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Research Article

PHYSICOCHEMICAL PROPERTIES OF SILT LOAMY SOIL AND DIVERSITY OF DIATOM SPECIES UNDER WINTER WHEAT AND OATS

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ABSTRACT

The aim of the research was to investigate the soil properties and the species diversity of diatoms growing in different agricultural fields with silt loamy soil. The field experiment was conducted in 2014 in Kosina, near Łańcut (SE Poland), at three sites (indicated as fields K1, K2, K3) with different soil environmental conditions and plants. The growth of winter wheat *Triticum aestivum* (cv. Bogatka) in fields K1 and K2 and oats *Avena Sativa* (cv. Haker) in field K3 under different soil management were studied. The soil samples were collected from the top layers (0–5 cm depth) each month, from April to December. Certain physical and chemical parameters of soil were measured. The pH of soil was acidic and slightly acidic in fields K1 (5.0–5.4), K2 (4.9–5.9) and K3 (4.5–5.1). The soil in field K3 had a significantly greater content of organic matter (1.06–1.30%) and water content (12.9–33.8%, v/v) than fields K1 and K2. A total of 91 diatom taxa were found. The diversity was greatest in field K2 (71 taxa), lower in K1 (54 taxa) and K3 (24 taxa). In K1, the most numerous species were *Luticola* D.G. Mann *cf. mutica*, *Mayamaea atomus* var. *permitis* (Hust.) Lange-Bertalot, and *Stauroneis thermicola* (Petersen) Lund, with more than a 20% share in the assemblage. In K2, very abundant assemblages were formed by *Mayamaea atomus* (Kütz.) Lange-Bertalot, *Mayamaea atomus* var. *permitis* (Hust.) Lange-Bertalot, and *Stauroneis thermicola* (Petersen) Lund with a 25 to 50% share in the total diatom community. In K3, with oat cultivation, a different diatom species structure was found. Here, the most abundant were *Halamphora montana* (Krasske) Levkov, *Hantzchia amphioxys* (Ehrenb.) Grunow, *Mayamaea atomus* (Kütz.) Lange-Bertalot, and *Nitzschia pusilla* Grunow, which attained a share in the assemblage exceeding than 20%. The effects of different soil management regimes under different plants on the physical and chemical properties of the soil, and on the diversity of diatoms, were significant ($P<0.05$). Soil water and organic matter content affects the yield of winter wheat and oats. Significant effects of water content and pH of silt loamy soil on the growth and the diversity of species of diatoms were found.

Keywords: diatoms, physical and chemical soil properties, yield of winter wheat and oats

INTRODUCTION

Agriculture in the Podkarpackie voivodeship is characterized by large fragmentation of farms, most of which are small. According to a study by Buczek et al. [2010], on the basis of the analysis of 144 districts of the Podkarpackie Province, in accordance to its current administrative division for the years 2001 and 2002, the cultivation of cereals is dominant, with an average of 65.3%.

Among cereals, the cultivation of wheat occupies the average of 31.7% of the total area of the all districts, then oats average 9.4%; rye and mixtures of grains and barley cover slightly smaller areas. The sowing structure in most municipalities of the Podkarpackie is typically cereals-potato. The forecrop of cereals, are usually potatoes, which average 18.9%. However, according to the Provincial Statistical Office in Rzeszów in the year 2014, wheat and oat became increasingly common, averaging 40.9% and 12.1%, respectively, in relation to the total area of districts [Statistical Office in Rzeszów 2015].

Physical and chemical properties of the soil determine the environment of biological life as well as the growth and development of crop plants [Czyż 2000, Czyż, Dexter 2008, Gajda et al. 2017]. Soil algae play a varying role in the soil ecosystem, contributing to the enrichment of the soil with an organic substance through extracellular secretions. They also participate in the release of nutrients into the environment and affect the changes that occur in the soil, its properties and stability [Evans, Johansen 1999].

Soil, as a living environment of various organisms, has been subject to many intensive ecological, physiological, biochemical and microbiological studies in recent years. Algae developing in the soil have become valuable research subjects because of its important role in the colonization of poor or degraded soils. Photoautotrophic soil algae produce organic matter, their biomass is a source of humus and nitrogen, and the compounds they produce (such as amino acids, organic acids, polysaccharides and vitamins) affect the lives of other soil organisms and greater crop yield plants [Johansen, Shubert 2001, Zancan et al. 2006, Kalinowska, Pawlik-Skowrońska 2008].

There are few papers on the ecological preferences and composition of diatom species developing in soils, especially cultivated soils [Bérard et al. 2004, Al-Fredan, Fathi 2007, Dorokhova 2007, Škaloud 2009, Stanek-Tarkowska, Noga 2012a,b, Stanek-Tarkowska et al. 2013, 2015]. Algae developing in the soil are mainly examined for the presence of greens and cyanobacteria, while diatoms are usually rare [Ettl, Gärtner 1995, Sieminiak 2000, 2007, 2009, Skowroński et al. 2002, Kalinowska et al. 2008].

The aim of the study was to determine certain physicochemical properties of silt loamy soil, species diversity of diatoms developing under winter wheat and oats and the yield of plants.

STUDY AREA

The village of Kosina is located near the Kosinka stream and is hilly. For this reason, the village is divided into two parts: the upper and lower. The region is characterized by a high amplitude of temperature and weather variability, which is related to the movement of fronts of the masses of Atlantic and continental air. The average annual air temperature during the period of 1956–2010 was 8.4°C, and the mean annual precipitation was 653 mm [Kożuchowski 2011]. In Kosina, the average air temperature for 2014 was 9.0°C, which was higher than the long-term average (8.4°C). The sum of precipitation was 776.4 mm and was also higher than the average of the long-term (Table 1). In year 2014, meteorological

Table 1. Meteorological conditions in 2014 and long-term mean of 1956–2010.

Month	Temperature (˚C)		Rainfal (mm)	
	2013/2014	Long-term 1956–2010	2013/2014	Long-term 1956–2010
IX	11.2	13.5	68.5	69.3
X	9.8	8.6	42.0	42.6
XI	5.1	3.4	98.0	37.1
XII	1.2	-1.0	15.3	37.5
I	-0.9	-2.3	24.7	30.5
II	1.8	-1.3	16.1	29
III	5.6	2.8	49.6	36.7
IV	8.7	8.5	34.8	46.7
V	13.3	14.0	109.8	81.4
VI	15.2	16.8	71.6	82.6
VII	19.6	18.8	145.1	90.7
VIII	17.5	18.1	101.7	68.5
MEAN/SUM	9.0	8.4*	776.4	652.6**

conditions were good for germination of the grain and plant growth.

The studied sites were located in Kosina (50°04'391"N, 22°16'746"E) and included the following facilities (Figure 1):

- Field K1 was located on a slope, slightly inclined towards the west. There were uncultivated farmlands without trees in the vicinity.
- Field K2 was located on a gentle western slope, adjacent to detached houses at a distance of about 100 meters. Both fields are separated by about 2 km in a straight line and National Road 94.
- In the autumn of 2013, winter wheat was sown in both K1 and K2 fields.
- Field K3 was located in an off-road, 20 m from National Road 94 road, near the gas station. Oats were sown in spring 2014.

MATERIALS AND METHODS

The source material in the presented manuscript is the result of studies carried out in 2014 on silt loam soil texture (SiL) belonging to the wheat faulty complex, class IVa, on three fields in an individual farm under cereal crops (winter wheat for K1 and K2, spring oats for K3). The cultivated fields were typical for small farms in the Podkarpackie region: 0.8 ha winter wheat in field K1, 0.5 ha winter wheat in field K2 and 0.5 ha oats in field K3. The research site was selected taking into account the typical cereal production technology in this area and the location of the crop fields. Soil samples were taken from the fields where traditional plowed land and manure fertilization were used in crop rotation. Potatoes constituted forecrops for wheat; 30 t/ha of ma-

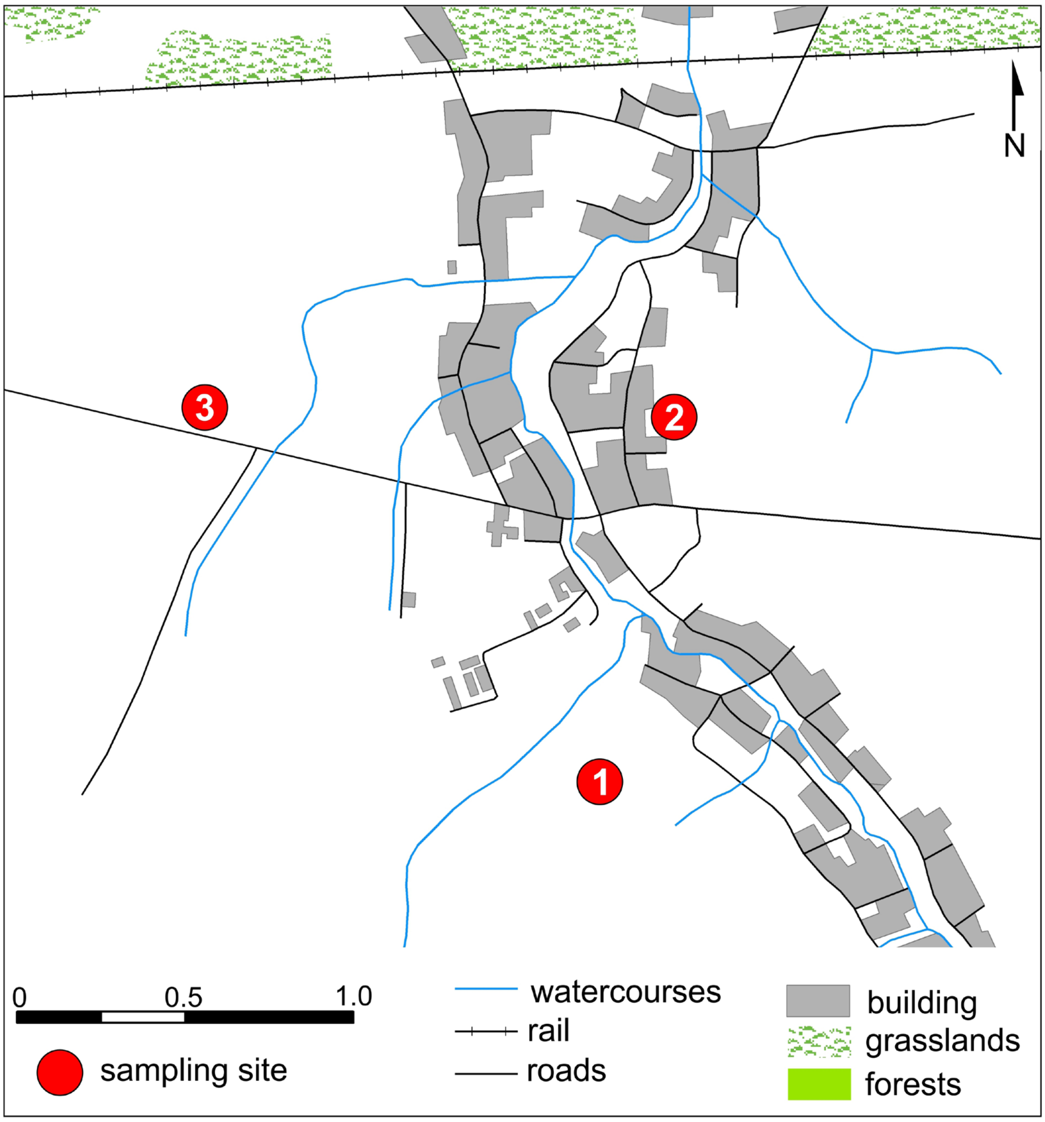

Figure 1. Location of the study and sampling sites on Kosina in the Podkarpackie voivodeship

nure was applied underneath every 4 years. On the other hand, forecrops for oats included sugar beet. Nitrogen fertilization was 120 kg N·ha^{-1}, and phosphorus and potassium fertilization was fixed at 50 kg P$ha^{-1}$and 90 kg K·ha^{-1}. Winter wheat and oats were grown according to the fertilization and weed control recommendations used in Poland. Winter wheat fields were sown on 24 September 2013, whereas oats on 16 April 2014. The protection of the wheat and oats was in line with IOR-PIB recommendations. Cereal harvest was carried out at full maturity. Grain yield was determined in tons per hectare for 15% grain humidity on selected fields. The yield structure was also investigated in the study: seedling per unit area, number of seeds per spike/per year, weight of one thousand seeds and yield variability (%).

Soil materials (soil samples) for physicochemical studies were collected from the three fields once a month, from April to December 2014. The topsoil samples (0–5 cm) were taken to determine a basic physicochemical analysis. At the same time, undisturbed soil samples were collected to Kopecky's cylinders (with three replications) to measure soil moisture. In each case, immediately after returning from the field, the water content of the soils was determined by the oven-dry method. The water content of soil samples was determined gravimetrically by drying at 105°C to a constant weight (usually for 48 h). The particle size distributions of the studied soils were determined by means of Cassagrande's aerometric method, modified by Prószyński [Lityński et al. 1976]. The soil type was identified according to the Polish Society of Soil Science [PTG-2008]. The organic matter contents of the soils were measured by wet oxidation using the Tiurin method [Ostrowska et al. 1991]. Total N content was determined using the Kjeldahl method [Lityński et al. 1976]. Soil pH_{KCl} was measured potentiometrically in a 1 mol/L KCl solution. [Ostrowska et al. 1991]. Available P and K were determined using the Egner-Rhiem method, whereas available Mg using the Schachtschabel method. Physicochemical analyzes of soil were carried out at the Department of Soil Studies, Environmental Chemistry and Hydrology, Faculty of Biology and Agriculture, University of Rzeszów.

At the same time, soil was taken to determine the diversity of diatoms from the top layer of 0–3 cm and placed into three Petri dishes, 8.8 cm in diameter. The mean weight of fresh soil was about 90 g. A small amount of soil material (about 10 g) from the Petri dishes was placed in 100 ml beakers and mixed with solution of sulphuric acid and potassium dichromate at a ratio of 3:1. The material was then purified via centrifugation (2500 rpm). The exact laboratory treatment of diatom material was made according to the methods used by Kawecka [2012] and modified by Stanek-Tarkowska, Noga [2012a,b]. Persistent microscopic preparations were embedded in Pleurax synthetic resin (refractive index 1.75). Diatoms were determined at 1000x magnification using a NIKON ECLIPSE 80i light microscope and using specialized keys: Krammer, Lange-Bertalot [1986, 1988, 1991a,b], Ettl, Gärtner [1995], Krammer [2000], Hofmann et al. [2011]. The photos of diatoms were taken under light microscope (NIKON ECLIPSE 80i) and scanning electron microscope (HITACHI SU8010) in the Podkarpackie Center for Environmental Research and Innovation in Rzeszow. The diatom count was obtained by counting all the valves in randomly selected microscope viewing fields until a total of 300 valves were counted. On the basisof the Polish Red List of Algae Siemińska et al. [2006] prepared for Poland, diatom species were assigned to threat categories.

RESULTS

The highest soil water content was under oats (field K3) from 12.9 to 33.8% v/v, average 18.8% v/v. On the other hand, in fields K1 and K2 under winter wheat soil water content were lower and averaged 10.9 and 9.3% v/v, respectively. The dynamics of soil moisture under winter wheat (K1 and K2) and oat (K3) is shown in Figure 2. Soil water content in the studied fields during the vegetative season of the plants was modified both by the growth and development of crop plants, as well as by the amount and distribution of precipitation.

In the studied fields in Kosina, the soil was characterized by acidic and slightly acidic pH (4.9–5.9) – Figure 3. The mean pH value measured in the 1M KCl suspension was higher for the fields under wheat (K1 and K2) and amounted to 5.3 and 5.4, respectively. On the other hand, the soil pH under oats (K3) was significantly lower at 4.7.

The content of organic matter in the soil was the highest in the field under oats (K3) and ranged from 1.06 to 1.30 (average 1.16), and lower under wheat (K1 and K2) (Figure 4).

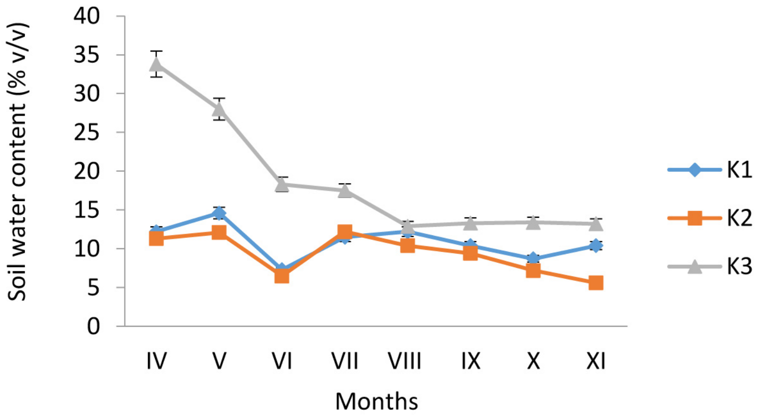

Figure. 2. Dynamics of soil moisture in three production fields under winter wheat (K1 and K2) and oat (K3)

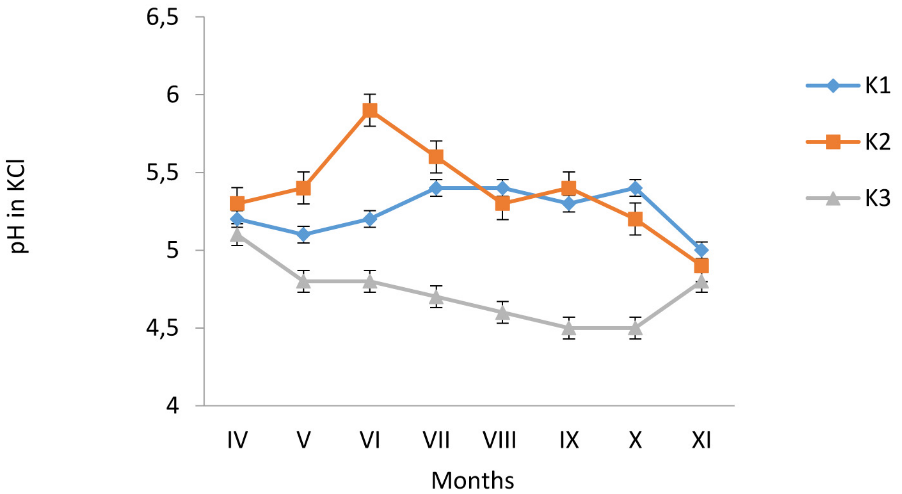

Figure 3. Dynamics of soil pH in three production fields under winter wheat (K1 and K2) and oat (K3)

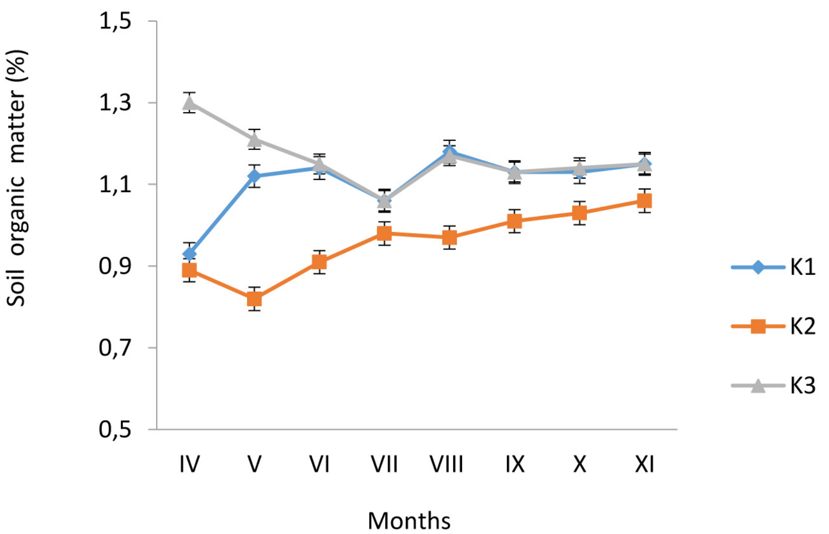

Figure 4. Dynamics of soil organic matter content in three production fields under winter wheat (K1 and K2) and oat (K3)

Total nitrogen content in soils was low. There was no significant difference in nitrogen content (Figure 5). In field K1, the average nitrogen content was 0.13% and its range was 0.11–0.16%, K2 was lower at an average of 0.12%, with a range of 0.10–0.14%. Similarly, the content of nitrogen in the soil in field K3 was about 0.13%, with a range of 0.11–0.15%.

During the study conducted in Kosina from April to December 2014, a total of 91 taxa, including K1 – 54, K2 – 71 and K3 – 24 taxa were determined. Among the diatom taxa, 14 were considered dominant, i.e. those with the share in the community of at least 5% (Table 2).

Eight of the taxa reached over 20% of the community. In each of the studied fields, the structure of domination was different, showing great diversity between fields and in particular months.

In the K1 field, taxa which reached over 20% of the share in the community were *Luticola para mutica, Mayamaea atomus* var. *permitis* (Hust.) Lange-Bertalot and *Stauroneis thermicola* (Petersen) Lund. Whereas in K2, this group comprised were *Mayamaea atomus* (Kütz.) Lange-

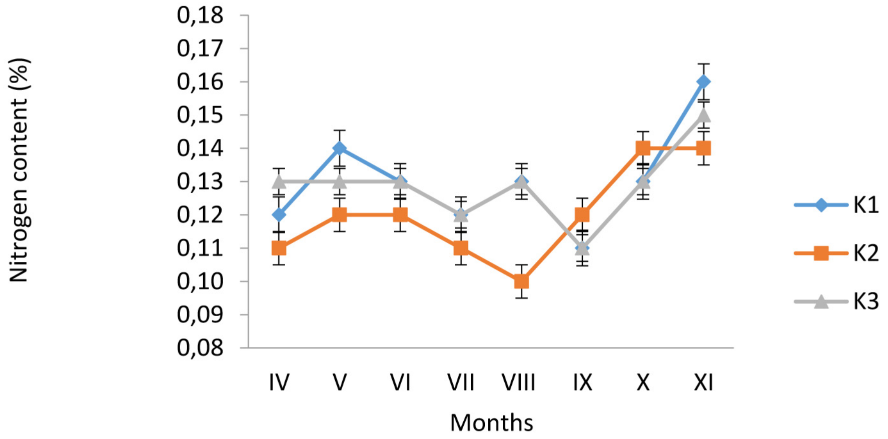

Figure 5. Dynamics of nitrogen content in soil under winter wheat (K1 and K2) and oat (K3)

Table 2. List of taxa dominating the surveyed positions K1, K2, K3 in Kosina

Site	K1								K2								K3							
Months	4	5	6	7	8	9	10	11	4	5	6	7	8	9	10	11	4	5	6	7	8	9	10	11
Eolimna minima	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	5%–20%	5%–20%	<5%	5%–20%	5%–20%	<5%	<5%	<5%
Halamphora montana	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	5%–20%	<5%	5%–20%	<5%	<5%	>20%	>20%
Hantzchia amphioxys	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	<5%	<5%	<5%	5%–20%	<5%	<5%	5%–20%	>20%	<5%	5%–20%	5%–20%	<5%	<5%	<5%
Luticola paramutica	>20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	<5%	<5%	5%–20%	<5%	<5%	<5%	5%–20%	<5%	<5%	5%–20%	5%–20%	5%–20%	<5%	5%–20%	<5%	<5%	<5%
Mayamaea atomus var. *atomus*	<5%	5%–20%	<5%	<5%	5%–20%	<5%	<5%	<5%	>20%	5%–20%	>20%	<5%	<5%	<5%	<5%	5%–20%	>20%	>20%	5%–20%	5%–20%	5%–20%	<5%	<5%	>20%
M. atomus var. *permitis*	5%–20%	5%–20%	<5%	<5%	>20%	<5%	<5%	<5%	5%–20%	5%–20%	5%–20%	>20%	>20%	5%–20%	>20%	5%–20%	<5%	5%–20%	<5%	<5%	5%–20%	<5%	<5%	<5%
Navicula lanceolata	<5%	<5%	<5%	5%–20%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED
Nitzschia pusilla	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	5%–20%	>20%	>20%	5%–20%	5%–20%	<5%	<5%	<5%
Pinnularia borealis	5%–20%	<5%	<5%	5%–20%	<5%	<5%	<5%	5%–20%	<5%	5%–20%	<5%	<5%	<5%	5%–20%	<5%	<5%	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED
P. obscura	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	>20%	5%–20%	<5%	<5%	>20%	5%–20%	5%–20%	5%–20%	5%–20%	<5%	5%–20%	5%–20%	<5%	<5%	<5%
P. schoenfelderi	<5%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	5%–20%	<5%	<5%	<5%	<5%	<5%	5%–20%	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED
P. sinistra	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	5%–20%	<5%	<5%	5%–20%	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED	NOT OCCURRED
Stauroneis parathermicola	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	5%–20%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%
S. thermicola	5%–20%	5%–20%	>20%	5%–20%	5%–20%	<5%	>20%	>20%	5%–20%	<5%	5%–20%	5%–20%	<5%	>20%	>20%	>20%	<5%	5%–20%	<5%	<5%	5%–20%	<5%	<5%	<5%

NOT OCCURRED	<5%	5%–20%	>20%

Bertalot var. *atomus, Mayamaea atomus* var. *permitis* (Hust.) Lange-Bertalot, *Pinnularia obscura* Krasske and *Stauroneis thermicola* (Petersen) Lund. The diatom species found on the Red List of Algae in Poland were also described in the study material [Siemińska et al. 2006]. One species extinction (category E) was found – *Pinularia schoenfelderii* Krammer, and two rare species (category R) – *Amphipleura pellucida* (Kütz.) Kützing, *Luticola acidoclinata* Lange-Bertalot. One species, *Gomphonema tergestinum* (Grunow) M. Schmidt, was in category I – indetermined.

The yield of winter wheat (var. Bogatka) in field K1 was higher (7.87 t·ha^{-1}) than in field K2 (7.41 t·ha^{-1}). In field K2, winter wheat yields were lower than as the soil moisture from April to June, in comparison to field K1. The seedling height and number of seeds were higher in the spike and weight of 1000 grains in field K1 compared to field K2 under winter wheat (Table 3). On the other hand, the oat yield (var. Haker) of field K3 was 6.30 t·ha^{-1}.

DISCUSSION

The main source of water in the soil is atmospheric precipitation. Water content in soil is a very important factor that determines many occurring processes, such as fertility, the intensity of biochemical processes, the growth and yield of crop plants [Czyż 2000, Czyż et al. 2008, Czyż, Dexter 2008, 2009, Leszczyńska, Noworolnik 2010, Mikanová et al. 2012, Mühlbachová et al. 2015, Gajda et al. 2017]. Soil moisture is the most important factor in the development of algae and the growth and yielding of crops. In the vegetation period and during the year, the water content in the soil varies dynamically depending on the quantity and frequency of precipitation, as well as the increased demand of plants (Figure 2). In the months when crops had the highest water requirement, fields K1 and K2 were characterized by small water content in April K1 – 12.2%, K2 – 11.3% and May K1 – 14.6%, K2 – 12.1%. At the same period, the water content was higher in K3 field in April 33.8% and May 28%. These differences may have been due to the location of the fields and the cultivated plant, as oats have a higher water requirement than winter wheat [Chmura et al. 2009]. Different types of soil show different retention abilities [Czyż et al. 2003, 2006, 2009, Dexter et al. 2001, 2008a,b, Asgarzadeh et al. 2014].

Table 3. Yield of winter wheat and oats and yield components expressed relative to conventional production systems

Specification	K1	K2	K3
Yield (t·ha^{-1})	7.41	7.87	6.30
Number of ears (pcs.·m^{-2})	594	619	-
Number of grains per ear/ per panicle	36.1	36.6	47.1
Weight of 1000 grains/ seeds (g)	38.2	41.0	37.1
Variation coefficient for the yield (%)	23	20	25

Soil reaction is a decisive factor in the biochemical and physicochemical processes occurring in the soil. As the optimum factor for biological processes related to the metabolism of most plant species and soil microorganisms, the pH value is in the range of 5.5 to 7.2. When the pH values in soil solutions fall below 4.5, soluble forms of aluminum appear, damaging the plant's root defenses by impairing the uptake of water and nutrients. In the fields in Kosina, the soil was found to be acidic (4.5–5.9) compared to the cultivated soils in the Podkarpackie voivodeship (6.5–7.2). Particularly, the soil under reduced tillage system was characterized by lower pH (4.4–5.8) and (4.1–5.3), respectively [Stanek-Tarkowska et al. 2013, 2015]. Monitoring studies for Poland have shown that the pH of soil, measured with 1M HCl, is generally in the range of <4.0–7.5 [Siebielec et al. 2012].

Soil organic matter is a basic indicator of soil quality that determines its processes, and above all, its physicochemical properties and biological processes, which are responsible for many transformations as well as soil retention characteristics, including water content in the soil. In Poland, the content of organic matter in the soil is 1% low, 1–2% medium, 2–3.5% high, and > 3.5% very high [Siebielec et al. 2012].

The experimental fields showed relatively low nitrogen content (0.10–0.16%) compared to the soil of the Podkarpackie voivodeship, where in the years 2010–2012, the content was 0.080–0.259%. Nationally, the average nitrogen content of the samples collected during the 2010–2012 monitoring period was 0.11%, and its range was 0.04–0.41% [Siebielec et al. 2012].

The type of tillage systems and the manner in which it is fertilized, as well as the plants growing there, influence the species diversity of diatoms. *Stauroneis termicola* was the most developed.

In the period from August to November, it represented more than 25% of specimens in the K1 and K2 collections, while in K3 it was over 10%. According to [Krammer, Lange-Bertalot 1988, Hofmann et al. 2011], *Stauroneis thermicola* is an earophilic species that grows in moist mosses, only isolated on soils and observed primarily in small waters flowing in silicates.

On agricultural soils of Podkarpacie voivodeship, the species was designated as dominant [Stanek-Tarkowska, Noga 2012a,b]. The studies on cultivated soils show that species such as *Sellaphora nana*. *Stauroneis borrichii* and *Stauroneis thermicola* are the diatoms typical of soils. They are often larger in size compared to those that develop in aquatic environments [Stanek-Tarkowska et al. 2013, 2016]. Moreover, in Pogórska Wola, its share in diatom populations was recorded only in the first months of research (the most common in April – 29%) [Stanek-Tarkowska et al. 2016]. It is the second dominant species classified as rare and potentially threatened found on the Red List of Algae. On the field, its population was found to be very high. Species such as *Mayamaea atomus var. atomus* and *Mayamaea atomus var. permits* have grown exponentially in the surveyed fields, reaching more than 50% of the assemblage in the community. As reported by Krammer, Lange-Bertalot [1986], *Mayamaea atomus var. permits* is found in water bodies, is massively present in heavily saprobed zones up to the polysaccharide zone, and often occurs together with *Mayamaea atomus var. atomus*. Studies conducted over several years in the Podkarpacie and Małopolska provinces indicate that both species occur frequently, forming large populations of soils on cultivated soils [Stanek-Tarkowska et al. 2013, 2016]. More than 60% of *Mayamaea atomus var. atomus* was reached in the case of field K3 in April and May, with acidic soil (pH 4.8–5.1). In the remaining months, its share in the community ranged from 5.1% to 20%. It is similarly related to the reaction of the soil.

Halamphora montana is a cosmopolitan species occurring throughout Central Europe. It is defined as aeric [Krammer, Lange-Bertalot 1986] and found in both flat and mountainous areas, but usually as single cells, rarely forming large populations. However, as indicated by the previous studies by Stanek-Tarkowska, Noga [2012a], the largest populations were formed by diatoms characteristic of wet and periodically dry sites. Ettl, Gärtner [1995] report that it can also develop in the soil.It produced the most populations in field K3,, especially in September and November, and its development was likely to favor acidic soil (pH 4.5–4.8). The previous studies by Stanek-Tarkowska, Noga [2012b] appear to confirm that this species forms numerous populations in soils with acidic reactions.

Nitzschia pusilla was the most developed in field K3 in May, exceeding 50% of the population. It is defined as a cosmopolitan species, found in Central Europe. It is often identified in water communities of differing quality, and develops in wetlands with a large environmental tolerance. This species propably tolerates eutrophic conditions, but not elevated saprobity. It tolerates low temperatures [Krammer, Lange-Bertalot 1986]. Soil in this field was acidic (pH 4.5–4.8) and showed the highest water content throughout the research period.

Pinnularia schoenfelderi developed in the K1 and K2 fields, reaching 20% of the population, while in field K3, it was not found in the annual study at all. The species is probably cosmopolitan, it develops in waters with low to medium concentrations of electrolytes, and is relatively common in peat bogs and among mosses. The species occurs in dispersed form, locally frequent, growing more abundantly in flowing water and peat bogs classified as anthropogenically transformed and dystrophic, with poor electrolytes content [Krammer 2000, Hofmann et al. 2011]. *Pinnularia schoenfelderi* is included on the Polish Red List of Algae [Siemińska et al. 2006] in the category of critically endangered range or extinct (Category E).

The studies found significant effects of the moisture and pH of silt loamy soil on the growth and diversity of species of diatoms.

In 2014, the average yields of winter wheat (var. Bogatka) in the fields of Kosina (K1 and K2) were high (7.41–7.87 $t{\cdot}ha^{-1}$) and did not differ significantly in comparison with the yields for the years 2011–2014 in the experimental fields of Podkarpacie in Przecław (average 7.99 $t{\cdot}ha^{-1}$) [Buczek, Bobrecka-Jamro 2015]. The average yield of winter wheat for Poland was significantly lower and amounted to 4.57 $t{\cdot}ha^{-1}$, while for individual farms it was 3.49 $t{\cdot}ha^{-1}$ [GUS 2015]. The yield of oat seed (var. Haker) in field K3 was 6.30 $t{\cdot}ha^{-1}$and was significantly higher than that obtained from individual farms in Podkarpacie (2.66 t/ha) [GUS 2015]. It was found that the physicochemical properties of the soil and the distribution of precipitation during the period of intensive growth of the plants significantly influenced the winter wheat (var. Bogatka) and oat yields (var. Haker).

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