38.5%) were running non-agricultural production enterprise or another non-agricultural enterprise. Fewer women (11.5%) were dealing with the trade of means for agricultural production, foodstuffs and clothing or operated agricultural produce purchase centre. As for men, the non-agricultural activity varied more considerably. Most men (20.8%) dealt with agricultural processing or operated agricultural produce purchase centre. Slightly fewer men (16.7%) marked another non-agricultural enterprise. Only 12.5% of men dealt with craftsmanship or transport services. The lowest number of men (8.3%) operated non-agricultural production activity or provided construction services.

The scope of non-agricultural enterprises run by the respondents covers also the area where the enterprise activity is developed. Most respondents (25.6%) replied that the territory of their non-agricultural activity was the Inowrocław commune. Slightly fewer respondents answered that the scope of their non-agricultural activity was the village where they lived and the locations in the vicinity (20.9%), the Inowrocław county (20.9%) or the entire Kuyavian-Pomeranian Province (20.9%). Only 11.6% of the respondents claimed that the scope of the territory of their enterprise covered the entire territory of Poland, and even other countries. None claimed that the area of the non-agricultural activity was only the village they live in, the Kuyavian-Pomeranian Province only as well as the provinces in the vicinity or only the entire country.

The respondents were asked to specify the share of their non-agricultural income in the total household income. Most respondents (30.2%) declared that the share of non-agricultural income in the total household income was up to 25%. Slightly fewer respondents (27.9%) replied that such share was over 75%, slightly fewer (25.6%) claimed that the share of non-agricultural income in the total household income was about 26-50%. Only 16.3% of the respondents replied that the share was about 51-75 % (Fig. 11).

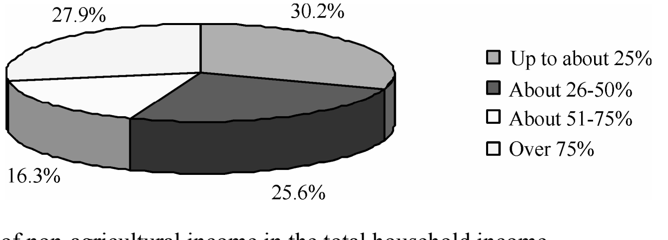


Fig. 11. Share of non-agricultural income in the total household income

Upon Poland's joining the European Union in 2004, the countryside and agriculture were covered by the financial support programs as part of the EU Common Agricultural Policy. Of many programs focused on the development of rural areas, there were also those directly available to the farmers interested who wanted to develop their enterprise alternative to agricultural production. The respondents, asked about subsidies from the European Union related to the non-agricultural enterprise over the last 5 years, mostly (76.7%) answered that they did not use any EU non-agricultural enterprise subsidies. Only 16.3% of the respondents claimed that they used the subsidies for the establishment and development of micro-enterprises. Even fewer (7.0%) benefited from the co-financing for diversifying their activity towards non-agricultural enterprise.

Conclusions

The research carried out in the Inowrocław commune demonstrated that in the new reality, the agricultural farm income very frequently does not provide sufficient finance to support one's family up to the expected standard. To enhance the living standard, the persons with agricultural enterprise have launched other enterprises connected with agriculture but often going beyond the standard agricultural production, which was usually conditioned by the education background and possibilities supported by experience and skills of the individuals, especially enterprise attitudes. What was also essential was the location of a given farm or the entire commune and the resultant help or barriers for launching enterprise alternative to agriculture and searching for additional sources of income.

The present research demonstrates that the respondents have usually operated a farm for a dozen or so years and most often planned increasing their farm acreage, or keeping the acreage unchanged. As seen from the present study, the respondents usually perceived a possibility of increasing their farm income, mostly by increasing its acreage or specialising in a single production mainstay. For most of the respondents, agriculture was the main area of activity and of generating income. Additional household income was, most frequently, generated by old-age and disability pensions. Slightly fewer people declared that additional income was generated by hired jobs outside the farm. The same number of people claimed that the household had no additional sources of income.

Some respondents operated non-agricultural enterprise, and most often it was operated in the area of the Inowrocław commune. Even though most of the farmers under study have not benefited from any non-agricultural subsides from the European Union over the last 5 years, still some were getting financed for the establishment of micro-enterprise or launching non-agricultural enterprise.

As seen from the present study, in the Inowrocław commune, the farm income was usually connected with its acreage. The respondents who intended to launch their non-agricultural enterprise most often operated small farms. The idea of increasing their farm acreage was most often reported by the respondents whose farm was bigger, above 10 ha. The farmers with small farms, in order to increase their income, usually intended to specialise in a single production mainstay and to consult their actions with the agricultural advisor. According to the opinions of the respondents, the factor making the launch or operation of the non-agricultural enterprise most difficult was a lack of demand for non-agricultural services or production. The enterprises the respondents wanted to choose in the future were transport services, agricultural processing and tourist services.

As seen from the present study, the Inowrocław commune farmers have launched non-agricultural enterprise since every third respondent has been dealing with non-agricultural enterprise. Most often the respondents have started their non-agricultural activity over the last 15 years. However, the most numerous was the group of farmers who have not started any non-agricultural enterprise yet. As it seems, in the future the development of the rural areas and agriculture will result in a growing diversity in agricultural income, thus making the farmer families search for alternative sources of income to provide a sufficient standard of living.

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SUPPORTING AGRICULTURE AND RURAL AREAS OF THE KUYAVIAN-POMERANIAN PROVINCE OVER 2004-2006

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Introduction

Rural areas in Poland have been defined based on the territorial division of the country according to the Official Register of the Territorial Division of the Country (TERYT) and, according to the standards applied by the Central Statistical Office (GUS), account for 93.4% of the country's area. Since there are different classification methods applied for these areas across the European Union, there are differences in the area quoted.

The methodology of defining rural areas applied by the Organization for Economic Co-operation and Development (OECD) defines them as the areas where the population density is up to 150 people per square kilometre. According to the European Charter for Rural Areas (EKOW) of 1996, the rural areas cover the areas where the population density is lower than 100 persons per square kilometre. The same criterion is applied by Eurostat.

Applying the OECD methodology, the rural areas would account for 91.7% of the country's area, and applying the rural areas classification according to Eurostat – for 85.7% (Heller 2000). Irrespective of the type of rural areas classification applied, over 80% of their share in the total area of the country shows the importance of an integrated approach to their multifunctional development. According to EKOW, these areas should play different functions, e.g. agricultural, economic, social and cultural, ecological, and tourist etc. The implementation of tasks which are to ensure the multifunctional rural areas development is supported by the EU structural policy instruments and the mechanisms offered by the Common Agricultural Policy.

Due to the regional variation in the Polish agriculture, it is justifiable to evaluate the directions and the scope of support across provinces. The Kuyavian-Pomeranian Province is among the country's agricultural leaders but it also needs support. The aim of the present paper is to present the directions and the scope of support for agriculture and rural areas of the Kuyavian-Pomeranian Province over 2004-2006 as part of the Sectoral Operational Program 'Restructuring and modernization of food sector and rural development 2004-2006'.

As reported by GUS, in 2005 the average population density in Poland was 122 people per square kilometre. In the Kuyavian-Pomeranian Province the indicator was

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slightly lower than the country's average and it was 115 people per square kilometre. As for the population in rural areas (38.5%), the province is the ninth in the country. Most people reside in the smallest locations from 100 to 500 people (66% of the population) and only 6% reside in the locations with the population over 1000 (PROW 2007).

Due to the fact that the agricultural sector has a dominant share in the rural areas enterprise structure, also the structural transformations affect both the situation of the farms and the rural areas residents. Bearing that in mind, the structural policy and the Common Agricultural Policy implemented upon Poland's joining the EU are of special importance. As part of the EU fund transfers from the EU to Poland over 2004-2006, of every 100 PLN (Polish zloty), 27 PLN was allocated to the agricultural policy only (Zawojska 2006).

Restructuring of food sector and rural development as part of SOP 'Agriculture'

The first budget period for Poland (2004-2006) covered two programs addressed to farmers, agrifood producers and rural areas residents: Sectoral Operational Programme 'Restructuring and modernization of food sector and rural development 2004-2006' (SOP 'Agriculture'; SOP 2004) and Rural Development Plan for 2004-2006.

Additionally one shall stress that, as part of the Integrated Regional Operational Programme for 2004-2006 (IROP), the first priority 'Development and modernization of' infrastructure to enhance the competitiveness of regions', there were also implemented projects in the rural areas to enhance the state of the local and regional infrastructure and as part of the second priority – educational projects addressed to the rural areas residents, e.g. measure: 'Vocational reorientation of persons leaving agriculture sector'. Upon IROP implementation, 186.99 PLN was allocated, expressed in the value of the executed projects, per 1 resident of the rural areas in the Kuyavian--Pomeranian Province (IROP 2004).

SOP 'Agriculture', approved by the European Commission on 07.07.2004 was to support the implementation of primary objectives included in the National Development Plan 2004-2006, and formulated in the agriculture and rural areas development strategy. The general aim was to restructure the food sector and to develop rural areas. The implementation of the projects as part of seven measures approved for implementation all across the country was to address three strategic objectives:

- enhanced competitiveness and permanent and sustainable agricultural sector development,
- enhanced processing industry competitiveness,
- multifunctional rural areas development.

Each of the SOP 'Agriculture' priorities focused on supporting the implementation of specific objectives. As part of the first priority 'Supporting of changes and adjustments in agricultural and food sector', the following measures were implemented in all the provinces:

1.1. Investments in farms.
1.2. Setting up of young farmers.
1.3. Training.
1.4. Advisory services for farmers.
1.5. Improving the processing and marketing of agricultural products.

The measures, apart from two (1.3; 1.4), were investment-oriented and their aim was to modernize farms and processing plants, to enhance the quality and production organization, to adjust farms to the EU standards, and to enhance production conditions.

As part of the second priority ‘Sustainable development of rural areas’, the following measures were implemented:

2.1. Forestry production potential recovery.
2.2. Land consolidation.
2.3. Village renewal and cultural heritage preservation.
2.4. Diversifying of agricultural and agriculture-related activity.
2.5. Agricultural water resources management.
2.6. Agriculture-related technical infrastructure development and enhancement.
2.7. Pilot Programme Leader+ (SOP ‘Agriculture’).

The aim of this priority was to ensure support for the activities addressed to rural areas development. What was also essential was the pursuit of diversification in the enterprises in operation or launched in rural areas by providing financial assistance to specific services, production and other enterprises. The projects implementation was to result in creating new jobs outside agriculture, offering a possibility of generating additional income by limiting the unemployment in rural areas, whereas the other measures were aimed at enhancing the living conditions and farming in rural areas and supporting the multifunctional rural development, also by stressing the need to make these areas more attractive.

The measure Pilot Programme Leader+ (PPL+) has assumed a special place in this priority; it aimed at triggering the activity of local communities and building their involvement in the cooperation in creating the Local Action Groups (LAG). The LAGs created have developed the Integrated Rural Areas Strategy which was the springboard for the implementation of multi-sector projects to help rural areas development.

SOP ‘Agriculture’ was financed from the Guarantee Section of the European Agricultural Guidance and Guarantee Fund (EAGGF) and from the domestic funds, both public and private. In total the implementation of all the domestic projects amounted to over 6.9 billion PLN, of which the share of the European Agricultural Guidance and Guarantee Fund was over 4.6 billion PLN (MRiRW 2008b).

Interestingly, as far as the total contracted funds are concerned, the Kuyavian--Pomeranian Province has ranked fourth in the country and as per rural resident, in the province there have been gained 7.3% of the public funds contracted as part of the whole SPO ‘Agriculture’ – ranking 5th in the country (MRiRW 2008b).

In total in the Kuyavian-Pomeranian Province, as part of SOP ‘Agriculture’ over 2004-2008 (following principle n+2), there were implemented 3195 projects, including 23 projects implemented under Technical Assistance. If we consider the total number of projects implemented in a given province from the funds available from SOP to be the criterion of effective gaining of EU funds, then the Kuyavian-Pomeranian Province has ranked sixth in the country. The total number of projects in the country was 50,375; most projects implemented fell under measure 1.1 Investments in farms (24,250) and 1.2. Setting up of young farmers (MRiRW 2008b).

Effects of SPO 'Agriculture' implementation considering the measures taken in the Kuyavian-Pomeranian Province rural areas

Table 1. Implementation of SOP 'Agriculture' measures in the Kuyavian-Pomeranian (K-P) Province considering the value of the contracted funds and the total number of projects implemented over 2004-2008. Based on: Use of the Sectoral Operational Programme funds 'Restructuring and modernization of food sector and rural development' across provinces on 30.09.2008 MRiRW

Measure no	Measure name	Total amount of contracted public funds in the K-P Province [million PLN]	Number of projects implemented in the Province
1.1.	Investments in farms	206.18	1985
1.2.	Setting up of young farmers	68.46	1129
1.3.	Training	3.03	11
1.4.	Advisory services for farmers	7.57	2
1.5.	Improving the processing and marketing of agricultural products	146.35	84
2.1.	Forestry production potential recovery	0	0
2.2.	Land consolidation	0	0
2.3.	Village renewal and cultural heritage preservation	22.64	178
2.4.	Diversifying of agricultural and agriculture-related activity	18.96	243
2.5.	Agricultural water resources management	23.06	21
2.6.	Agriculture-related technical infrastructure development and enhancement	11.45	213
2.7.	Pilot Programme Leader+	10.12	26

Analysing the financial support provided and the scope of the projects implemented under three measures (1.1; 1.5; 2.4) with an essential effect on supporting the changes and adjustments in the agriculture sector and food economy, one shall note a very high interest among the potential beneficiaries (Table 1) in the possibility of gaining financial assistance for the implementation of projects, which is seen from the number of the applications filed in the regions (ARiMR 2007).

As part of Measure 1.1. Investments in farms, as much as 84% of the investments in the country involved the purchase of new agricultural equipment and accessories which aimed at modernizing the machine park on the farms. Of all the support applicants in the country, over 80% of the farmers declared that the investment would result in achieving one of the following objectives:

– agricultural production organization enhancement – 53.4% of the applicants,
– farm competitiveness enhancement – 14.5% of the applicants,
– agricultural income increase – 12.7%,
– agricultural production costs cuts – 9.3% (Agrotec Polska, IERiGŻ 2007).

As far as the effect of the investment on the economic situation of the farm is concerned, the following dominated: production organization enhancement – 22.3%; property recovery – 14%; working conditions and safety improvement – 12.9%, produce quality improvement – 11.3%. Additionally the group of beneficiaries researched declared that as a result of the investments made they would expect also an increase in income in the future. The number of applications filed shows clearly very high investment requirements of the farms, which has been confirmed also by the respondents; over 2007-2013 66% of them would like to benefit from the EU funds for the purchase of agricultural machinery and equipment, 40% would like to invest in the modernization of farm buildings, whereas 15% of them plan to purchase land (Agrotec Polska, IERiGŻ 2007).

Most projects (3257) in the country falling under this measure were implemented on the farms of the economic size from 10 to 15 ESU (European Size Unit) and 20-30 ESU (3145) and so on small farms the competitiveness of which on the market did not get much better and the effect of investment on the economic situation of the farm was inconsiderable.

In the Kuyavian-Pomeranian Province in the first round 2381 applications were filed and in 2007 in the additional, second, round – 1296. Analysing the number of projects (1985) which cover investments in farms made in the Kuyavian-Pomeranian Province, one can state that the investments were made only by 1.18% of all the farms (concerning the number of farms 101.130), and the average level of economic viability of the farms was 48.3 ESU. The total amount of the financial assistance awarded in the province was 187.6 million PLN, and the average amount of financial assistance per project was 199.5 thousand PLN (ARiMR 2007).

As for Measure 1.5. Improving the processing and marketing of agricultural products, in the country there were implemented 1119 projects, of which in the Kuyavian-Pomeranian Province 105 applications were filed and 84 projects were co-financed. In total 167.0 million PLN was allocated to that measure in the province. In total in the province the financial assistance was provided to 12% of the alimentary idustry firms, and 66.7% of them having their registered seat in the rural areas. In the country of all the beneficiaries under this measure, 66% stated that thanks to the funds gained, the following objectives are to be met in their works:

- sanitary-and-hygiene and veterinary production conditions improvement – 23.8%,
- production quality enhancement – 22.3%,
- new production technologies support – 19.6%.

In the Kuyavian-Pomeranian Province, in the opinion of the beneficiaries, the projects implemented mostly contributed to the improvement of sanitary-and-hygiene and veterinary production conditions. The beneficiaries were dominated by legal-person firms. Interestingly, over 47% of the beneficiaries showed that the own contribution required was made up by own funds only.

Under Measure 2.4. Diversifying of agricultural and agriculture-related activity, as many as 81% of the beneficiaries declared that they aimed at creating alternative sources of income, while in their opinion, the implementation of the project financed from the EU funds was to enhance the farm income (31%); the quality of the services rendered (23.5%); diversification of the sources of income (21.1%). As part of the projects, irrespective of the kind of enterprise, the following costs dominated: purchase of machinery, equipment, accessories and machinery. As for the economic size, 49% of all the beneficiaries in the country were very small farms up to 2 ESU. Similarly under this measure, over 50% of the beneficiaries declared that the own contribution required was made up by their private funds.

In total in the Kuyavian-Pomeranian Province, 395 applications were filed, and 243 projects were selected, including as many as 233 implemented by physical persons mainly in rural areas (98%). As compared with the total number of farms in the province, the projects implemented accounted for 0.24% of the entities only. In the entire province the financial support granted amounted to 19.2 million PLN (ARiMR 2007). A growing interest of the farmers in seeking EU funds is demonstrated in Table 2.

Measure 2.6. Agriculture-related technical infrastructure development and enhancement, supplemented the catalogue of investment activities; the beneficiaries could implement their projects aimed at enhancing the state of the technical infrastructure and natural environment protection. In the Kuyavian-Pomeranian Province 341 applications were filed, of which 221 projects at the total amount of 11,899 thousand PLN were approved. The investments were dominated by the costs of repair and building of internal roads to access farms (ARiMR 2007).

Table 2. Increase in the number of applications filed under Measures 1.1; 1.5; 2.4 over 2004-2006. Based on the data provided by O/R ARiMR in Toruń

SOP 'Agriculture' Measure	2004 Round	2005 Round (progressively)	2006 Round (progressively)
1.1. Investments in farms	211	2381	2381 + 1294 (additional round 2007)
1.6. Improving the processing and marketing of agricultural products	5	105	105
2.4. Diversifying of agricultural and agriculture-related enterprise	11	166	394

The agriculture modernization process was supported by regional and national training and counselling services projects implemented as part of Measures 1.3 and 1.4 which aimed at enhancing the knowledge and skills of farmers and rural areas residents of e.g. seeking the EU funds, farm management compliant with new EU standards and informatics technic applications on the farm.

The main effect of the investments made was the modernization of farms and their adjustment to agrifood producers standards in the EU. The investments made enhance the specialization and concentration of agricultural production and increase in its efficiency, especially clearly visible on large farms (Ziętara 2009). Additionally, the investment boom in agriculture had a positive effect on agriculture-related entities and the services and construction market, and hence a seasonal increase in the demand for new jobs.

Due to a high demand for continued investments in the new budget period 2007-2013, there is a possibility of farm modernization (1.1; measure numbering in SOP 'Agriculture' 2004-2006), increasing the value added of basic agricultural and forestry production (1.5), improvement and development of infrastructure related to the development and adaptation of agriculture and forestry (2.6), diversification towards non-agricultural activities (2.4), basic services for the rural economy and population as well as village renewal and development (2.3) LEADER type projects, on the other hand, were identified as part of 4th Rural Development Programme 2007-2013.

As for the already launched rounds of applications in the Kuyavian-Pomeranian Province in 2007 under Measure of farm modernization, there were filed 1339 applications which by September 2008 had not been processed by the agency. The average value of the application was 130,000 PLN, and the total value of the applications accounted for 165.61% of the allocation available under that measure. Interestingly, as in the previous period about 80% of the applications cover the purchase of agricultural equipment and machinery, which still points to high demand for the modernization of farms, both small and large.

As part of the application round in 2008 under the measure of increasing the value added of the basic agricultural and forestry production, 76 applications were filed, and under diversification towards non-agricultural activities – 176 applications. The application processing is handled by 27 employees of the regional branch of the Agency for Restructuring and Modernization of Agriculture in Torun.

The SOP 'Agriculture' measures implementation experience was used to verify the accessibility criteria for potential beneficiaries in the new Rural Development Programme for 2007-2013. Due to the seven-year budget perspective and the implementation of a single programme instead of the previous two, similarly, the number of measures increased offering new instruments, e.g. the participation of farmers in food quality systems.

Measures for sustainable development of rural areas

Three SOP 'Agriculture' measures (2.2; 2.3; 2.5) were implemented at the regional level by province marshal authorities. In the Kuyavian-Pomeranian Province Measure 2.3. Village renewal and the cultural heritage preservation and protection, involved a total of 98 communes and municipalities-and-communes, which accounted for 77.17% of all the communes entitled. This index value made the province come second in the country as far as the activity of the communes was concerned. In total 271 applications were filed, of which 178 projects were implemented, including 57 communes – 1 project each, 22 communes – 2 projects each, and 8 communes – 3 projects each. The total value of the projects implemented was 35.39 million PLN, and the average value of the project per 1 resident of the rural areas of the province was 44.28 PLN (MRiRW 2008a).

According to the costs category, in the province the following applications dominated:

- for the construction, adaptation or repair of cultural infrastructure – 50.36%; 136 projects concerned rural day-rooms, 18 – cultural centres, and 2 – libraries,
- for recreational, sports, tourist infrastructure – 33.81%; 62 sports fields, 66 playgrounds, 2 gyms, and 5 bike lanes,
- for development and management of rural areas and rural centres – 14%; 12 leisure centres for the residents, 5 bridges, 2 water reservoirs (MRiRW 2008a).

The implementation of Measure 2.3 in the Kuyavian-Pomeranian Province resulted in a considerable cultural and recreational infrastructure quality enhancement and repeated resident-friendly rural centres development.

Measure 2.5 Agricultural water resources management, resulted in the investments in the construction or improvement of the condition of water land-improvement equipment, basic (18) and advanced, as part of 24 projects, which ensured the use of the limit allocated to the province which accounted for 152% of the total allocation. These investments, for example, improved the effectiveness of agricultural land protection from floods (ARiMR 2007).

Due to a lack of beneficiaries in the province showing interest in Measure 2.2 Agricultural land consolidation, the funds allocated under this Measure were reallocated to cover the needs of the applicants representing other provinces. Pilot Programme Leader+ aimed at activating local rural communities and encouraging them to act for the development of rural areas and small communities. An added effect of the LAG operation is to reinforce the social capital, which is an important factor defining the residents of the village (Kamiński and Błąd 2005).

In the country as a whole, there were filed 225 applications, of which contracts were entered into with 174 entities. In the Kuyavian-Pomeranian Province this Measure also attracted a lot of interest, 20 LAG emerged to cover the entire province, except for the cities of Bydgoszcz and Torun as being excluded from LAG activity (in 2009 21 LAG).

Effects of an inadequate implementation of projects in SOP ‘Agriculture’

An essential aspect of the EU funds absorption process is the adequacy of their spending and knowing how to settle the projects following the applicable guidelines for a given measure as well as the need to meet all the conditions provided for in the co-financing contract. A detailed procedure in the case of identifying and stating irregularities is regulated by applicable provisions which make the member state obliged to notify of any such cases to the European Commission.

Compliant with the applicable procedures, the Polish party has notified the European Commission of stating a total of 497 irregularities from May 2004 through December 2007, of which the agricultural projects accounted for 39% (193) of all the irregularities for the total amount of over Euro 6.4 m (Ministry of Finance... 2008). Of that number, 123 irregularities have been eliminated so far. Analysing the kind of irregularity according to the kind of the fund the activities were financed from, the EAGGF comes first, however, as for the total amount of money the irregularities identified make up, it accounts for 0.6% of the amount of the allocation for all the approved applications. Due to the kind and scope of irregularities identified, only some of them are qualified to be handed over for investigation. 94 of such SOP ‘Agriculture’ cases were notified of. According to the kind of irregularities, public procurement law procedure breach comes first, document falsifying comes second, and expenditure non-qualifying for co-financing – third.

Conclusions

The experience of implementing the first Programmes addressed to agriculture and rural areas has made it possible to determine the first positive effects of the EU co-financed project implementation. Thanks to the financial support granted there were many important investments made in the country without which the agriculture modernization would be limited and in many cases – just impossible.

The analysis of the scope and kinds of the support granted over 2004-2006 also facilitated specifying new objectives the implementation tool of which are e.g. the measures under the Rural Development Programme 2007-2013 which are gradually being implemented, offering possibilities of further development to the farmers, producers and residents of rural areas.

Although the agriculture of the Kuyavian-Pomeranian Province demonstrates a relatively high effectiveness of support, the interest in seeking funds as part of the Sectoral Operational Programme was very high. The directions and scope of this support concerned both the agricultural production and the sustainable development of rural areas and their multifunctional character. This support helped the implementation of many important investments enhancing the modernization of agriculture and rural areas of the Kuyavian-Pomeranian Province.

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FARM INCOME DEPENDING ON THE COW NUMBER

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Poland is one of the top European Union countries and one of the top ten countries of global agriculture as far as the amount of milk production is concerned. The domestic milk production concerns 1.3 million farms. To achieve the EU standards, dairy farms have been made to make considerable investments. As a result, dairy farms have been getting diversified; there emerge specialised farms of adequately high cow herds and the farms keeping small dairy herds for milk consumption for the farmer's family, for animal feed purposes and operating in the direct sale system. The dairy production concentration enhances the quality of the milk material and decreases the production costs (Seremak-Bulge 2006; Cieślik and Żmija 2007). Following the integration with the EU, the milk production has been directly covered by the Common Agricultural Policy (CAP). One of the main objectives of the CAP is to ensure reasonable income to those involved in agricultural production (Czyżewski and Henisz-Matuszczak 2004).

Depending on the needs, the farm income can be measured with the gross margin, gross farm income, and with the farm net income. Many economists investigated dairy farm profitability, e.g. evaluating the effect of such factors as: milk purchase price, unitary cow milk efficiency, production cost-consumption and the size of the cow herd (Sznajder 2000; Mańko 2005). Farms of inconsiderable production of scale cannot generate sufficient income which would guarantee an adequate payment for the job of the farmer and his family (Cieślik and Żmija 2007). The production scale is determined by the cow numbers and the milking capacity. The size of the cow herd which ensures generating of adequate parity income is at least 20 dairy cows (Mańko 2005; Skarżyńska 2006). A chance for enhancing the profitability of farms with a lower number of cows can be multi-direction production where milk production income can be supplemented by beef livestock production based on permanent grassland animal feed (Cieślik and Żmija 2007). The aim of the present paper was to evaluate the profitability of farms of different number of cows, after the integration with the EU.

Materials and methods

The basic source of information was provided by FADN (Farm Accountancy Data Network) results for 2004-2006. The area of Poland for FADN purposes has been broken into four macroregions: region no 785 – Pomerania and Mazuria, region no 790

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– Greater Poland and Silesia, region no 795 – Masovia and Podlasie, region no 800 – Małopolska and Pogórze. The macroregions were identified based on similarity of the production conditions, farm acreage structure as well as based on the production technologies applied (Józwiak and Mirkowska 2004). The Kuyavia and Pomerania Province is part of the Greater Poland and Silesia region.

The present research covered farms with 2004-2006 continuous FADN accountancy, keeping at least 5 cows; 272 from the Kuyavia and Pomerania Province, 872 from the Greater Poland and Silesia region as well as 3094 from all across the country. The farms have been broken into groups depending on the number of cows per herd: 5-10, 10-15, 15-20, 20-30, 30-80, 80 and more (Table 1). Due to a low number, the analyses do not cover farms with 80 cows and more (Tables 2-18).

Table 1. Number of studied farms according to the number of cows kept

Area	Year	Farms according to the number of cows						
		Total	5-10	10-15	15-20	20-30	30-80	80 and more
Poland	2004-2006	3 094	1 109	808	507	426	225	19
Greater Poland and Silesia		872	282	222	142	139	75	12
Kuyavia and Pomerania		272	83	71	46	50	21	1

Results and discussion

Farm potential

The acreage of the cow farms researched in the Kuyavia and Pomerania Province, in the region and all across Poland over 2004-2006 was increasing regularly (Table 2). In 2004 the average utilized agricultural area of the farm researched in the Kuyavia and Pomerania Province was 33.7 ha, whereas in 2006 – 35.2 ha and it was higher that the corresponding acreage of the average farm researched in Poland. However, it was smaller than the utilized agricultural area of the average farm in the region.

The utilized agricultural area of the farms researched in the province keeping 10-15 cows was lower than the farms with 5-10 cows. In the other Kuyavia and Pomerania farm groups, the higher the number of the cows kept, the higher the average utilised agricultural area.

Table 2. Utilized agricultural area of the farms studied over 2004-2006 [ha]

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	31.3	21.6	26.7	30.6	37.9	58.2
	2005	32.1	22.0	27.3	31.6	39.2	59.8
	2006	32.5	22.0	27.2	32.3	40.7	61.2
Greater Poland and Silesia	2004	37.9	25.7	29.7	33.0	38.9	57.4
	2005	38.6	26.0	30.6	34.0	40.3	58.9
	2006	39.0	26.1	31.3	34.6	40.9	59.6
Kuyavia and Pomerania	2004	33.7	28.4	26.3	30.5	37.0	56.5
	2005	34.8	28.9	27.5	31.3	37.6	61.4
	2006	35.2	28.9	28.0	32.1	38.6	59.4

The biggest utilized agricultural area in the province, region and in Poland was recorded for the farms with the biggest number of cows. The utilized agricultural area of these farms was almost two-fold higher than the farms keeping up to 30 cows and 1.5 higher than the acreage of farms with 20-30 cows.

The number of cows kept is also correlated with economic size (Table 3). In the years 2004-2006 an increase in the economic size of the farms researched, irrespective of the number of cows kept, was recorded. The economic size of the average cow-keeping farm in the Kuyavia and Pomerania Province over 2004-2006 was 24.5, 25.3, 25.9 ESU (European Size Unit), respectively. It was higher than the economic size of the average farm in the country (economic size 19.7, 20.3, 21 ESU, respectively), however, lower than the economic size of the farms in the region (the economic size: 27.7, 28.6, 29.4 ESU, respectively). This relationship also concerned the farm broken into groups depending on the number of cows, except for farms keeping 5-10 cows. The economic size of the farms with 5-10 cows was higher than the economic size of the corresponding farms both in the region and in the country.

The economic size of the farms of the Kuyavia and Pomerania Province keeping up to 15 cows was similar and it was about 20 ESU. In the other groups of farms keeping over 15 cows, it was increasing regularly. The economic size of the farms with 30-80 cows was about 2-fold higher than the farms with 15 cows. The situation on the farms in the region and in the country was slightly different; the higher the number of cows, the greater the economic size of the farm.

Table 3. Economic size of the farms studied over 2004-2006 [ECU]

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	19.7	12.6	16.7	20.1	25.8	39.7
	2005	20.3	12.8	17.0	20.7	27.2	42.0
	2006	21.0	13.2	17.5	21.5	27.9	43.7
Greater Poland and Silesia	2004	27.7	18.7	22.0	26.2	31.8	44.2
	2005	28.6	18.9	22.3	26.9	33.9	47.5
	2006	29.4	19.3	23.1	28.0	34.5	49.1
Kuyavia and Pomerania	2004	24.5	19.9	20.0	22.5	29.0	41.7
	2005	25.3	20.4	20.1	23.0	30.4	44.7
	2006	25.9	20.8	20.3	23.6	31.2	46.2

Changes in the density, milk yield, and total specific costs of milk production

The diary cow stocking density in the Kuyavia and Pomerania Province, region, and in Poland differed a lot and ranged from 26.2 to 77.6 LU (Livestock Unit) for every 100 ha of utilized agricultural area (Table 4). A low stocking density was recorded for the farms with 5-10 cows, an average stocking density for 10-15 and 15-20 cows, and high for 20-30 and 30-80 cows. Over the years of study the cow number on the farms increased. In 2005 it increased by about 4% on the farms in Poland and in the region, whereas in the Kuyavia and Pomerania Province slightly less (3.3%). The growing trend was maintained also in 2006; on the farms in the province and the region the cow stocking density increased by almost 6%, and Poland by 6.7%.

The farms of the Kuyavia and Pomerania Province with the number of cows 5-10 and 30-80 demonstrated a lower stocking density than the farms with a similar number of cows in the region and in Poland. In the other farm groups (10-15, 15-20, 20-30) the number of cows per 1 ha of utilised agricultural area in the Kuyavia and Pomerania Province was higher than on average in the region and in Poland.

Table 4. Cow number in LU/100 ha of the utilised agricultural area on the farms studied over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	49.5	33.3	45.7	55.9	63.2	69.1
	2005	51.5	34.1	48.1	57.5	64.9	72.6
	2006	52.8	35.0	50.4	58.9	64.8	74.2
Greater Poland and Silesia	2004	45.4	28.4	41.2	51.8	62.3	70.3
	2005	47.2	28.9	42.6	52.4	64.2	75.2
	2006	48.1	28.8	43.1	53.9	65.5	77.6
Kuyavia and Pomerania	2004	47.8	26.2	46.8	57.0	65.0	67.8
	2005	49.4	26.9	49.9	59.2	67.2	67.3
	2006	50.7	26.7	51.3	62.0	67.6	72.6

Higher stocking density resulted in a higher milk yield of cows. Similar correlation between the milk yield and the cow number occurred (Table 5). The highest milk yield was recorded for the farms with the number of cows 30-80, the lowest for the ones with 5-10 cows. The average cow milk productivity was higher on the farms with 5-10 and 10-15 cows researched in the Kuyavia and Pomerania Province than on the farms with the corresponding number of cows in the region and in the country. In the group of farms with 15-20 and 20-30 cows, the milk yield was slightly higher on the farms of the region. Similar situation was in the group of farms keeping 30-80 cows.

Table 5. Milk yield of cows in l/cow on the farms studied over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	4 722	3 775	4 251	4 604	5 048	5 585
	2005	5 102	4 046	4 574	4 948	5 410	6 115
	2006	5 164	4 038	4 629	5 030	5 490	6 184
Greater Poland and Silesia	2004	4 893	3 641	4 209	4 760	5 191	5 835
	2005	5 374	3 925	4 657	5 100	5 665	6 441
	2006	5 449	3 891	4 732	5 226	5 653	6 539
Kuyavia and Pomerania	2004	4 674	3 757	4 457	4 582	4 967	5 411
	2005	5 172	4 057	5 036	4 962	5 533	5 986
	2006	5 363	4 054	5 206	5 384	5 578	6 196

Over 2004-2006 the farms recorded an increase in the costs directly determining the size of milk production, except for the farms keeping 5-10 cows and 10-15 from the region and Poland as well as 30-80 cows from the Kuyavia and Pomerania Province (Table 6). The farms, especially with the number of cows 5-10, in 2005 decreased the total specific costs of milk production. The costs were higher on the farms of the Kuyavia and Pomerania Province than on the farms analysed across the country. The situation of the respective farm groups, identified according to the number of cows of the Kuyavia and Pomerania Province as compared with the farms in the region, was slightly different. In the groups of farms keeping 5-10 and 10-15 cows, the total specific costs of milk production were higher on the farms in the province, except for 2004 when it was opposite. The costs were higher also on the farms of the region than of the province keeping 20-30 and 30-80 cows.

Table 6. Total specific costs of milk production on the farms studied over 2004-2006 [thousand PLN per farm]

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	35.9	12.5	23.6	35.7	57.2	119.6
	2005	36.3	12.1	23.3	36.6	60.1	124.7
	2006	41.8	14.0	27.6	41.7	69.6	141.9
Greater Poland and Silesia	2004	45.1	13.8	24.3	40.4	63.4	134.9
	2005	45.9	12.8	24.3	41.4	70.3	140.9
	2006	50.9	14.2	28.2	44.1	76.6	157.9
Kuyavia and Pomerania	2004	37.7	14.5	23.3	36.9	58.6	126.1
	2005	40.6	14.4	28.3	39.5	65.3	122.8
	2006	46.1	15.3	32.9	47.1	70.8	143.3

Production and income

Increasing the cow stocking density and unitary production was reflected in the increase in production on the farms of the Kuyavia and Pomerania Province, region, and Poland, except for the farms keeping 5-10 cows on which the production in 2005 decreased slightly (Table 7). However, in the year 2006 also its increase was recorded. All that could have been due to a decrease in the total specific costs determining the production output, recorded in 2005 on the farms. The farms with 5-10 cows of the Kuyavia and Pomerania Province showed a higher production output than the farms of the region and the country. In the other groups, identified depending on the number of cows kept, the highest production output was reported on the farms of the region, while the lowest – on the farms of Poland.

Table 7. Total output in thousand PLN per farm over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	143.2	85.3	115.6	143.1	194.6	313.2
	2005	148.8	83.2	116.6	149.1	207.7	355.4
	2006	160.7	91.6	127.3	161.4	223.4	380.1
Greater Poland and Silesia	2004	193.8	120.2	145.1	177.8	223.3	335.4
	2005	200.2	115.5	145.9	181.1	238.3	384.8
	2006	212.2	124.4	156.4	193.6	251.9	414.4
Kuyavia and Pomerania	2004	173.1	133.4	141.7	159.1	207.6	324.5
	2005	180.0	131.0	143.4	164.5	226.6	369.4
	2006	196.7	135.5	156.5	180.2	244.5	405.1

The increasing number of cows resulted in an increasing share of milk and dairy products in the production of the farms (Table 8). The highest share of milk and dairy products in the total output reaching 70% and more was recorded for the farms with 30--80 cows, while the lowest share, not more than 30%, for the farms keeping 5-10 cows.

The share of milk and dairy products in the total output on most of the farms of the Kuyavia and Pomerania Province, the region and Poland increased in 2005, however, in the successive year it decreased. Such situation seems to be due to exceeding the quota of raw milk for processing awarded for Poland, referred to as 'wholesale quota' for milk in the accounting season 2005/2006 and, as a result, fines for many suppliers (Seremak--Bulge 2006).

Table 8. Share of the value of milk and dairy products in the total output [%]

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	45.3	24.4	37.8	48.2	56.3	68.0
	2005	52.8	29.7	45.5	55.5	63.4	75.0
	2006	51.2	27.8	44.2	54.0	61.6	74.0
Greater Poland and Silesia	2004	36.5	16.4	28.1	36.9	47.6	62.0
	2005	44.8	20.6	36.0	44.4	56.6	71.8
	2006	44.0	19.1	35.6	43.9	55.5	70.9
Kuyavia and Pomerania	2004	37.2	15.5	31.3	41.9	51.3	58.4
	2005	47.0	20.0	43.4	51.6	60.0	70.3
	2006	46.6	19.2	43.4	55.3	58.3	69.6

Over 2004-2006 the following factors involved in the production process: land, labour, and capital were used more and more effectively. The value of newly-produced goods was increasing. On the studied farms the gross farm income was growing regularly (Table 9). This category is applicable to compare the farms irrespective of the property ownership structure, hired jobs number and the farm debt (Goraj and Mańko 2009). The gross farm income was increasing on the farms researched of the province, region, and country with an increase in cow numbers. On the farms with 30-80 cows it was 2-fold higher than on the farms with 15-20 cows, the latter being almost 2-fold higher than on the farms with 5-10 cows.

The gross farm income was higher on the farms of the Kuyavia and Pomerania Province keeping 5-10 and 10-15 cows than on the corresponding farms in the country and higher on the farms with 5-10 and 10-15 cows in the province than in the region. Similarly, the farms with 30-80 cows located in the Kuyavia and Pomerania Province reached in 2006 a higher gross farm income than on the farms in the region and in the country. It was due to a decrease in the total specific costs on these farms. On the farms of the Kuyavia and Pomerania Province keeping 20-30 cows the gross farm income was lower than on the farms of the region and in the country, similarly as on the farms with 30-80 cows in the first years analysed.

Table 9. Gross farm income in thousand PLN per farm over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	84.0	48.6	67.8	84.8	115.8	193.7
	2005	92.6	50.1	71.8	93.7	129.7	231.9
	2006	108.6	62.2	87.5	110.3	149.7	262.0
Greater Poland and Silesia	2004	104.2	63.6	82.5	95.4	119.1	187.0
	2005	113.9	63.4	85.2	101.0	132.4	229.6
	2006	129.7	75.6	99.3	119.1	150.8	265.6
Kuyavia and Pomerania	2004	98.7	71.1	87.8	93.9	114.0	178.8
	2005	105.1	71.8	88.7	97.2	126.9	227.5
	2006	126.6	85.3	105.1	118.8	148.3	273.6

With an increase in the number of cows, the gross farm income per ha of utilized agricultural area on the farms in the country and in the region was also growing (Table 10). In the Kuyavia and Pomerania Province the gross farm income per ha of utilized agricultural area was increasing up to the number of 10-15 cows. The highest gross farm income per ha of utilized agricultural area was recorded on the farms with 30-80 cows in the province, region and in Poland on which in 2006 it amounted to 4606 PLN (Polish zloty), 4457 PLN, and 4286 PLN, respectively, whereas the lowest – on the farms with 5-10 cows (2953 PLN, 2894 PLN and 2829 PLN, respectively).

The gross farm income per ha of utilized agricultural area was in the years analyzed in the groups identified according to the number of cows kept higher on the farms of the Kuyavia and Pomerania Province than on the farms of the region and in the country, except for the farms with 30-80 cows where over 2004-2005 the situation was just opposite.

Table 10. Gross farm income in PLN per ha of utilized agricultural area over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	2 681	2 257	2 537	2 771	3 059	3 329
	2005	2 887	2 281	2 633	2 964	3 305	3 877
	2006	3 345	2 829	3 215	3 413	3 683	4 286
Greater Poland and Silesia	2004	2 750	2 475	2 776	2 893	3 062	3 256
	2005	2 949	2 433	2 789	2 967	3 282	3 895
	2006	3 326	2 894	3 174	3 447	3 685	4 457
Kuyavia and Pomerania	2004	2 931	2 502	3 339	3 077	3 078	3 166
	2005	3 022	2 485	3 221	3 100	3 379	3 708
	2006	3 600	2 953	3 749	3 696	3 846	4 606

In all the farm groups, irrespective of the number of cows kept, over the research years the economic labour efficiency expressed in the gross farm income per 1 person in full-time job was growing. Its increase occurred with an increase in the number of cows (Table 11). In 2006 in the country on the farms with 30-80 cows it was almost 3-fold higher than on the farms with 5-10 cows and, respectively, on the farms in the province – 2-fold and the region – 1.6-fold.

Over 2004-2006 the farms of the Kuyavia and Pomerania Province with the number of cows of 5-10, 10-15, and 15-20 reached a higher gross farm income per person in full-time job as compared with the corresponding farms in the country and the region, except for the farms keeping 15-20 cows on which the gross farm income per person in full-time job over 2005-2006 was similar in the province and in the region. On the farms with 20-30 cows the gross farm income per person in full-time employment was lowest on the farms of the province and in the group of farms with the biggest number of cows – lower than in the region (Table 11).

Table 11. Gross farm income in PLN per person in full-time employment over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	40 999	26 046	34 434	42 425	53 903	74 421
	2005	44 924	27 120	36 520	46 700	60 082	85 293
	2006	52 267	33 526	44 268	54 282	68 376	96 507
Greater Poland and Silesia	2004	48 700	34 128	41 079	47 405	53 858	72 842
	2005	52 476	34 139	42 933	50 176	60 024	86 313
	2006	59 021	40 172	49 373	59 258	67 814	99 665
Kuyavia and Pomerania	2004	48 090	38 910	43 562	48 242	51 108	67 201
	2005	51 136	39 607	44 133	48 871	57 298	84 167
	2006	60 087	45 493	51 240	59 254	66 155	99 497

In all the farm groups, irrespective of the location, also the gross farm income was increasing for every 100 PLN of the assets. Its increased was also recorded with an increase in the cow stocking density on the farm (Table 12). The highest gross farm income for every 100 PLN of assets was reported for the farms with 30-80 cows, the lowest – the farms with 5-10 cows; an exception were the farms keeping 15-20 and 20--30 cows in the province and the region. On these farms the gross farm income for every 100 PLN of assets was slightly lower than on the farms with 10-15 cows.

The gross farm income for every 100 PLN of assets was higher on the farms of the Kuyavia and Pomerania Province than on the farms in the region and in Poland, except for the farms keeping 30-80 cows. In that group the gross farm income for every 100 PLN of assets in 2004 was higher on the farms in the country. In 2006 the gross farm income for every 100 PLN of assets was, on average, on the farms of the Kuyavia and Pomerania Province 20.9 PLN, of the region 19.1 PLN, and of the country 19.5 PLN.

Table 12. Gross farm income for every 100 PLN of assets in total over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	17.2	15.1	16.5	17.0	17.5	19.2
	2005	18.1	15.6	17.1	17.9	18.4	20.5
	2006	19.5	18.0	19.0	19.2	19.5	21.0
Greater Poland and Silesia	2004	17.4	15.6	17.3	17.0	17.0	17.5
	2005	18.1	15.6	17.3	17.1	17.7	18.6
	2006	19.1	17.4	18.5	18.3	18.5	19.7
Kuyavia and Pomerania	2004	18.6	16.8	20.1	18.7	17.8	18.9
	2005	19.4	17.4	20.1	19.1	19.5	21.2
	2006	20.9	18.8	20.7	21.0	20.0	23.0

The increase in the output and in the gross farm income over 2004-2006 was accompanied by an increase in the farm net income, except for the farms in the Kuyavia and Pomerania Province, and in the region keeping 5-10 cows on which the agricultural income in 2005 decreased slightly (Table 13). On the farms of the province, region, and in the country the farm net income was also correlated with the cow herd size. In the Kuyavia and Pomerania Province and in the region more than 3-, and in the country more than 4-fold lower income was generated in 2006 on the farms with 5-10 cows, as compared with the income on the farms keeping 30-80 cows.

The average income recorded over 2004-2006 for the farms of the Kuyavia and Pomerania Province with 5-10, 10-15, and 15-20 cows was higher than the income on similar farms from the region and in the country. In the group of farms keeping 20-30 and 30-80 cows the situation was opposite, except for the farms of the highest number of cows in 2006. The average farm net income in the Kuyavia and Pomerania Province over 2004-2006 was, respectively, 70.8 thousand PLN, 73.7 thousand PLN and 90.1 thousand PLN.

Table 13. Farm net income in thousand PLN over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	59.2	33.4	47.7	60.7	83.2	141.2
	2005	64.9	33.9	49.8	67.0	92.4	168.6
	2006	78.3	44.5	62.7	80.3	109.4	193.1
Greater Poland and Silesia	2004	71.9	43.8	58 5	67.7	83.7	131.4
	2005	79.0	42.5	60.0	71.0	93.9	163.0
	2006	91.2	53.1	69.4	85.9	106.9	194.0
Kuyavia and Pomerania	2004	70.8	50.5	66.4	68.4	82.0	120.3
	2005	73.7	50.0	65.9	70.1	90.4	147.7
	2006	90.1	60.8	74.2	88.0	104.4	199.1

The farm net income per ha of utilized agricultural area increased in 2006 on all the studied farms (Table 14). The farm net income in 2005 was slightly different as compared with 2004; in 2005 it decreased on the farms in the province with 5-10, 10-15, 15-20 cows, in the region with: 5-10 and 10-15, in Poland with 5-10 cows. On all the farms of the Kuyavia and Pomerania Province, irrespective of the number of cows kept, it was higher than the income on the corresponding farms in the region and in Poland, except for the farms with the highest number of cows. In 2004-2005 the farms from the region and in Poland generated income per 1 ha of utilized agricultural area higher than the income of the farms with a similar number of cows in the province.

In Poland and in the region the farm net income per ha of utilized agricultural area was increasing with an increase in the cow density. The highest income per ha was recorded for the farms with the highest number of cows. The farms in the province, region and in Poland keeping 30-80 cows reached in 2006 the income per ha of utilized agricultural area which was 1.5-fold higher than on the farms with 5-10 cows. On the farms of the Kuyavia and Pomerania Province the farm net income per ha of utilized agricultural area was increasing over 2004-2005, and in 2006 depending on the stocking density of 10-15 cows and 15-20 cows.

Table 14. Farm net income in PLN per ha of utilized agricultural area over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	1 888	1 549	1 785	1 985	2 199	2 427
	2005	2 025	1 543	1 827	2 118	2 354	2 818
	2006	2 412	2 026	2 301	2 485	2 690	3 159
Greater Poland and Silesia	2004	1 898	1 706	1 971	2 053	2 153	2 288
	2005	2 045	1 634	1 963	2 085	2 327	2 765
	2006	2 337	2 034	2 216	2 485	2 611	3 254
Kuyavia and Pomerania	2004	2 101	1 778	2 526	2 239	2 215	2 129
	2005	2 119	1 730	2 394	2 237	2 407	2 407
	2006	2 580	2 106	2 648	2 739	2 708	3 353

The farm net income generated for every 100 PLN of assets in 2005 was lower than in 2004 on the farms of the region with the number of cows of 5-10, 10-15 and 15-20 and of the province with 10-15 cows (Table 15). The other farms, broken down according to the number of cows kept, demonstrated a higher income in 2005. In 2006 in all the farm groups there was recorded an increase in the income for every 100 PLN of assets as compared with the initial year.

The farms located in the Kuyavia and Pomerania Province generated an average farm net income for every 100 PLN of assets higher than the corresponding farms of the region and Poland, except for the farms with 20-30 and 30-80 cows. The farms with 20-30 cows in Poland in 2006 recorded the income similar to the income reported for the farms of the province, whereas the farms with 30-80 cows of Poland in the first years analysed generated the income for every 100 PLN of assets higher than the farms of the province.

On the farms researched in the country the income generated for every 100 PLN of assets increased with an increase in the cow density. On the farms of the province and the region it was increasing in 2004 and in 2005 up to 10-15 cows kept, whereas in 2006 up to 15-20 cows.

Table 15. Farm net income in PLN for every 100 of assets in total over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	12.1	10.4	11.6	12.2	12.6	14.0
	2005	12.7	10.6	11.9	12.8	13.1	14.9
	2006	14.1	12.9	13.6	14.0	14.2	15.5
Greater Poland and Silesia	2004	12.0	10.7	12.3	12.1	12.0	12.3
	2005	12.6	10.5	12.2	12.0	12.5	13.2
	2006	13.4	12.2	12.9	13.2	13.1	14.4
Kuyavia and Pomerania	2004	13.4	11.9	15.2	13.6	12.8	12.7
	2005	13.6	12.1	14.9	13.8	13.9	13.7
	2006	15.0	13.4	14.6	15.6	14.1	16.7

In 2005 and 2006 an increase in farm net income for every 100 PLN of the total output was noted, except for the farms with 10-15 and 15-20 cows in the Kuyavia and Pomerania Province (Table 16). In 2005 these farms recorded a temporary decrease in the income as compared with 2004.

The income generated for every 100 PLN of the production output on the farms of the Kuyavia and Pomerania Province with 5-10, 10-15, 15-20, and 20-30 cows was over 2004-2006 higher than the one on the farms of the region and lower than the income reported on the farms of the country with, 5-10, 20-30, and 30-80 cows, respectively.

Over 2004-2005 the farms of the Kuyavia and Pomerania Province with 10-15 and 15-20 cows generated the income for every 100 PLN of the total output higher than the farms with the same number of cows in the country. In 2006 the situation changed slightly; a slightly higher income for every 100 PLN of the production output was reported for the farms in the country.

In the group of farms with 30-80 cows the income for every 100 PLN of the production output over the years researched was higher on the farms of the region and the country, except for 2006. In 2006 a higher income for every 100 PLN of the production output was recorded for the farms of the Kuyavia and Pomerania Province than the farms of the region.

Over 2004-2006, on the farms of the Kuyavia and Pomerania Province the farm net income for every 100 PLN of the production output was increasing according to the number of 10-15 and 15-20 cows. A similar relationship was reported on the farms of the region. On the farms of the country in 2004 it was increasing with an increase in the cow herd, while in 2005 and 2006 it was increasing on the farms with up to 15-20 cows.

Table 16. Farm net income in PLN for every 100 PLN of the total output over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	41.3	39.2	41.3	42.4	42.8	45.1
	2005	43.6	40.7	42.7	44.9	44.5	47.4
	2006	48.7	48.6	49.2	49.7	49.0	50.8
Greater Poland and Silesia	2004	37.1	36.5	40.3	38.1	37.5	39.2
	2005	39.5	36.8	41.1	39.2	39.4	42.4
	2006	43.0	42.7	44.4	44.4	42.4	46.8
Kuyavia and Pomerania	2004	40.9	37.9	46.9	43.0	39.5	37.1
	2005	40.9	38.2	46.0	42.6	39.9	40.0
	2006	46.1	44.9	47.4	48.8	42.7	49.1

The family farm income/FWU over 2004-2005 was quite different (Table 17). In 2005 it was lower than in 2004 on the farms of the province with 5-10 and 10-15 cows and of the region with 5-10 cows. In the other farms groups it was higher than in 2004, while in 2006 it increased on all the farms, irrespective of the number of cows kept.

The farms of the Kuyavia and Pomerania Province with 5-10, 10-15, 15-20, and 20-30 cows generated the family farm income/FWU higher than the farms with the corresponding number of cows in the region and in the country, unlike the farms of the highest number of cows (30-80) in the region and in the country which generated the family farm income/FWU higher than the farms of the province.

The family farm income/FWU was also correlated with the number of cows; it was increasing with an increase in the number of cows kept on the farm. The lowest income was recorded on the farms with 5-10 cows in the country where it was, in successive years, 18.409 PLN, 18.925 PLN and 24.905 PLN, respectively. The highest family farm income/FWU was generated by the farms with 30-80 cows, irrespective of the location.

The family farm income/FWU in 2006 on the farms from Poland and the region with 30-80 cows was over 3-fold higher than on the farms with 5-10 cows and over 2-fold higher than on the farms with 15-20 cows; on the farms in the province it was 2.8 and 2, respectively.

The farm net income must cover the payment for the farmer's labour, pay the credit instalments as well as provide margin for the own capital involved on the farm and the risk connected with the farm operation (Goraj and Mańko 2009). In 2004 the farms in Poland with 5-10 cows generated the income at the level of parity own labour payment*, while the income which makes it possible to exceed the level of parity labour payment was recorded in 2004 and in 2005 by the farms keeping 10 cows and more, while in 2006 – by the farms with 5 cows and more. In the province and in the region, the income making it possible to go beyond the level of parity payment for own work over 2004-2006 was reported by the farms with 5 cows and more.

Table 17. Family farm income/FWU in PLN over 2004-2006

Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	31 254	18 409	25 317	32 008	41 801	66 866
	2005	34 440	18 925	26 430	35 234	46 663	79 079
	2006	41 449	24 905	33 136	42 137	54 787	90 434
Greater Poland and Silesia	2004	38 407	24 638	31 178	36 616	42 544	62 559
	2005	42 336	23 850	32 020	38 485	48 570	78 838
	2006	48 760	29 712	36 848	46 503	55 108	94 211
Kuyavia and Pomerania	2004	39 776	30 314	36 806	39 013	44 455	59 039
	2005	41 224	29 520	36 361	39 565	49 755	74 923
	2006	50 385	35 738	40 435	49 816	57 120	98 402

The negative indicators of the return on investment in production, assets ad own capital point to a negative value of the profit evaluated, which demonstrates a loss generated on the farms with 5-10 cows (except for the farms of the Kuyavia and Pomerania Province in 2006), 10-15 cows (except for the farms of the Kuyavia and Pomerania Province), 15-20 cows (in the country over 2004-2005; Table 18). On the farms with 20-30 cows the return on investment indices are positive. However, the own capital return on investment exceeds the interest of the long-term bank deposits only on the farms of the province and the country keeping more than 30 cows over 2004-2006, and in the region as well as on the farms with 30 cows and more in 2006, which means that the farms benefit from the effect of the so-called financial leverage by supporting the activity with foreign capital. If the return on investment into own capital does not exceed the interest of deposit, the capital deposited on the farm does not ensure the adequate return on capital. It would be more favourable, having paid back the liabilities, to deposit in the bank the funds invested in the farm (Goraj and Mańko 2009).

* Parity level of own labour payment corresponds to the annual net remuneration in the national economy. The remuneration in 2004 amounted to 18,348 PLN, in 2005 –19,272 PLN, in 2006 – to 19,840 PLN.

Table 18. Return on investment in production, assets and own capital on the farms studied over 2004-2006

Return on investment in production [%]							
Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	-2.43	-17.43	-8.03	-1.96	2.71	8.98
	2005	-1.27	-18.74	-8.50	-0.94	4.10	10.69
	2006	2.47	-11.55	-3.45	2.68	6.80	12.64
Greater Poland and Silesia	2004	2.09	-6.65	-2.26	1.50	2.88	7.16
	2005	3.18	-9.11	-2.80	1.63	4.75	10.13
	2006	5.49	-4.62	-0.32	5.10	6.60	12.88
Kuyavia and Pomerania	2004	4.11	-0.20	2.61	4.31	5.11	6.68
	2005	3.77	-2.39	1.00	3.29	6.51	10.00
	2006	7.46	1.46	2.57	8.19	8.53	14.38
Return on investment in assets [%]							
Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	-0.71	-4.62	-2.26	-0.56	0.80	2.78
	2005	-0.37	-4.87	-2.36	-0.27	1.21	3.36
	2006	0.71	-3.07	-0.95	0.76	1.98	3.85
Greater Poland and Silesia	2004	0.68	-1.96	-0.69	0.48	0.92	2.25
	2005	1.01	-2.59	-0.83	0.50	1.51	3.16
	2006	1.71	-1.32	-0.09	1.52	2.05	3.96
Kuyavia and Pomerania	2004	1.34	-0.06	0.85	1.37	1.65	2.28
	2005	1.25	-0.76	0.32	1.06	2.27	3.43
	2006	2.42	0.44	0.79	2.61	2.82	4.89
Return on investment in capital [%]							
Area	Year	Farms according to the number of cows					
		Total	5-10	10-15	15-20	20-30	30-80
Poland	2004	-0.80	-4.94	-2.47	-0.62	0.91	3.46
	2005	-0.42	-5.23	-2.58	-0.30	1.38	4.13
	2006	0.81	-3.31	-1.06	0.85	2.29	4.72
Greater Poland and Silesia	2004	0.77	-2.11	-0.76	0.53	1.04	2.78
	2005	1.14	-2.80	-0.91	0.55	1.70	3.82
	2006	1.95	-1.44	-0.10	1.71	2.36	4.76
Kuyavia and Pomerania	2004	1.54	-0.07	0.94	1.58	1.89	2.86
	2005	1.47	-0.86	0.36	1.24	2.61	4.53
	2006	2.87	0.49	0.92	3.03	3.44	6.39

Conclusions

1. The present research demonstrated that the number of cows on the farm affects its income.
2. In the respective farm groups broken down according to the number of cows kept the highest gross farm income and farm net income were reported on the farms with 30 cows and more and the lowest on the farms with 5-10 cows.
3. The average income reported over 2004-2006 by the farms of the Kuyavia and Pomerania Province with 5-20 cows was higher than the income of the similar

farms from the region and the country. In the group of farms with 20-80 cows it was opposite, except for the farms with 30 cows and more in 2006.
4. The income generated for every 100 PLN of production output on the farms of the Kuyavia and Pomerania Province with 5-30 cows over 2004-2006 was higher than the income on the farms of the region and lower than the income generated by the farms of the country with 5-10 and 20-80 cows, respectively.
5. The family farms located in the Kuyavia and Pomerania Province generated farm net income for every 100 PLN of assets higher than the corresponding farms of the region and Poland, except for the farms with 20-30 and 30-80 cows. The farms with 20-30 cows in Poland in 2006 recorded a similar income to the one reported by the farms in the province, whereas the farms with 30-80 cows in Poland over the first years analyzed reported the income for every 100 PLN of assets higher than the farms in the province.
6. The farm net income per ha of utilised agricultural area on all the farms of the Kuyavia and Pomerania Province, irrespective of the number of cows, was higher than the income of the corresponding farms researched in the region and in Poland, except for the farms of the highest number of cows. In 2004-2005 the farms of the region and of the area of Poland generated a higher income per 1 ha of utilized agricultural area than that of the farms with a similar number of cows in the province.
7. The farms of the Kuyavia and Pomerania Province with 5-10, 10-15, 15-20, and 20--30 cows reported the family farm income/FWU higher than the farms with the same number of cows in the region and in the country, unlike on the farms of the highest number of cows (30-80). The farms from the region and the country generated the family farm income/FWU higher than the farms of the province.
8. In 2004 the farms from the area of Poland with 5-10 cows reported their income at the level of parity own labour payment, the income which makes it possible to exceed the level of parity labour payment was reported in 2004 and in 2005 by the farms with 10 cows and more, whereas in 2006 the farms with 5 cows and more. In the province and in the region the income which makes it possible to go beyond the level of parity own labour payment over 2004-2006 was reported by the farms with 5 cows and more.
9. The negative return on investment points to a loss generated by the farms with 5-10 cows (except for the farms of the Kuyavia and Pomerania Province in 2006), 10-15 cows (except for the Kuyavia and Pomerania Province farms), 15-20 cows (in the country over 2004-2005).
10. The return on investment in own capital exceeded the interest of the long-term bank deposits only on the farms of the province and the country with more than 30 cows (over 2004-2006), and the region (also on the farms with 30 cows and more) in 2006. On the other farms the capital invested in the assets did not ensure an adequate return on capital.

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LEVEL OF SUSTAINABILITY OF FARMS IN REGION 790 GREATER POLAND AND SILESIA AGAINST OTHER FADN REGIONS

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The main objectives of Common Agricultural Policy (CAP) is supporting the farmer's income and preserving rural heritage, protecting natural environment and growing enhanced-quality and competitive agricultural production. Despite a few dozen or so years of CAP implementation, agriculture of European Union countries varies a lot (Mańko et al. 2007a, b; Sobczyński 2008a-e). Turning from industrial agriculture towards top-quality production maintaining the conditions of environmental protection and animal welfare defined in Council Regulation (EC) no 1782/2003 calls for taking a closer look at the regional variation in the effect of farms on the environment in the EU.

Defining an adequate method to evaluate the degree of sustainability of farms, suggesting objective and realistically definable measures and indices of socioeconomic and natural balance is not easy. The set and importance of the indices assumed must factor in the specific character of the habitat conditions and economic-and-organizational conditions of agriculture in the regional perspective, which poses an additional difficulty for parameterisation. Today's state of knowledge does not offer an unambiguous answer to the question which evaluation method is best, applicable and feasible in the context of available data and acceptable costs of measurement (Krasowicz 2005; Wilk 2005; Baum 2007).

Characters of sustainable agriculture at the country or regional level are a derivative of characters of respective farms and a reflection of their specific character and diversity (Krasowicz 2005; Baum 2007). Analyses at the regional level make it possible to diagnose the accumulation of potential threats in a given area. Single farms, of excessively high animal numbers or fertiliser and pesticide consumption, scattered, do not pose such a threat for the environment as those clustered in the regions of production specialization (Sobczyński 2008d).

The aim of the present research was to provide an analysis of regional variation in the level of sustainability of farms from European Union located in the Baltic region and to evaluate the position of farms of Farm Accountancy Data Network (FADN) 790 region, Greater Poland and Silesia. The area selected involves 29 FADN regions and covers 1 253.15 thousand commodity farms represented in the database, using a total of 48 382.95 thousand ha of agricultural land (Fig. 1).

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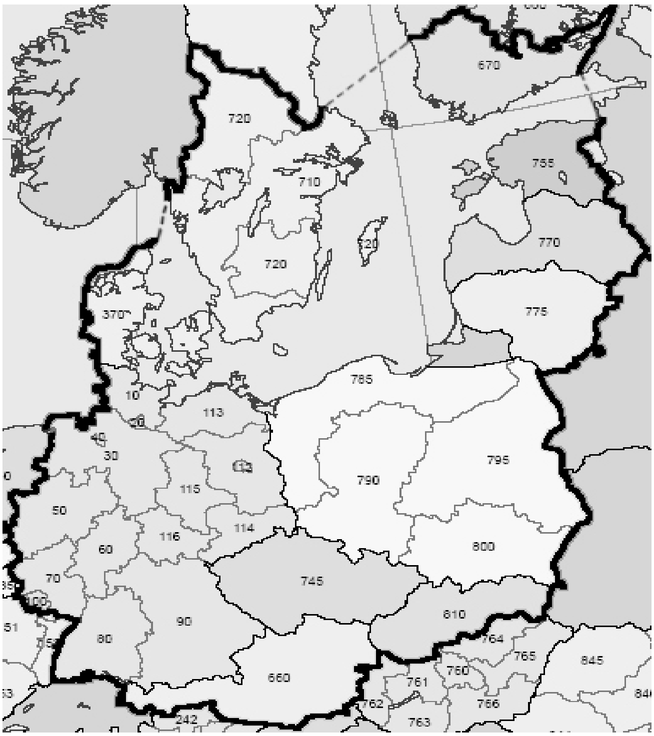
Materials and methods

The only commonly available, comprehensive source of information, collected according to homogenous principles from a representative sample of commodity farms operating in the EU, is the data collected in the accountancy data system from FADN farms. FADN database variables, described in detail, unambiguously defined and, to make it more user-friendly, marked with symbols and algorithms used to calculate them are commonly available (Farm Accountancy Data Network 2009). The FADN region is the lowest level at which the principle of representativeness is maintained. It excludes detailed analyses at the level of Kuyavia and Pomerania Province; what is only possible is the generalizations for FADN 790 region Greater Poland and Silesia which, besides the above province, include also the Greater Poland, Lower Silesia and Opole Provinces.



10 Schleswig-Holstein
20 Hamburg
30 Niedersachsen
40 Bremen
50 Nordrhein-Westfalen
60 Hessen
70 Rheinland-Pfalz
80 Baden-Württemberg
90 Bayern
100 Saarland
110 Berlin
112 Brandenburg
113 Mecklenburg-
-Vorpommern
114 Sachsen
115 Sachsen-Anhalt
116 Thueringen
360 The Netherlands
370 Denmark
660 Austria
670 Etela-Suomi
710 Slattbygdslan
720 Skogs-och mellanbygdslan
745 Czech Republic
755 Estonia
770 Latvia
775 Lithuania
785 Pomerania-Masuria
790 Greater Poland-Silesia
795 Masovia-Podlasie
800 Lesser Poland-Pogórze
810 Slovakia

Fig. 1. FADN regions covered by the present research (Farm Accountancy Data Network 2009)

Due to the character of the data available, the methods of analysis of statistical series, methods of horizontal analysis, regression equation, as well as visualization with plots were applied.

Earlier research (Mańko et al. 2007a, b; Sobczyński 2008a-e) show that the degree and range of disturbing balance of farms is specific for the country, farm type and economic size. With that in mind, the evaluation of the differentiation in the level of sustainability of farms from selected regions has focused on threats which are most important for a given group.

A variation in the fertiliser and crop protection costs per land unit and per wheat yield unit as well as on field crop farms (TF13; this and successive symbols are in accordance with the FADN system) was analysed; it was supplemented by an analysis of the share of cereals (SE035) in total utilised agricultural area (SE025) for field crop farms and with granivores livestock (TF50). The last type of farms was covered by the evaluation of mostly environmental threat as a result of excessively high animal density.

High intensiveness of fertilisation and plant protection on horticultural farms (TF20) can pose a considerable challenge for the environment and so in that type of farms the analysis involved a variation in costs of fertilisers and pesticides per land unit.

Sustainability in the socio-economic aspect was analysed by evaluating the relationship between the paid and unpaid labour inputs (SE020/SE015) and balance of subsidies and taxes per unpaid-labour person and economic convergence of farm net value added per unit of total labour input (AWU – annual work unit; SE425) and family farm income per unit of unpaid labour (FWU – family work unit; SE430). All that was supported by an analysis of the level of subsidies per unit of unpaid labour (own family) which depends on the economic size of the farm.

The research, based on Farm Accountancy Data Network (2009), covered the 2004-2006 period for which data is available for the studied regions. To alleviate the effect of random factors, the analysis was performed for means of the studied period.

Results

Of all the agricultural types, field crop farms (TF13) represent the group of the greatest share of payments in incomes (Sobczyński 2008b). Maybe, thanks to such a considerable assistance, the farms have a less destructive effect on the environment?

In the field crop farm type the highest productivity measured with average wheat yields was recorded for farms representing regions in Germany: 010 Schleswig-Holstein – 89.8 dt·ha^{-1}, 050 Nordrhein-Westfalen – 81.0 dt·ha^{-1}, 030 Niedersachsen – 77.9 dt·ha^{-1}, 060 Hessen – 76.9 dt·ha^{-1}, 113 Mecklenburg-Vorpommern – 73.6 dt·ha^{-1}), and the lowest – in regions: 755 Estonia – 27.4 dt·ha^{-1}, 770 Latvia – 34.9 dt·ha^{-1} and 670 Etela-Suomi – 38.2 dt·ha^{-1}. As for the Polish regions, the highest productivity was reported for region 790 Greater Poland and Silesia (55.0 dt·ha^{-1}; Table 1).

The highest fertiliser cost per hectare of arable land was reported in Germany (010 Schleswig-Holstein – 153.45 €·ha^{-1}, 113 Mecklenburg-Vorpommern – 137.01 €·ha^{-1}, 050 Nordrhein-Westfalen – 119.79 €·ha^{-1}, 030 Niedersachsen – 115.05 €·ha^{-1}) and in Poland (790 Greater Poland and Silesia – 121.12 €·ha^{-1}, 785 Pomerania and Masuria – 109.32 €·ha^{-1}), and the lowest – in regions: 810 Slovakia – 51.42 €·ha^{-1}, 755 Estonia – 53.58 €·ha^{-1}, 770 Latvia – 55.21 €·ha^{-1} (Table 1).

The highest cost of crop protection per hectare of agricultural land was identified in Germany (010 Schleswig-Holstein – 169.41 €·ha^{-1}, 050 Nordrhein-Westfalen – 132.84 €·ha^{-1}, 113 Mecklenburg-Vorpommern – 114.39 €·ha^{-1}), and the lowest in regions: 755 Estonia – 24.20 €·ha^{-1}, 770 Latvia – 26.57 €·ha^{-1}, 775 Lithuania – 31.61 €·ha^{-1}. Region 790 Greater Poland and Silesia with the cost of pesticides of 61.92 €·ha^{-1}

was slightly inferior to region 785 Pomerania and Masuria, however, Polish regions in that respect were clearly inferior to the average for a given community (Table 1).

Table 1. Yields of wheat and indices of fertilisers and pesticides costs per land unit on field crop farms (TF13 specialist cereals, oilseed and protein crops) of the FADN regions researched; the 2004-2006 means

FADN region		Wheat yield SE110 [dt·ha^{-1}]		Fertilisers SE295/SE025 [€·ha^{-1}]		Pesticides SE300/SE025 [€·ha^{-1}]	
		Mean	Vσ [%]	Mean	Vσ [%]	Mean	Vσ [%]
745	Czech Republic	50.2	8.94	65.40	12.07	68.39	11.89
370	Denmark	66.7	3.40	77.61	8.82	63.30	7.42
010	Schleswig-Holstein	89.8	1.45	153.45	8.28	169.41	13.60
030	Niedersachsen	77.9	3.76	115.05	11.63	105.71	13.81
050	Nordrhein-Westfalen	81.0	0.48	119.79	7.65	132.84	10.83
060	Hessen	76.9	5.71	106.89	5.22	105.40	6.40
070	Rheinland-Pfalz	67.5	7.18	100.98	3.17	64.77	13.14
080	Baden-Württemberg	63.5	7.53	109.12	11.09	84.00	12.58
090	Bayern	65.5	11.32	103.76	4.52	79.76	7.78
112	Brandenburg	56.4	22.64	77.50	5.47	61.97	7.05
113	Mecklenburg-Vorpommern	73.6	3.82	137.01	3.61	114.39	7.48
114	Sachsen	68.6	16.23	93.83	11.43	86.76	3.84
115	Sachsen-Anhalt	68.6	8.71	101.04	5.01	100.13	9.77
116	Thueringen	67.3	10.76	97.48	3.34	106.09	1.94
755	Estonia	27.4	14.24	53.58	8.27	24.20	4.02
775	Lithuania	40.2	26.02	69.37	7.68	31.61	3.44
770	Latvia	34.9	6.94	55.21	18.65	26.57	11.57
660	Austria	50.2	11.43	71.27	6.80	37.96	5.66
785	Pomerania and Masuria	53.2	13.96	109.32	4.94	63.48	1.96
790	Greater Poland and Silesia	55.0	14.83	121.12	7.97	61.92	8.21
795	Masovia and Podlasie	48.4	19.10	99.89	10.03	41.33	23.53
800	Lesser Poland and Pogórze	47.9	11.41	103.69	6.61	46.95	2.91
670	Etela-Suomi	38.2	5.15	86.37	3.40	34.58	5.98
710	Slattbygdslan	58.4	4.19	93.02	5.01	32.74	7.42
810	Slovakia	41.8	12.07	51.42	15.32	51.71	10.15
Mean		58.8	7.65	94.93	6.12	71.84	5.39
Standard deviation σ		15.6		21.83		30.52	
Coefficient of variation Vσ [%]		26.6		21.56		37.55	

High fertilisation intensiveness does not have to correspond to a considerable threat for the environment if nutrients are absorbed by equally high yields (Kopiński 2006; Wilk 2006). An index of the cost of fertilisers per wheat decitonne is an attempt at evaluating the balancing of components supplied with fertilisers and taken away with harvest (Sobczyński 2008a, d).

The highest index of the fertiliser cost per wheat decitonne was reported for field crop farms in regions: 670 Etela-Suomi – 2.27 €·dt^{-1}, 790 Greater Poland and Silesia – 2.25 €·dt^{-1}, 800 Lesser Poland and Pogórze – 2.19 €·dt^{-1}, 795 Masovia and Podlasie – 2.13 €·dt^{-1}, 785 Pomerania and Masuria – 2.09 €·dt^{-1}, and the lowest: 370 Denmark – 1.16 €·dt^{-1}, 810 Slovakia – 1.26 €·dt^{-1}, 745 Czech Republic – 1.31 €·dt^{-1} (Table 2).

One can assume that field crop farms from German regions of the highest fertiliser costs per land unit, thanks to high yields and effective absorption of nutrients, do not pose such a high threat for the environment as the Polish farms which produce too low yields as compared with the fertilisation. Unfortunately, in that respect, region 790 Greater Poland and Silesia score lowest (Table 2).

Table 2. Indices of the fertiliser and pesticide cost per wheat yield unit on field crop farms (TF13 specialist COP) of the FADN regions researched; the 2004-2006 means

FADN region		Fertilisers per dt of wheat SE295/SE025/SE110 [€·dt^{-1}]		Pesticides per dt of wheat SE300/SE025/SE110 [€·dt^{-1}]	
		Mean	Vσ [%]	Mean	Vσ [%]
745	Czech Republic	1.31	17.99	1.37	17.27
370	Denmark	1.16	7.50	0.95	4.02
010	Schleswig-Holstein	1.71	9.36	1.89	14.38
030	Niedersachsen	1.48	14.43	1.36	15.50
050	Nordrhein-Westfalen	1.48	7.69	1.64	10.96
060	Hessen	1.39	9.14	1.38	11.15
070	Rheinland-Pfalz	1.50	9.92	0.96	13.21
080	Baden-Württemberg	1.72	10.81	1.32	11.57
090	Bayern	1.60	15.13	1.22	5.81
112	Brandenburg	1.44	31.01	1.15	29.03
113	Mecklenburg-Vorpommern	1.87	6.46	1.55	5.17
114	Sachsen	1.41	27.00	1.29	17.11
115	Sachsen-Anhalt	1.48	10.06	1.46	10.33
116	Thueringen	1.46	11.89	1.59	8.33
755	Estonia	1.99	20.01	0.90	17.48
775	Lithuania	1.84	34.04	0.83	27.15
770	Latvia	1.59	22.76	0.77	17.97
660	Austria	1.44	17.49	0.76	14.92
785	Pomerania and Masuria	2.09	19.66	1.21	15.66
790	Greater Poland and Silesia	2.25	23.75	1.15	23.23
795	Masovia and Podlasie	2.13	25.18	0.87	25.36
800	Lesser Poland and Pogórze	2.19	17.65	0.99	13.86
670	Etela-Suomi	2.27	6.50	0.91	4.72
710	Slattbygdslan	1.60	9.14	0.56	10.01
810	Slovakia	1.26	28.54	1.26	23.28
Mean		1.67	15.21	1.17	12.37
Standard deviation σ		0.34		0.29	
Coefficient of variation Vσ [%]		21.13		22.77	

Even though the share of cereals in the acreage of agricultural land on field crop farms (TF13) of the studied FADN regions varied in the range of almost 53-83%, no strong relationship with wheat yields was found. The share of cereals and the factors co-variable with it accounted for the variation in wheat yield only in about 5.33%, whereas a clearly decreasing yield trend was reported once 66% has been exceeded. Field crop farms from Polish FADN regions over 2004-2006 represented a group of the highest share of cereals (Fig. 2).

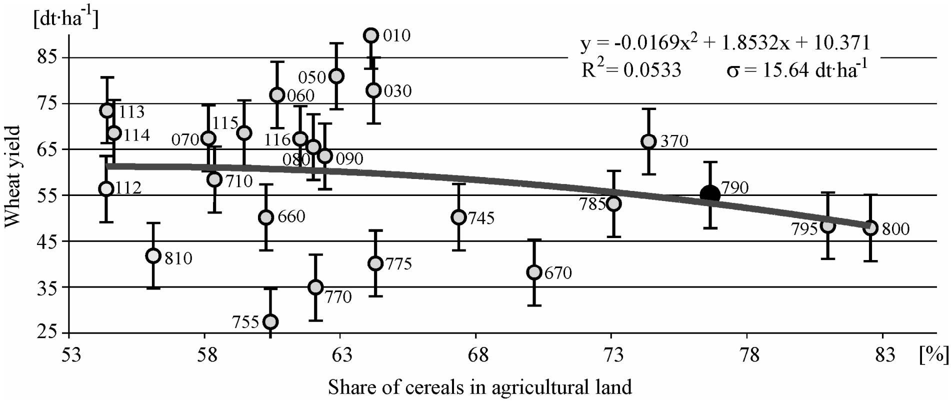


Fig. 2. Proportion of cereals in the acreage of agricultural land and wheat yields on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means. For FADN region numbers see Table 1. Error bars are the SD

Detailed analyses demonstrated that the share of cereals in the acreage of agricultural land of Polish field crop farms decreases with an increase in the economic size and ranges from about 70% in the biggest class (6) ≥100 ESU to 85% in the smallest class (1) 0 ≤ 4 ESU. A similar relationship was observed on Danish farms, however it was not found on German farms. For that reason in region 800 Lesser Poland and Pogórze, where the smallest farms dominate, problems with an excessive share of cereals in cropland can be faced.

Fertilisers and pesticides on field crop farms of the studied regions were strongly complementary to one another, namely they did not replace one another but increasing one input was accompanied by increasing another one. Costs of fertilisers per ha and co-variable factors accounted for 63.04% of variation in the pesticide costs. It was observed to be accompanied by a growing increase in pesticides as compared with an increase in fertilisers. Farms of the Polish regions were found clearly below the regression line, which can mean that there dominate technologies of excessively high inputs of fertilisers as compared to pesticides. One shall therefore improve fertilisation management, and the savings allocate to a better plant protection (Fig. 3).

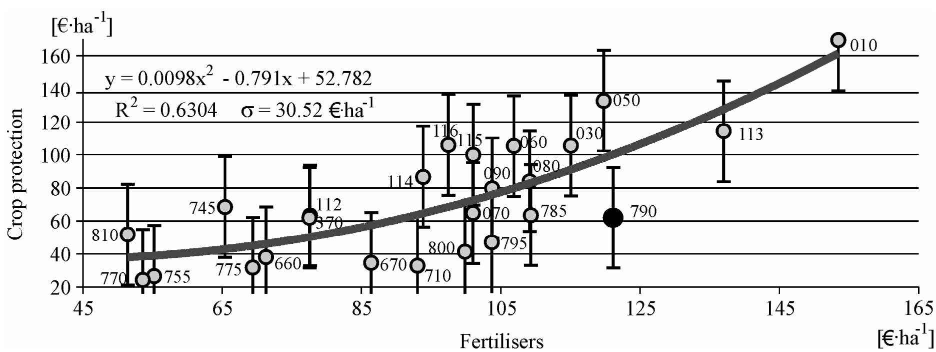


Fig. 3. Costs of fertilisers and pesticides on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means. Error bars are the SD

Wheat yields and co-variable factors accounted for as much as 88.20% of the variation in pesticide costs, with a growing increase in pesticides as compared with an increase in yields. Pesticides appeared to be a distinguishing feature of high yield technologies (Fig. 4).

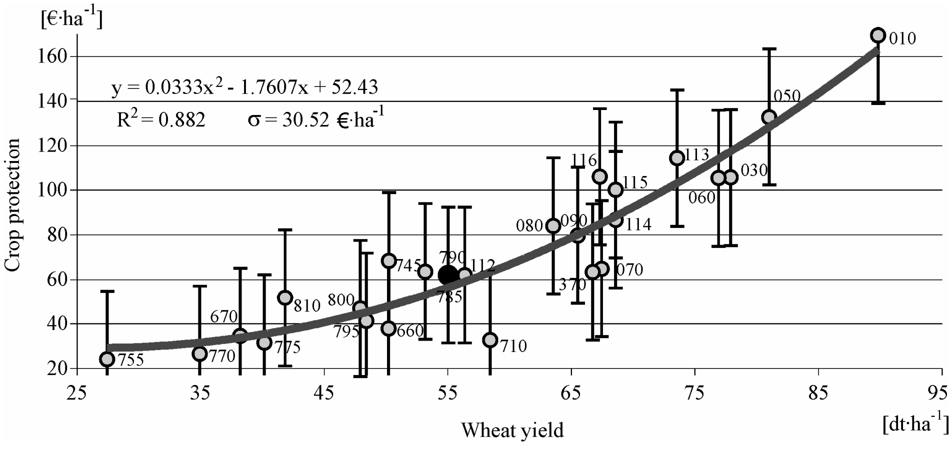


Fig. 4. Wheat yields and pesticides costs on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means. Error bars are the SD

Pesticides and co-variable factors only accounted for as much as 84.25% of the variation in wheat yield (Fig. 5). A combined entry of costs of fertilisers and pesticides helped explaining the variation in wheat yields slightly only (84.94%; Fig. 6).

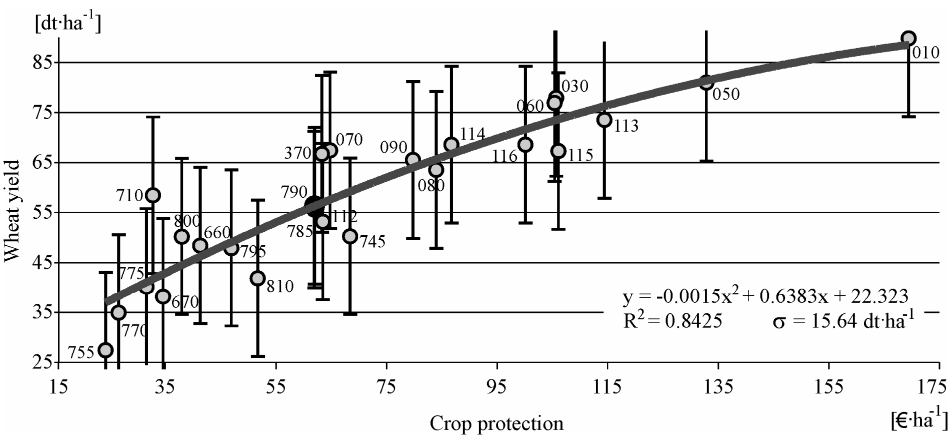


Fig. 5. Costs of pesticides and wheat yields on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means. Error bars are the SD

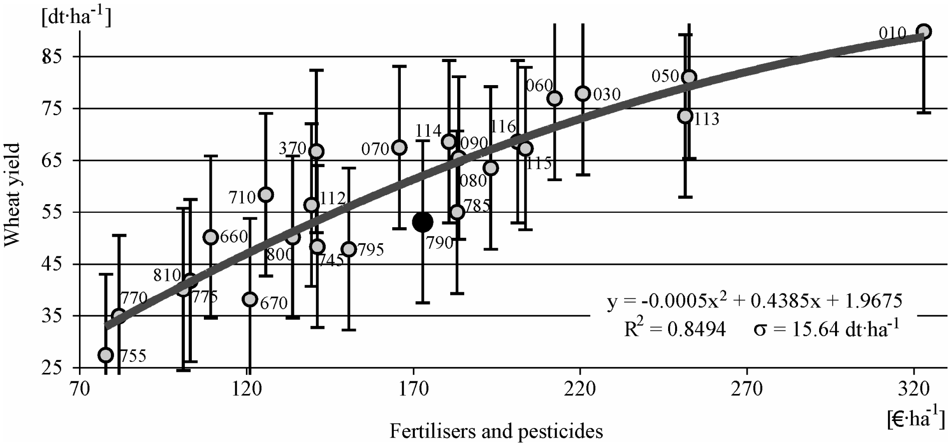


Fig. 6. Costs of fertilisers and pesticides and wheat yield on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means. Error bars are the SD

Polish field crop farms of all the regions were clearly above the regression line of the fertiliser cost per yield unit, which means extremely ineffective fertiliser application, which decreases the cost-competitiveness of production and can threaten the environment by the emission of unabsorbed fertiliser components. Unfortunately, region 790 Greater Poland and Silesia scores low in that respect (Fig. 7).

High fertiliser cost index per dt of wheat yield should not be accounted for by expensive fertilisers in Poland and relatively cheap e.g. in Slovakia and Denmark (those regions were found below the regression curve in Fig. 7). Producers in their decisions therefore, adjust the level of inputs in the way to make the marginal productivity equal to the relationship between the input price and the product price.

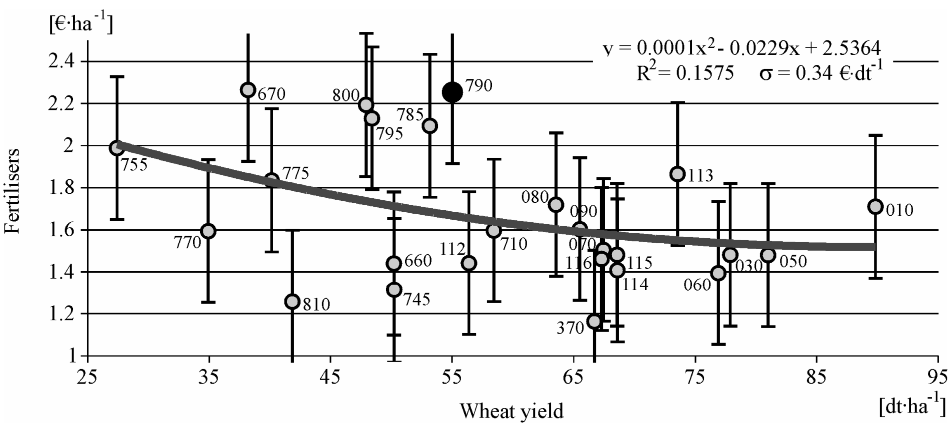


Fig. 7. Wheat yields and the fertiliser cost index per yield unit on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means. Error bars are the SD

On the farms with granivores livestock (TF50) the main environmental threat results from an excessively high animal density which, in the period researched, in region 360 The Netherlands exceeded 62 LU·ha^{-1}. Similarly, very high animal density occurred in region 745 Czech Republic (45.35 LU·ha^{-1}) and 770 Latvia (10.94 LU·ha^{-1}), which comes from a high concentration of herds and the dominance of animal keeping farm systems. In that respect region 790 Greater Poland and Silesia scored very high; of all the regions researched it showed the lowest density of 2.69 LU·ha^{-1}. Unfortunately, the proportion of cereals in agricultural land reached here almost 85%, which excludes adequate crop rotation. The situation in the other Polish regions was similar (Table 3).

Table 3. Animal density and the share of cereals in agricultural land on the farms with granivores livestock (TF50 specialist granivores) of the FADN regions researched; the 2004-2006 means; LU – livestock unit

FADN region	Animal density SE080/SE025 [LU·ha^{-1}]		Share of cereals in agricultural land SE035/SE025 [%]	
	Mean	Vσ [%]	Mean	Vσ [%]
360 The Netherlands	62.34	2.00	19.56	12.79
745 Czech Republic	45.35	47.98	67.82	10.34
770 Latvia	10.94	15.02	22.88	25.13
370 Denmark	6.80	1.88	76.20	1.07
710 Slattbygdslan	6.33	17.46	64.00	3.28
030 Niedersachsen	5.86	16.49	62.11	3.70
050 Nordrhein-Westfalen	5.34	4.04	64.20	4.01
090 Bayern	5.25	3.27	72.76	3.48
080 Baden-Württemberg	5.19	2.76	68.81	2.09
800 Lesser Poland and Pogórze	4.71	10.57	83.16	5.09
785 Pomerania and Masuria	4.05	13.87	84.48	2.97
660 Austria	3.67	0.92	70.38	1.12
670 Etela-Suomi	3.56	14.48	81.42	5.59
060 Hessen	3.43	7.57	61.89	6.90
795 Masovia and Podlasie	2.79	9.09	84.67	0.30
790 Greater Poland and Silesia	2.69	8.60	84.92	1.27
Mean	11.14	11.00	66.83	5.57
Standard deviation σ	17.07		19.67	
Coefficient of variation Vσ [%]	153.17		29.44	

On horticultural farms (TF20) a few-fold to a dozen-fold or so higher indices of fertiliser and pesticide costs per hectare of agricultural land than on the field crop farms were observed. All-time high fertilisation was reported on farms of the following regions: 010 Schleswig-Holstein (3367.59 €·ha^{-1}), 116 Thueringen (2893.32 €·ha^{-1}) and 020 Hamburg (2889.69 €·ha^{-1}), and low: 755 Estonia (82.71 €·ha^{-1}), 775 Lithuania (108.96 €·ha^{-1}) and 745 Czech Republic (259.54 €·ha^{-1}). Horticultural farms of region 790 Greater Poland and Silesia with the fertiliser cost of 1324.42 €·ha^{-1} (much over the Dutch farms) score high, which can have an unfavourable effect on the environment and the product quality (Table 4).

The highest costs of pesticides were reported on farms from the following regions: 030 Niedersachsen (1955.07 €·ha^{-1}) and 360 The Netherlands (1579.92 €·ha^{-1}), and low: 755 Estonia (28.60 €·ha^{-1}) and 775 Lithuania (40.83 €·ha^{-1}). In region 790 Greater Poland and Silesia the costs of pesticides were clearly below the average for a given group of horticultural farms (Table 4).

Table 4. Costs of fertilisers and pesticides per hectare of agricultural land on horticultural farms (TF20 specialist horticulture) of the FADN regions researched; the 2004-2006 means

FADN region		Fertilisers SE295/SE025 [€·ha^{-1}]		Pesticides SE300/SE025 [€·ha^{-1}]	
		Mean	Vσ [%]	Mean	Vσ [%]
010	Schleswig-Holstein	3367.59	19.71	558.52	38.26
116	Thueringen	2893.32	0.52	807.91	34.67
020	Hamburg	2889.69	7.64	657.55	15.94
080	Baden-Württemberg	2149.96	13.14	629.10	2.73
030	Niedersachsen	2099.09	32.71	1955.07	18.07
370	Denmark	1605.96	13.09	571.09	15.65
060	Hessen	1409.35	38.01	733.68	43.78
790	Greater Poland and Silesia	1324.42	4.34	445.40	20.08
360	The Netherlands	1027.23	10.61	1579.92	10.10
785	Pomerania and Masuria	855.59	43.75	436.62	53.88
710	Slattbygdslan	846.05	14.65	504.85	9.83
795	Masovia and Podlasie	817.02	38.31	337.09	39.08
800	Lesser Poland and Pogórze	794.81	5.42	429.68	10.85
050	Nordrhein-Westfalen	776.02	17.02	780.75	6.36
670	Etela-Suomi	754.99	38.10	409.87	18.85
090	Bayern	575.68	6.76	457.65	8.27
114	Sachsen	493.11	11.11	291.20	21.32
070	Rheinland-Pfalz	361.17	19.46	244.33	13.98
745	Czech Republic	259.54	41.41	318.47	52.31
775	Lithuania	108.96	16.28	40.83	20.00
755	Estonia	82.71	22.02	28.60	20.19
Mean		1213.92	19.72	581.82	22.58
Standard deviation σ		954.73		449.69	
Coefficient of variation Vσ [%]		78.65		77.29	

The ratio of paid to unpaid labour inputs (SE020/SE015) stands for the number of persons of hired labour per person of own farm family labour. According to the concept of family farms, hired labour inputs should not exceed 50% of total inputs, namely the ratio of paid to unpaid labour inputs should not exceed 1 person per unpaid work unit. Earlier research show that agricultural entrepreneurs from many countries of the former east bloc who employed even a few hundred persons, including management, at a very low farm net value added and payment for labour, have created an effective mechanism of absorption of funds offered as part of CAP which is to support family farms (Sobczyński 2008e).

On farms of the regions researched there was reported a strong relationship between ratio of paid to unpaid labour inputs and the level of subsidies per own-labour person (R^2 = 80.59%). In the regions located on the areas of the former East Germany, at high hired labour, there were absorbed highest payments per unpaid work person, e.g. in region 116 Thueringen for 8.14 hired-labour persons per own-labour person there were obtained payments at the amount of 186286 €·FWU^{-1}. For a comparison, in region 790 Greater Poland and Silesia at the ratio of paid to unpaid labour inputs of 0.22, the payments were 2503 €·FWU^{-1} (Fig. 8).

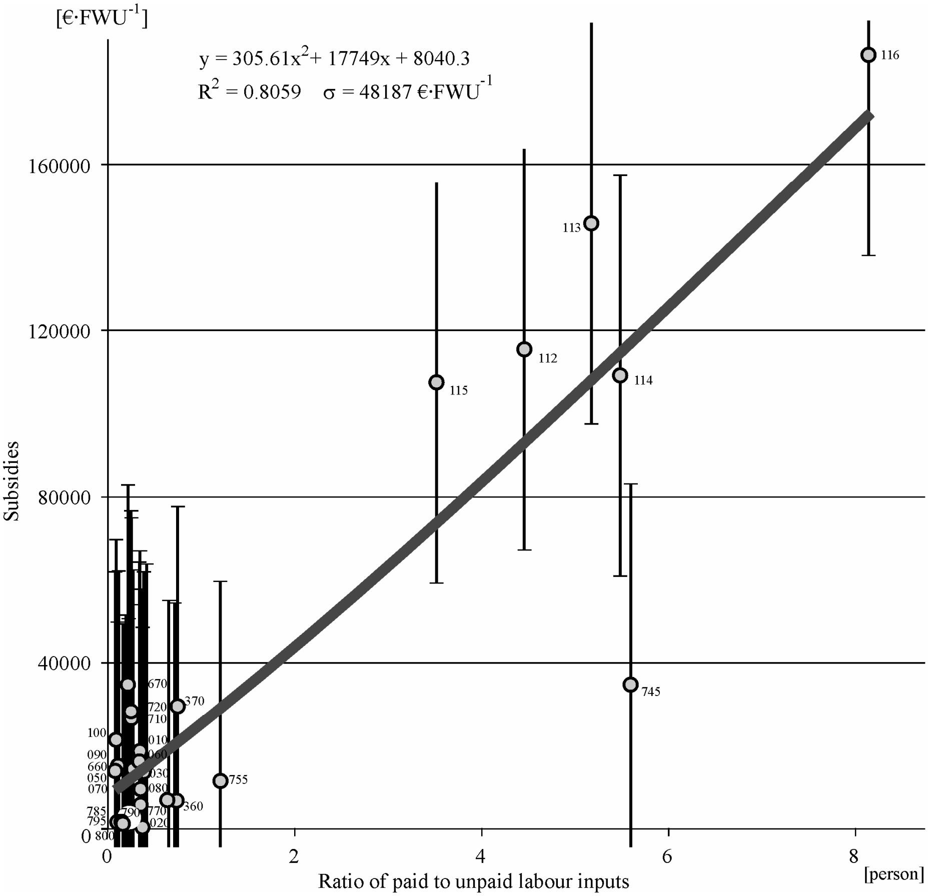


Fig. 8. Ratio of paid to unpaid labour inputs (SE020/SE015) and the balance of subsidies and taxes per own-labour (unpaid) person on farms of the FADN regions researched; the 2004-2006 means. Error bars are the SD

On farms of the regions researched an increase in farm net value added per AWU and co-variable factors account for about 88% of the variation in the family farm income per FWU of own labour. Therefore the basic relationship has been maintained between the farm net value added and farm net income. Farms of region 790 Greater Poland and Silesia represent the lowest-score group (Fig. 9).

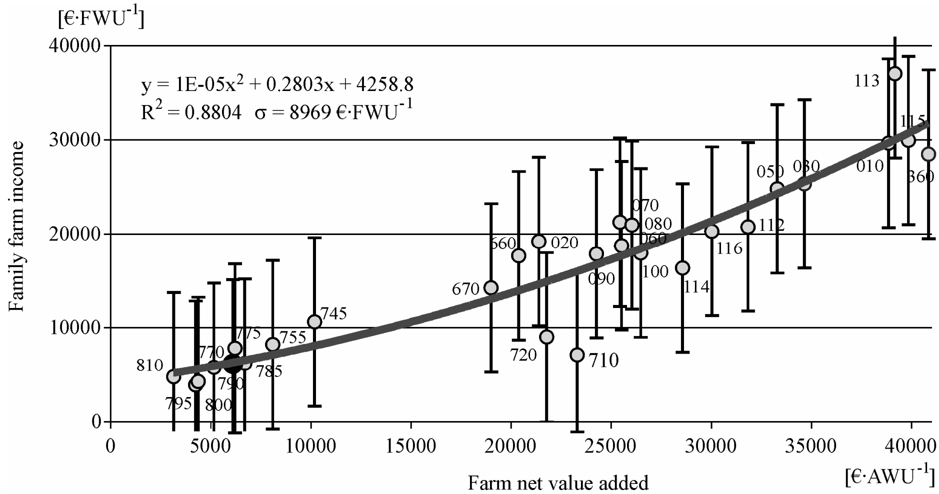


Fig. 9. Farm net value added per AWU (SE425) and family farm income per FWU (SE430) on the farms of the FADN regions researched; the 2004-2006 means. Error bars are the SD

Relationships between the hired labour, subsidies, farm net value added and farm net income differ due to the agricultural type and the economic size of farms. For example, for field crop farms (TF13) which are known to demonstrate the highest share of payments in income (Sobczyński 2008b), the power of the relationships researched measured by the coefficient of determination is lower. Despite standardisation of farms within the specific type, the productiveness of labour accounts for only about 67% of family farm income expressed per family labour unit, namely 21% less than on the farms in total (Figs. 10, 11).

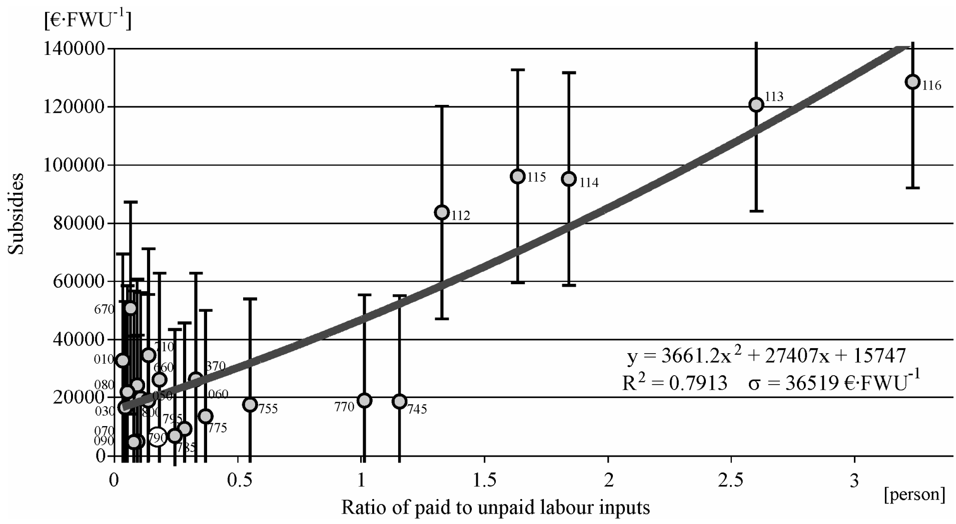


Fig. 10. Ratio of paid to unpaid labour inputs (SE020/SE015) and balance of subsidies and taxes per person of own labour (unpaid) on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means. Error bars are the SD

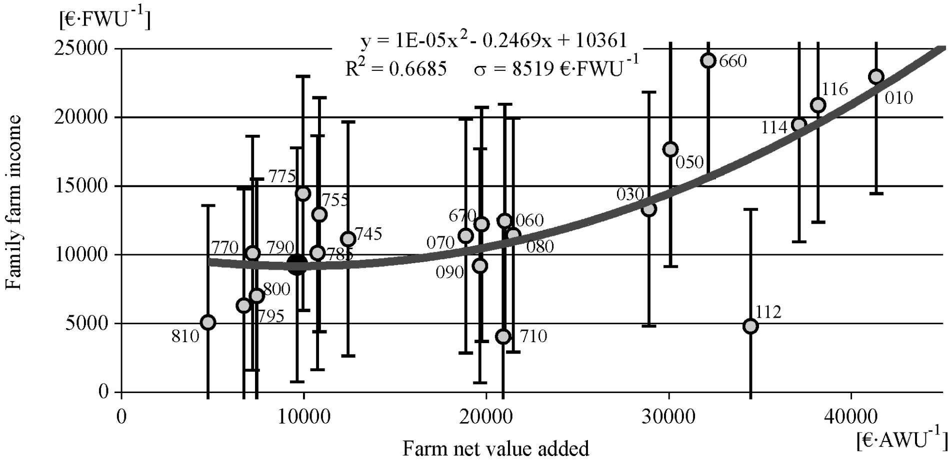


Fig. 11. Farm net value added per AWU (SE425) and family farm income per FWU (SE430) on field crop farms (TF13) of the FADN regions researched; the 2004-2006 means

A special role in obtaining payments is attributed to the economic size. Farms of the group of the highest economic size ((6) ≥100 ESU) of the FADN regions researched employed even a few hundred people per unit of unpaid labour and obtained a few hundred thousand in payments. Farms of group (5) 40 ≤ 100 ESU demonstrated considerably lower hired labour and payments. The power of the relationship measured with the coefficient of determinacy was also by about 25% lower (Figs. 12, 13).

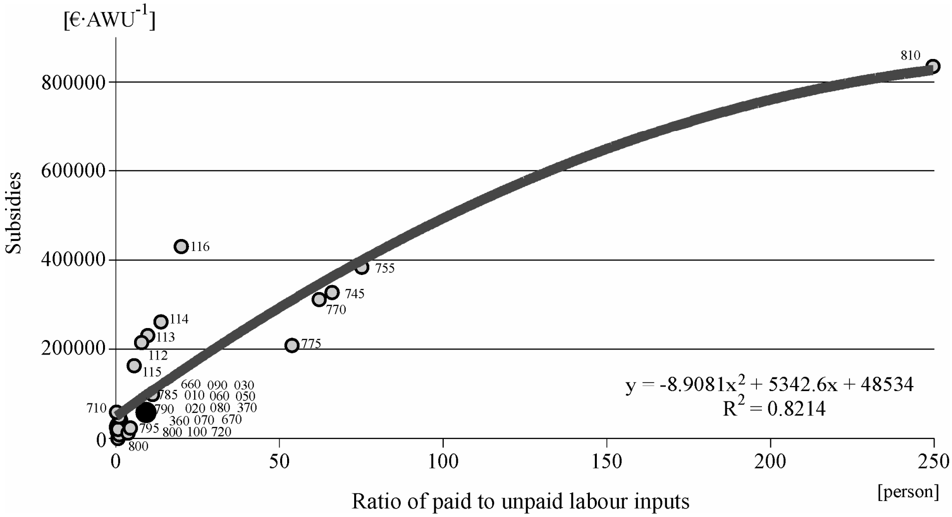


Fig. 12. Ratio of paid to unpaid labour inputs (SE020/SE015) and balance of subsidies and taxes per person of own labour (unpaid) on farms of the group of the highest economic size ((6) ≥100 ESU) of the FADN researched; the 2004-2006 means

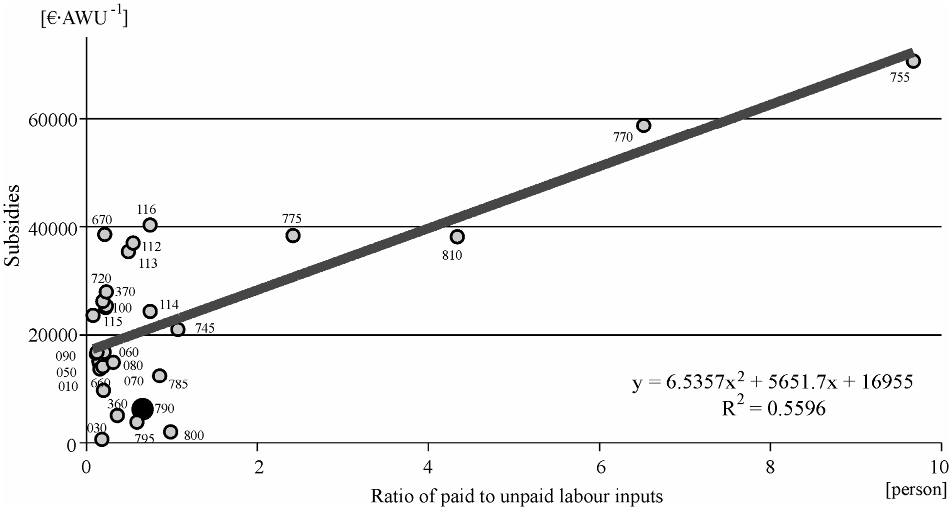


Fig. 13. Ratio of paid to unpaid labour inputs (SE020/SE015) and the balance of subsidies and taxes per own labour person (unpaid) on farms of the economic class (5) 40 ≤ 100 ESU of the FADN regions researched; the 2004-2006 means

The analysis of payments for the three biggest economic size classes makes it clear that the family farm income of unpaid labour was heavily affected by budget retransfers. The greater the economic size, the higher the level of payments per unpaid labour unit (FWU). All-time high payments were obtained over the research period by farms from the following regions [€·FWU^{-1}]: 810 Slovakia (835278), 116 Thueringen (430485), 755 Estonia (384192) and 745 Czech Republic (327812). A low level of payments in regions 020 Hamburg or 360 The Netherlands results from the fact that horticultural farms and farms with granivores livestock of the lowest share of payments in the income dominate there (Sobczyński 2008b). In region 790 Greater Poland and Silesia in size class (6) the payments per person of unpaid labour were almost 14-fold and about 7-fold higher than in classes (4) and (5) (Table 5).

Table 5. Balance of subsidies and taxes per unpaid labour unit (FWU) on farms of the FADN regions researched depending on the economic size: the 2004-2006 means

FADN region		Economic size class		
		(4) 16 ≤ 40 ESU	(5) 40 ≤ 100 ESU	(6) ≥100 ESU
745	Czech Republic	8461	20995	327812
370	Denmark	19123	25040	41100
010	Schleswig-Holstein	8448	15130	24647
020	Hamburg		614	208
030	Niedersachsen	7261	13713	21864
050	Nordrhein-Westfalen	8810	14180	19787
060	Hessen	11275	16818	23879
070	Rheinland-Pfalz	7655	9684	11448
080	Baden-Württemberg	9638	14941	19487
090	Bayern	9979	16284	22955
100	Saarland		23570	25394
112	Brandenburg	16356	35337	231238

113	Mecklenburg-Vorpommern		36968	215215
114	Sachsen	14638	24297	261333
115	Sachsen-Anhalt	16912	25361	161934
116	Thueringen	23118	40268	430485
755	Estonia	14396	70565	384192
775	Lithuania	15451	38295	208877
770	Latvia	18680	58693	311700
360	The Netherlands	2293	5084	8164
660	Austria	13653	16921	20799
785	Pomeranian and Masuria	4716	12436	96058
790	Greater Poland and Silesia	3194	6213	43704
795	Masovia and Podlasie	2740	3851	12097
800	Lesser Poland and Pogórze	2065	2054	
670	Etela-Suomi	29551	38519	53582
710	Slattbygdslan	22031	26234	48687
720	Skogs-och mellanbygdslan	20553	27900	46462
810	Slovakia	17813	38123	835278
Mean		12647	23382	139585
Standard deviation σ		7184	16411	187795
Coefficient of variation Vσ [%]		56.81	70.18	134.54

Conclusions

The present research demonstrated that the degree and scope of disturbing the balance of farms is specific for a given country, agricultural type of the farm and for the economic size. With that in mind, investigating the variation in the level of the sustainability of farms from selected regions focused on the threats which are most important for a given group.

The analysis of field crop farms (TF13) demonstrated that the highest productivity measured with average wheat yields was recorded for farms of the north-western regions of Germany, and the lowest in Estonia, Latvia, and the south of Finland. Similarly, the average costs of fertilisers and pesticides per ha of agricultural land were proportional to the level of yields, however except for Polish field crop farms which, despite the level of yields below the mean value for the community researched, represented the group of the highest fertiliser costs per ha.

Fertilisers and pesticides on field crop farms of the regions researched were strongly complementary to one another. Polish farms are dominated by technologies of excessively high fertiliser inputs as compared with pesticides. One shall, therefore, improve the fertilisation management and to allocate the savings to enhance plant protection. Pesticides and co-variable factors accounted for as much as 84% of the variation in the wheat yield. Polish field crop farms of all the regions, next to the Finnish ones, showed the highest indices of fertiliser costs per yield unit, which means that they use fertilisers which are exceptionally ineffective. It decreases the cost-competitiveness of their production and it can threaten the environment by the emission of unabsorbed fertiliser components. Unfortunately, Polish field crop farms over 2004--2006 also represented the group of the highest share of cereals in the acreage of agricultural land.

On horticultural farms (TF20) a few-fold to a dozen-fold or so higher indices of costs of fertilisers and pesticides per hectare of agricultural land than on the field crop farms were observed. All-time low fertilisation was reported on farms from the following regions: 010 Schleswig-Holstein, 116 Thueringen and 020 Hamburg and very low: 755 Estonia, 775 Lithuania and 745 Czech Republic. Horticultural farms of region 790 Greater Poland and Silesia with the cost of fertilisers of 1324.42 €·ha^{-1} score high, which can have an unfavourable effect on the environment and the quality of products. However, the cost of pesticides here was clearly below the mean value for the group investigated. Poor plant protection can trigger losses of a part of yields and high fertiliser costs per unit.

On the farms with granivores livestock (TF50) the main environmental threat comes from an excessively high animal density which, over the period researched, in region 360 The Netherlands exceeded 62 LU·ha^{-1}. An excessively high animal density occurred in 745 Czech Republic and 770 Latvia. Region 790 Greater Poland and Silesia was very favourable in that respect; of all the regions investigated it demonstrated the lowest number: 2.69 LU·ha^{-1}. Unfortunately, the share of cereals in agricultural land here reached almost 85%, which excludes adequate crop rotation; in the other Polish regions the situation was similar.

On the farms of the regions investigated a strong relationship between the ratio of paid to unpaid labour inputs and the level of payments per unpaid labour person was noted. However, an increase in the productivity of labour and co-variable factors accounted for about 88% of the variation in the family farm income of unpaid labour; thus the basic relationship between the farm net value added and farm net income was maintained.

Relationships between the ratio of paid to unpaid labour inputs, subsidies, farm net value added and farm net income varied due to the agricultural type and economic size of farms. The economic size plays a special role in obtaining payments. In the group of the greatest economic size ((6) ≥100 ESU) the farms of the FADN regions vary a lot as regards the use of hired labour; from the farms supplementing their own labour resources by hiring of employees to those which employed even a few hundred persons per unit of own (unpaid) labour and obtained a few hundred thousand in payments each. The analysis of payments for the three biggest classes of economic size makes it certain that the farm net income of unpaid labour was strongly affected by budget retransfers.

Of all the European Union regions researched, located in the Baltic region, farms of region 790 Greater Poland and Silesia represent the group of low productivity and farm net income.

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