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DIVERSITY OF DIATOMS (BACILLARIOPHYCEAE) IN THE SOIL UNDER TRADITIONAL TILLAGE AND REDUCED TILLAGE

Abstract. Research on soil diatoms has been conducted in Podkarpacie voivodeship in Dąbrowa village (50°03'31″N 21°48'35″E) in the Subcarpathian Province in SE Poland. On the same soil type, i.e. silty clay loam (sand 0–23%, silt >40, clay 36–50%), two tillage systems were applied under maize (*Zea mays*): traditional and reduced. The major aim of the research was to analyse diatom diversity depending on the applied tillage system under maize (*Zea mays*). In the soil samples it was identified 62 taxa of diatoms, including 38 under traditional tillage, and 50 under reduced tillage. Under traditional tillage the most frequent species were *Stauroneis thermicola, Mayamaea* cf. *atomus* var. *permitis, Nitzschia palea*, and *Pinnularia obscura*. Under reduced tillage, *Amphora montana* was the most abundant. The dominant diatoms are characteristic of water reservoirs but are regulary found also on wet or moist sites.

Keywords: diatoms, Bacillariophyceae, soil moisture, reduced tillage, traditional tillage.

INTRODUCTION

Soil ecosystems are characterized by unstable environmental conditions. As a result of agricultural activity, soils are exposed to erosion and degradation due to drainage, crop protection chemicals, deep ploughing, and the use of fertilizers. Recently, conservation or reduced tillage has been used more and more often, to prevent soil erosion. Soil algae are primary producers of organic matter, and are sources of food for heterotrophic soil organisms. The algae cement soil particles together and thus contribute to soil stabilization. Beside bryophytes and lichens, soil algae play an important role as pioneer organisms during colonization of raw soils, areas destroyed by volcanoes, forest fire, etc. [2,5].

Relationships between individual groups of soil algae and higher plants are still poorly studied. Soil pH has an influence on species richness of soil algae as well as of higher plants. Calcareous, alkaline soils are generally richer in algal species than acidic siliceous soils [13].

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Research on soil algae is usually focussed on green and blue-green algae (Chlorophyta and Cyanophyta), while diatoms (Bacillariophyceae) are rarely studied [1,15,17,18,]. There is little published data on the influence of farming (type of land use) on the floristic diversity of diatoms. The aim of this study was to compare diatom diversity in two tillage systems: conventional and reduced.

STUDY AREA

The Subcarpathian region of SE Poland has a varied geomorphology, which results in the diverse relief, vegetation, and soils. Material for this study was collected in the village of Dąbrowa, which lies near the major route between Rzeszów and Kraków (Fig. 1). Dąbrowa is a small agricultural village, within the Świlcza Commune. It lies at the border between two macroregions: the Carpathian Foothills (Pogórze Karpackie) and Sandomierz Basin (Kotlina Sandomierska), which can be subdivided into the Rzeszów Foothills (Podgórze Rzeszowskie), Subcarpathian Proglacial Valley (Pradolina Podkarpacka), and Kolbuszowa Plateau (Płaskowyż Kolbuszowski). The Rzeszów Foothills are low hills (mostly 210-300 m a.s.l.). The highest hill, near the village of Trzciana, has an elevation of 342 m.

The experimental fields were part of a private farm. They were slightly sloping, with a western exposure (Fig. 1).

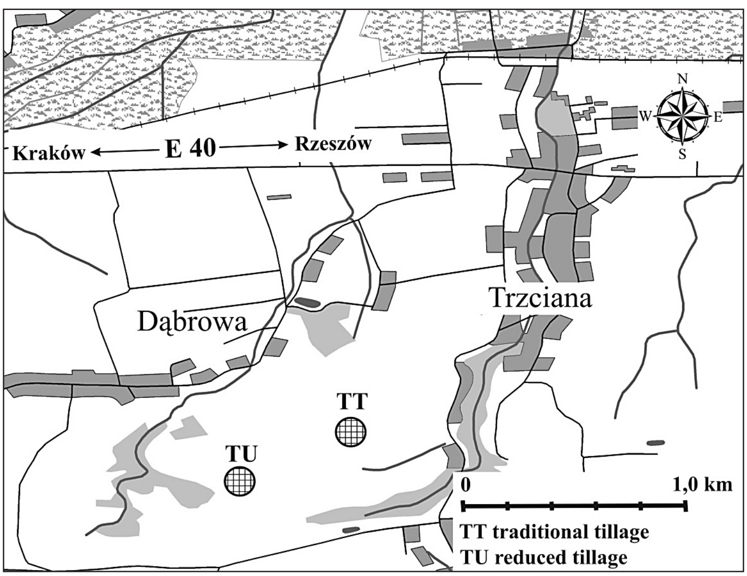


Fig 1. Location of research sites

MATERIAL AND METHODS

Studies have been conduced in 2009 in Podkarpacie voivodeship in Dąbrowa village . Soil samples were collected from private farms where: two tillage systems were applied under maize (*Zea mays*): TT - traditional, i.e. tilled with a reversible plough (ploughing to the depth of 30 cm) and additionally with traditional tools; and TU - reduced tillage (for 3 years) i.e. tilled with a cultivator with rigid shanks (mowing the surface soil layer, about 10 cm), and additionally with traditional tools. On both fields, chopped crop residue was left after harvest and it was applied herbicide (Merlin Super 537 S.C., at a rate of 1.5 L ha^{-1}) and fertilizers before sowing: 80 kg N, 50 kg P_2O_5, and 100 kg ha^{-1} K_2O, as ammonia nitrate and Polifoska 8-24-24 (a commercial N-P-K fertilizer: 8% N, 24% P, 24% K).

Soil samples were collected from the depth of 0-3 cm into Petri dishes (2 samples from each field: TT and TU), at the height of the growing season for maize, i.e. in. Directly after sample collection in the field, about half of each sample was macerated with acids (to get clean diatom valves). As reported by Siemińska [14], to investigate the development and variation of individual species, diatoms must be cultured. That is why the other half of each sample was left on a windowsill for 13 days and watered regularly with distilled water, to continue observations of diatoms that developed on the soil surface. After this time, the material was macerated with acids. Thus it was compared 4 variants:

- TT and TU (16 July 2009) samples collected from the field and macerated with acids on the same day.
- TT and TU (29 Jul 2009) samples after 13 days of culture, next macerated with acids.

From the cleaned material was made permanent slides after embedding in synthetic resin (PLEURAX, refractive index 1.75). After identification under a light microscope (NIKON ECLIPSE 80i), it was made micrographs of diatoms. Diatoms were indentified with usage of keys: Kramer, Lange-Bartalot [8,9,10,11].

Beside the samples for diatom identification, we collected also soil samples from the surface layer (0-10 cm), to analyse in the laboratory the major physicochemical properties of the soil: pH in KCl, organic matter by the Tyurin method and granulometric composition by the Casagrande method, modified by Pruszyński.

RESULTS

The analysis of selected physicochemical properties of the soil from both fields (TT and TU) indicates that on both fields the soil type was the same. Its granulometric composition (i.e. soil texture according to the Polish classification) corresponded to silty clay loam (płi: sand 0–23%, silt >40, clay 36–50%). In the field under traditional tillage (TT) organic matter content was much lower than in the field with reduced tillage (TU). Also soil pH clearly differed between TT and TU. Soil pH was close to neutral in TT, while acidic in TU (Table 1).

Table 1. Selected physicochemical properties of the soil in village of Dąbrowa

Tillage systems	Deph [cm]	Symbol of soil	Organic matter [%]	pH KCl
TT (traditional)	0–10	płi	1.72	7.2
TU (reduced)	0–10	płi	2.06	5.8

In the analysed soil samples, 62 taxa of diatoms were identified. Incubation of the soil samples did not result in any remarkable differences in diatom diversity (Table 2).

In the material identified directly after collection, 5 taxa dominated in TT: *Cocconeis pediculus, Mayamaea* cf. *atomus* var. *permitis*, *Nitzschia palea, Pinnularia obscura,* and *Stauroneis thermicola*. In TU, only one taxon was dominant: *Amphora montana.* After two weeks of culture, the number of dominants in TU increased from 1 to 4 (Table 3). Among the dominants, the highest abundance in samples was reached by *Amphora montana* (over 70%), *Stauroneis thermicola* (ca. 30%) and *Pinnularia obscura* (ca. 20%).

To characterize the ecological preferences of diatom communities in respect of soil moisture, it was used the classification of Van Dam *et al*. [16].

On both fields, the diatom communities were dominated by species found mostly in water reservoirs but also regularly on wet or moist sites (Fig. 2, category 3). Diatoms found mostly on wet or moist sites or in periodically dry habitats ranked second (Fig. 2, category 4). Diatoms preferring aquatic habitats (categories 1 and 2) were more abundant under reduced tillage (Fig. 2). The largest populations were formed there by diatoms characteristic of wet and periodically dry sites: *Amphora montana*, *Stauroneis thermicola*, and *Pinnularia obscura* (Table 3).

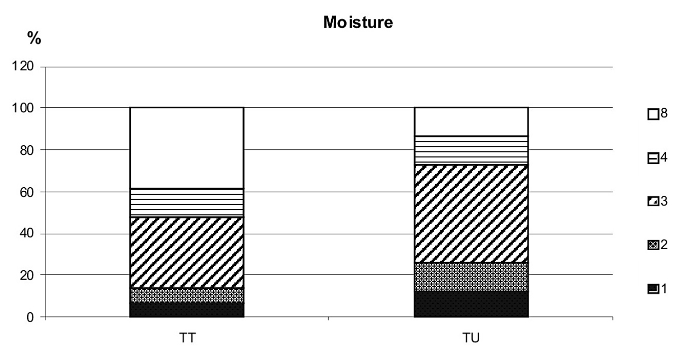


Fig 2. Dominance structure of soil diatoms, identified in the soil under maize (*Zea mays*), classified on the basis of moisture preferences, under traditional tillage (TT) and reduced tillage (TU): 1 – never or very rarely found outside water reservoirs; 2 – found mostly in water reservoirs; sometimes on wet sites; 3 – found mostly in water reservoirs, but also regularly on wet or moist sites; 4 – found mostly on wet and moist sites or in periodically dry habitats; 8 – unknown (others)

Table 2. List of taxa of diatoms found in a field under traditional tillage (TT) and reduced tillage (TU) conducted in a village of Dąbrowa in 2009. (16 July – directly after collection in the field; 29 July – after 13 days of culture)

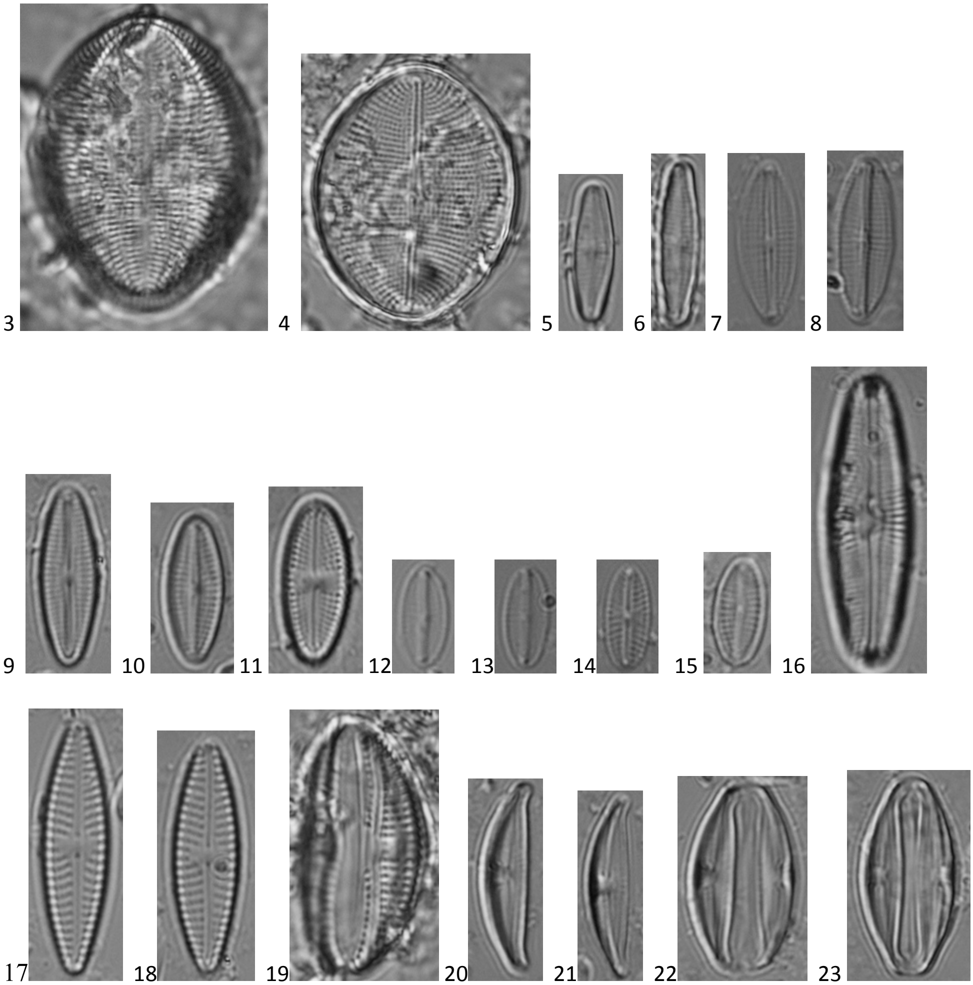
Taxa	TT 16.07	TT 29.07	TU 16.07	TU 29.07
Achnanthidium minutissimum (Kütz.) Czarn.	+	+	+	+
Amphora libyca Ehr.			+	
A. montana Krasske		+	+	+
A. pediculus (Kütz.) Grun.	+	+	+	+
Amphora sp.			+	
Cocconeis pediculus Ehr.	+	+	+	+
C. placentula var. *lineata* (Ehr.) Van Heurck.		+	+	+
C. placentula var. *euglypta* (Ehr.) Grun.	+			
Craticula cf. *molestiformis* (Hust.) D. G. Mann			+	+
Cyclotella meneghiniana Kütz.			+	+
Diatoma vulgaris Bory	+	+	+	+
Encionema minutum (Hilse) D. G. Mann	+	+		+
Eolimna minima (Grun.) Lange-B.	+			+
Fallacia monoculata (Hust.) D. G. Mann			+	+
Fragilaria capucina var. *vaucheriae* (Kütz.) Lange-B.	+	+	+	
F. parasitica var. *parastica* (W. Smith) Grun.			+	
Gomphonema parvulum (Kütz.) Kütz.	+	+	+	+
Gyrosigma acuminatum (Kütz.) Rab.			+	
Hantzschia abundans Lange-B.	+	+	+	+
H. amphioxys (Ehr.) Grun.	+	+	+	+
Hippodonta capitata (Ehr.) Lange-B., Metz. & Witk.	+		+	
Luticola mutica (Kütz.) D. G. Mann	+	+	+	+
L. ventricosa (Kütz.) D. G. Mann			+	+
Mayamaea agrestis (Hust.) Lange-B.				+
M. atomus var. *atomus* (Kütz.) Lange-B.	+	+	+	+
M. cf. *atomus* var. *permitis* (Hust.) Lange-B.	+	+	+	+
Mayamaea sp.			+	+
Muelleria cf. *gibbula* (Cl.) Spaulding & Stoermer			+	+
Navicula antonii Lange-B.				+
N. capitatoradiata Germ.	+	+		
N. cryptotenella Lange-B.	+	+	+	+
N. cryptotenelloides Lange-B.	+			
N. gregaria Donkin	+	+	+	+
N. lanceolata (Ag.) Kütz.	+	+	+	+
N. reichardtiana Lange-B.	+			
N. tripunctata (O. F. Müller) Bory			+	
N. trivialis Lange-B.	+		+	
N. veneta Kütz.			+	+
Nitzschia acidoclinata Lange-B.				+
N. debilis (Arn.) Grun.		+		
N. disspiata var. *dissipata* (Kütz.) Grun.	+	+		
N. fonticola Grun.				+
N. frustulum var. *frustulum* (Kütz.) Grun.	+	+		+

N. linearis var. *tenuis* (W. Smith) Grun.			+	
N. palea (Kütz.) W. Smith	+	+	+	+
N. perminuta (Grun.) Peragallo			+	+
N. pusilla Grun.		+	+	+
N. recta Hantzsch				+
Nitzschia sp.	+			
Pinnularia borealis Ehr.	+	+		
P. microstauron (Ehr.) Cl.		+		
P. obscura Krasske	+	+	+	+
Planothidium lanceolatum (Bréb.) Round & Bukht.	+	+	+	+
Rhoicosphaenia abbreviata (Ag.) Lange-B.	+	+	+	+
Sellaphora bacilloides (Hust.) Levkov, Krstic & Nakov		+		
Stauroneis thermicola (Petersen) Lund	+	+	+	+
Stephanodiscus hantzschii Grun.	+			
Surirella angusta Kütz.			+	+
S. brebissonii var. *kuetzingii* Kram. & Lange-B				+
S. minuta (Bréb.) Kütz.			+	+
Surirella sp. (cf. *terricola*) Lange-B.				+
Surirella sp.			+	+
Total taxa in sampels	**32**	**30**	**41**	**42**
Total taxa on site	**38**		**50**	

Table 3. Percentage contributions of dominant diatoms in the field under traditional tillage (TT) and reduced tillage (TU)

Taxa	TT. 16.07	TT.29.07	TU. 16.07	TU. 29.07
Achnanthidium minutissimum	5 – 20	<5	<5	<5
Amphora montana	no occurance	<5	>20	>20
Cocconeis pediculus	5 – 20	<5	<5	<5
Fallacja monoculata	no occurance	no occurance	<5	>20
Mayamaea cf. *atomus* var. *permitis*	5 – 20	>20	<5	<5
Nitzschia palea	<5	>20	<5	5 – 20
Pinnularia obscura	5 – 20	5 – 20	<5	<5
Stauroneis thermicola	>20	>20	<5	5 – 20

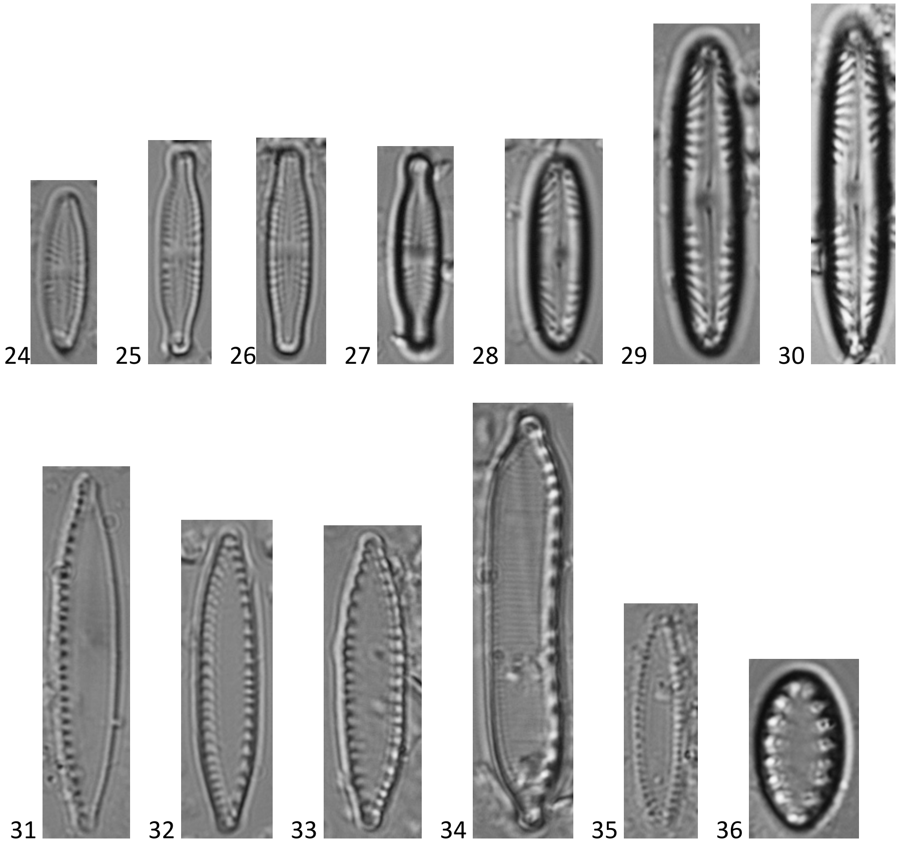
no occurance	<5	5 – 20	>20



Figs 3-23 3 & 4 - *Coconeis pediculus* Ehr; 5 & 6 - *Achnanthidium minutissimum* (Kütz) Czarn.; 7 & 8 - *Craticula molestiformis* (Hust.) D.G. Mann; 9 & 10 - *Fallacja monoculata* (Hust.) D.G. Mann; 11 - *Luticola mutica* (Kütz) D.G. Mann; 12 & 13 - *Mayamaea atomus* var *permitis* (Hust.) Lange-B; 15 - *Mayamaea atomus* var *atomus* (Kütz) D.G. Mann; 16 - *Muelleria cf gibbula* (Cl.) Sapulding & Stromer; 17 & 18 - *Navicula veneta* Kütz; 19 - *Amphora libyca* Ehr.; 20 & 21 & 22 & 23 - *Amphora montana* Krasske.

DISCUSSION

Traditional tillage was distinguished by lower organic matter content and higher soil pH than reduced tillage (Table 1). So large differences in organic matter content affected soil moisture, because if organic matter content is higher in a soil, then it can retain more moisture [4].



Figs 24-36 24 & 25 & 26 & 27 - *Stauroneis thermicola* (Petersen) Lund; 28 & 29 & 30 -*Pinnularia obscura* Krasske; 31 & 32 & 33 - *Nitzschia palea* (Kütz) W. Smith; 34 -*Hantzschia amphioxys* (Ehr.) Grun; 35 - *Nitzschia pusilla* Grun.; 36 - *Surirella* sp.

In the samples from both fields (TT, TU), 62 taxa of diatoms were recorded in total. The samples from TU were richer in species (50 taxa) than the samples from TT (38 taxa). In all probability, the higher soil moisture and organic matter content positively affected the development of the higher number of taxa of diatoms under reduced tillage, in spite of the acidic soil pH.

Reduced tillage appears to be very favourable for *Amphora montana*, which was the only dominant in the material identified directly after collection from TU. According to the description of this species in the key by Krammer & Lange-Baertalot [7], it is cosmopolitan, aerophilous, found in lowlands and highlands, but rarely forming so large populations. Ettl & Gärtner [1] report that it can also develope on the soil. The investigations showed that acidic pH was more favourable for this species (5.8), as its abundance decreased by a half during culture (perhaps the pH increased when the samples were watered with distilled water).

Falacia monoculata was found only in samples from TU and its abundance exceeded 20% after 13 days of culture. *F. monoculata* is probably cosmopolitan, dispersed in Central Europe, sometimes abundant in various water reservoirs [7]. The species was also reported from Britain, as found on soils [1]. Acidic pH probably limited its development, as its population size was very low in the material identified directly after collection.

Under traditional tillage, *Stauroneis thermicola* was most abundant. This species is reported from a wide spectrum of habitats (from planes to mountains). It is most commonly found in moss, rarely on the soil (Britain, Germany, Iceland, Denmark) [1, 3, 7]. Also *Pinnularia obscura* dominated only under traditional tillage. It is aerophilous, cosmopolitan, as like as *S. thermicola* preferring moist moss and wet soil [1].

In the diatom flora, the largest group of species were those found typically in water bodies but also regularly on wet or moist sites (Fig. 2). By contrast, in respect of abundance, the dominant diatoms were characteristic of moist and wet sites or periodically dry habitats (category 4) and they were: *Amphora montana*, *Stauroneis thrmicola* and *Pinnularia obscura* [16].

Preliminary research shows that it is necessary to continue research on soil diatoms, especially that there is little published data on this group of algae. In the few studies conducted in the 1980s on soil algae in vegetable fields near the city of Kraków (S Poland), mostly blue-green and green algae were considered, while diatoms were rarely identified; among them, *Hantzschia amphioxys* was most frequent [13,15,18]. There is little information on the species composition of soil diatoms found in arable fields and on the influence of tillage or fertilization on their diversity [17].

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RÓŻNORODNOŚĆ OKRZEMEK W DWÓCH SYSTEMACH UPRAWY ROLI – TRADYCYJNYM I UPROSZCZONYM

Streszczenie

Badania nad okrzemkami glebowymi prowadzono na terenie woj. Podkarpackiego w miejscowości Dąbrowa (50°03’31″N 21°48’35″E), gdzie na tej samej glebie zastosowano dwa systemy uprawy roli tradycyjny i uproszczony. Celem pracy było zbadanie różnorodności okrzemek w zależności od zastosowanego systemu uprawy roli na tej samej glebie - pyle ilastym (płi) pod uprawą kukurydzy. W materiale oznaczono 62 taksony okrzemek, w tym w próbkach z uprawy tradycyjnej – 38, natomiast z uprawy uproszczonej – 50 taksonów. Na polu z uprawą tradycyjną dominowały: *Stauroneis thermicola, Mayamae*a cf. *atomus* var. *permitis, Nitzschia palea* i *Pinnularia obscura*, natomiast na polu z uprawą uproszczoną najliczniej rozwijała się *Amphora montana*. W obydwóch systemach uprawy dominowały okrzemki występujące głównie w zbiornikach wodnych, ale także regularnie na mokrych i wilgotnych miejscach.

Słowa kluczowe, okrzemki, Bacillariophyceae, uwilgotnienie gleby, uprawa tradycyjna i uproszczona.