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Effect of microbial UGmax enricher on soil physical and water retention properties

Abstract: The paper presents the impact of UGmax enricher on soil physical and water retention properties. The experiment was established in 2005 in a 2 ha field 9 km from Lidzbark Warmiński in the village of Budniki. The studied soils were classified as Cambisols and Luvisols (IUSS Working Group WRB 2015), and they were formed from glaciolimnic deposits. Soil bulk density, soil particle density, texture, total porosity and water retention properties using low and high-pressure chambers were determined. The use of UGmax enricher on loamy soils used as arable lands in temperate climate of north-eastern Poland caused significant decrease of soil bulk density, increase of available water capacity and readily available water capacity. Statistically significant differences between examined soil properties were observed in most studied years.

Keywords: UGmax enricher, soil bulk density, water available for plants

INTRODUCTION

Soils are formed as a result of complex processes occurring in the lithosphere influenced by abiotic factors, such as parent material and climatic conditions, and biotic factors. Soil microorganisms have a significant impact on soil structure, soil properties, fertility and course of soil processes (Higa 2003). Crop protection chemicals used in agriculture, high doses of mineral fertilizers and monocultures have contributed to the deterioration of fertility of arable soils. In order to counteract the decline of quality of arable lands resulting from the decrease of organic carbon content, microbial activity and biodiversity, microbiological specimens are increasingly used in agriculture. The most popular include Effective Microorganisms, e.g. EM, EM-A, EM-1, UGmax, EmFarma and biostimulants, e.g. Bactil, Azoter (Javaid et al. 2008, Sulewska et al. 2009, Fatunbi and Ncube 2009, Mayer et al. 2010). Biological technologies are one of the methods that may increase soil microbial activity, accelerate the mineralization of organic matter, increase the resources of organic carbon (OC) and modify the arable soil fertility (Runowska-Hryńczuk et al. 1999, Nielsen and Winding 2002, Kucharski and Jastrzębska 2005, Sulewska et al. 2009, Fatunbi and Ncube 2009).

The factors determining soil aggregation and physical and water properties are texture, quantity and quality of humus, soil reaction and activity of soil microorganisms (Tisdall and Oades 1982, Chaney and Swift 1984, Owczarzak 2002). Most of the research devoted to microbiological specimens concerns their impact on biological and chemical soil properties as well as quantity and quality of crop yields (Sulewska et al. 2009, Kordas and Zbroszczyk 2012, Zarzecka et al. 2011, 2014). However, there is not enough research on the influence of effective microorganisms on soil structure and its physical and water properties. Similar studies in laboratory conditions were conducted by Kaczmarek et al. (2007, 2008), Gajewski et al. (2010, 2011) and Gajewski (2016).

The purpose of this research was to examine, in field conditions, the influence of UGmax enricher on the physical and water-retention properties of soil.

MATERIALS AND METHODS

The studies of the effect of UGmax enricher on soil properties were carried out in the years 2005, 2006, 2007 and 2008. The experiment was established at agricultural production area of 2 ha, located 9 km from Lidzbark Warmiński in the village of Budniki (54°11'54"N and 20°38'12"E) (Fig. 1). The field expe-

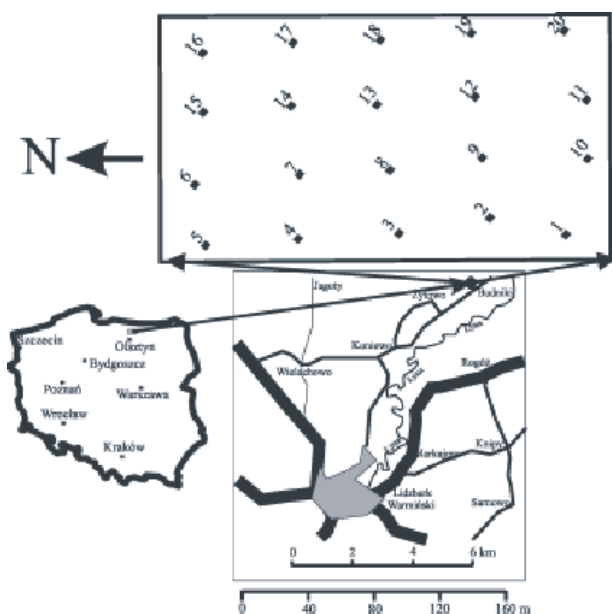


FIGURE 1. Location: study site and the sampling design

periment was conducted in September 2005 after the winter wheat harvest. Studied soils were classified as Cambisols and Luvisols (IUSS Working Group WRB 2015), formed from glaciolimnic deposits. Before application of the UGmax, 20 soil samples were collected from Ap horizons. Ten samples were collected from the area where the UGmax enricher was going to be applied, and 10 soil samples from the control area. The samples were located in a 40×25 m grid, and the location of the sampling points was set using the Magellan GPS receiver and the Elmid software. The UGmax enricher used in the experiment was an extract of animal manure and slurry. It consisted of various cultures of lactic acid bacteria, photosynthetic bacteria (*Lactobacillus* spp., *Penicillium*, *Azotobacter* spp., *Pseudomonas* spp.), yeasts as well as macro- and micronutrients N, P, K, Mg, S, Na, Mn (Kocoń and Gałązka 2015, Piotrowska et al. 2012). The soil enricher was applied in spring and autumn on the area of 1 ha. One dose in the amount of 0.7 l per hectare was applied at the stubble after wheat harvest (in 2005, 2006 and 2007). In spring, when the plants began to grow, a dose of 0.3 l per ha was applied (in 2006, 2007 and 2008). The remaining area (approx. 1 ha) was a control. Soil samples were collected after wheat harvest, before the next application of UGmax.

In collected soil samples, the following soil properties, using standard methods for mineral soil studies, were determined: soil texture using the areometric method of Bouyoucos modified by Casagrande and Prószyński, OC content using VarioMax

Cube CN Elementar Analyser, soil pH in H₂O and 1M KCl potentiometrically, soil specific density (Sd) by pycnometric method and soil bulk density (Bd) in undisturbed soil samples collected, in four replications, into 100 cm³ steel cylinders. Total porosity (Tp) was calculated according to the equation:

$$Tp = (Sd - Bd) \cdot Sd^{-1} \cdot 100 (\%)$$

Soil water retention properties were determined using low-pressure (in pF range 0–2.7) and high-pressure (in pF range 3.0–4.2) chambers. Water capacities (Wvol.) were examined at water potential of 98.1 hPa (pF 2.0), 490.5 hPa (pF 2.7), 981.0 hPa (pF 3.0) and 15 547.9 hPa (pF 4.2) (Zawadzki 1973, Walczak et al. 2002). The volume of the following soil pores and water capacities were calculated: macropores (total porosity – Wvol. at pF 2.0), micropores (Wvol. at pF 4.2), mesopores (Wvol. at pF 2.0 – Wvol. at pF 4.2). Mesopores correspond to potential useful water retention (AWC – available water capacity). Among AWC, readily available water capacity – RAWC (Wvol. at pF 2.0 – Wvol. at pF 3.0), and small pores available water capacity – SAWC (Wvol. at pF 3.0 – Wvol. at pF 4.2) were calculated (Zawadzki 1973, Walczak et al. 2002).

Statistical calculations were carried out using Statistica 10.0 software.

RESULTS AND DISCUSSION

Basic soil properties

The examined soils were qualified as Eutric, Gleyic Cambisols (IUSS Working Group WRB 2015). Most of studied soil samples (50%) had sandy loam texture, 40% sandy clay loam and 10% clay loam texture (PTG 2009). The content of clay fraction (diameter < 0.002 mm) in Ap humus horizons varied and ranged from 15.0% to 31.0% with an average value of 21.7%. The reaction of studied soils was slightly acidic and ranged from pH 5.5 to pH 6.6 (Table 1). Ap horizons contained low amounts of OC, ranging from 12.3 to 19.5 g·kg⁻¹ with an average of 15.4 g·kg⁻¹ (Piotrowska et al. 2012).

Physical and water properties

Bulk density of soil samples collected in 2005 from Ap horizons of the investigated area before the experiment was established was in the range of 1.31–1.56 Mg·m⁻³ with the average of 1.43 Mg·m⁻³ in soils where UGmax was applied later and 1.46 Mg·m⁻³ in soils at control area (Table 2, Fig. 2). A significant

TABLE 1. Basic soil properties in 2005 (before the establishment of experiment)

Parameter	pH	OC (g·kg ⁻¹)	% of particles (in mm)			
			> 2.0	2.0–0.05	0.05–0.002	< 0.002
Min	5.5	12.3	1.2	45.0	19.0	15.0
Max	6.6	19.5	7.5	64.0	28.0	31.0
Mean		15.4	3.8	55.1	23.2	21.7
Standard deviation – SD		1.6	9.2	9.5	6.2	4.6
Coefficient of variation – CV		10.3	32.0	29.4	18.3	21.0

TABLE 2. Selected physical and water soil properties

Properties		2005		2006		2007		2008	
		UGmax	control	UGmax	control	UGmax	control	UGmax	control
Bd* [Mg·m ⁻³]	MN	1.43	1.46	1.38	1.44	1.29	1.42	1.48	1.56
	SD	0.08	0.08	0.03	0.03	0.03	0.03	0.03	0.04
	CV	5.8	5.3	2.5	1.9	2.3	2.2	2.2	2.4
Tp [% vol.]	MN	44.6	43.9	47.0	45.0	47.1	45.6	43.1	40.2
	SD	3.39	3.24	1.72	1.31	1.30	1.18	1.35	1.64
	CV	7.6	7.4	3.7	2.9	2.8	2.6	3.1	4.0
Macropores [% vol.]	MN	12.8	13.2	13.1	13.4	13.6	13.6	9.1	7.9
	SD	1.53	1.91	1.01	1.71	0.91	1.15	2.06	1.48
	CV	11.9	14.5	7.7	12.6	6.7	8.5	22.7	18.8
AWC [% vol.]	MN	16.1	15.0	18.3	16.2	17.4	14.9	18.0	15.5
	SD	2.75	1.83	1.71	1.33	1.34	1.06	0.59	1.28
	CV	17.0	12.2	9.4	8.2	7.7	7.1	3.3	8.3
RAWC [% vol.]	MN	9.0	8.1	11.1	9.3	10.6	7.4	11.5	7.7
	SD	2.04	1.64	1.09	1.55	0.99	0.99	0.72	1.38
	CV	22.6	20.4	9.8	16.6	9.3	13.4	6.3	18.1
SAWC [% vol.]	MN	7.1	6.9	7.1	6.9	6.8	7.5	6.5	7.8
	SD	1.67	1.28	1.58	0.93	0.80	1.03	0.79	1.04
	CV	23.3	18.4	22.2	13.5	11.9	13.8	12.1	13.4
Micropores [% vol.]	MN	15.9	15.7	15.6	15.5	16.1	17.1	16.1	16.9
	SD	1.51	0.94	1.24	0.91	1.35	1.27	1.00	0.86
	CV	9.6	6.0	7.9	5.9	8.4	7.4	6.2	5.1

*Bd – bulk density, Tp – total porosity, AWC – available water capacity, RAWC – readily available water capacity, SAWC – small pores available water capacity, MN – mean, SD – standard deviation, CV – coefficient of variation.

decrease of soil bulk density was found in the first and second year at the area where UGmax was applied. However, in 2008 it fluctuated in the range of 1.43–1.51 Mg·m⁻³ and its average value slightly increased by 0.05 Mg·m⁻³. A significant increase of soil density, by 0.10 Mg·m⁻³, was found in the control area in comparison to the field with UGmax. Total porosity of studied soils before the establishment of experiment was in the range of 39.1–48.5% with an average of 44.6% in soils at the area where UGmax was later used and 43.9% for the control ones (Table 2, Fig. 3). However, in 2008 it decreased, on average, by 1.5% in soils enriched with UGmax and by as much as 3.7% in control soils. Comparative analysis of bulk

density and total porosity showed that the most favourable physical properties were in Ap horizons in 2006 and 2007 where the UGmax was applied, which was proved by the lowest values of bulk density (1.286 Mg·m⁻³ and 1.378 Mg·m⁻³) and the highest total porosity (over 47%), as illustrated in Figures 2 and 3. Research carried out by Kaczmarek et al. (2008) showed that only the use of very high doses of EM resulted in decrease of soil bulk density and increase of soil total porosity. The statistical calculations showed significant differences in bulk density in 2006, 2007 and 2008 and in total porosity in 2008 between the soils where UGmax was applied and the control (Table 3).

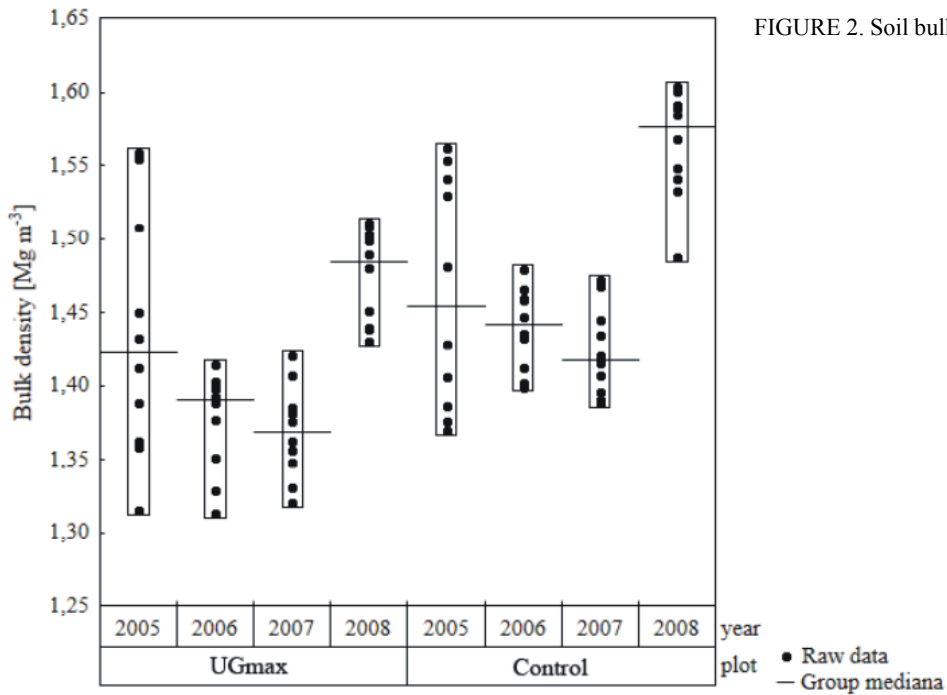


FIGURE 2. Soil bulk density during the experiment

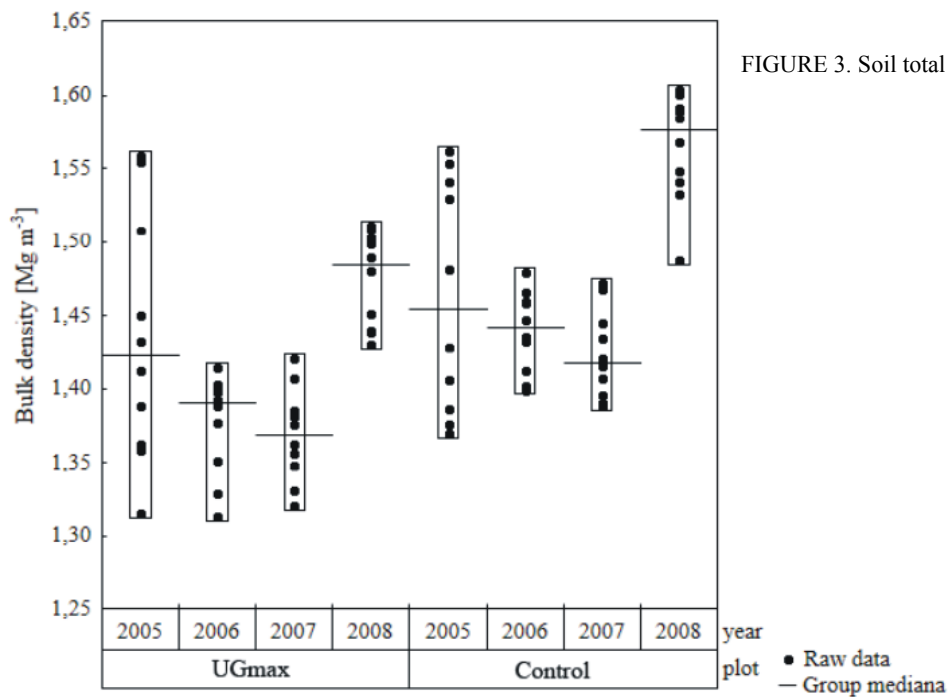


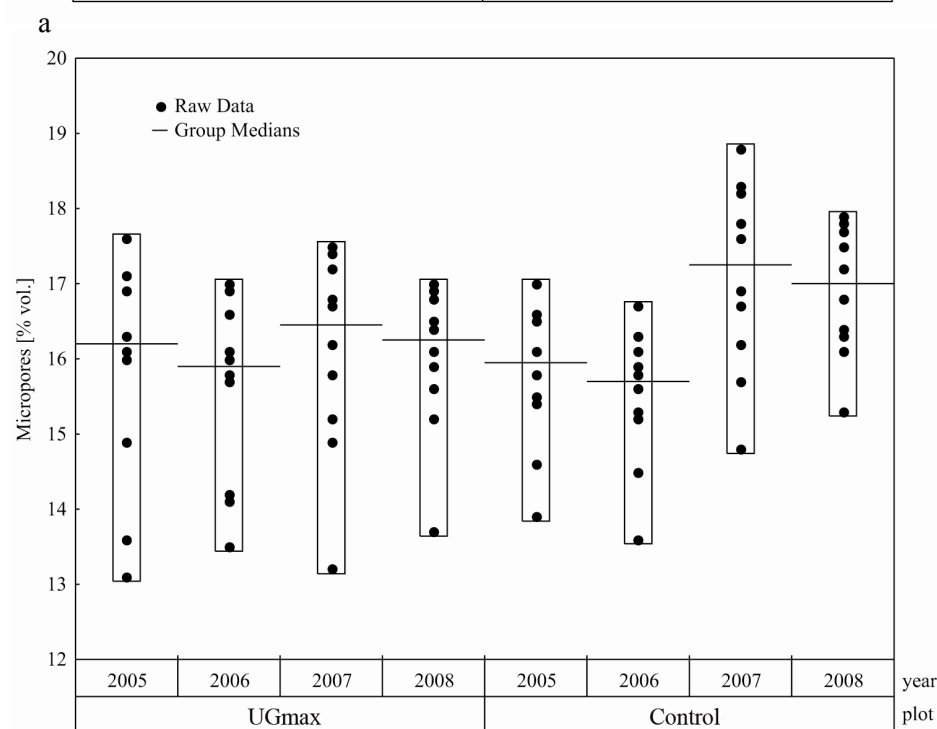
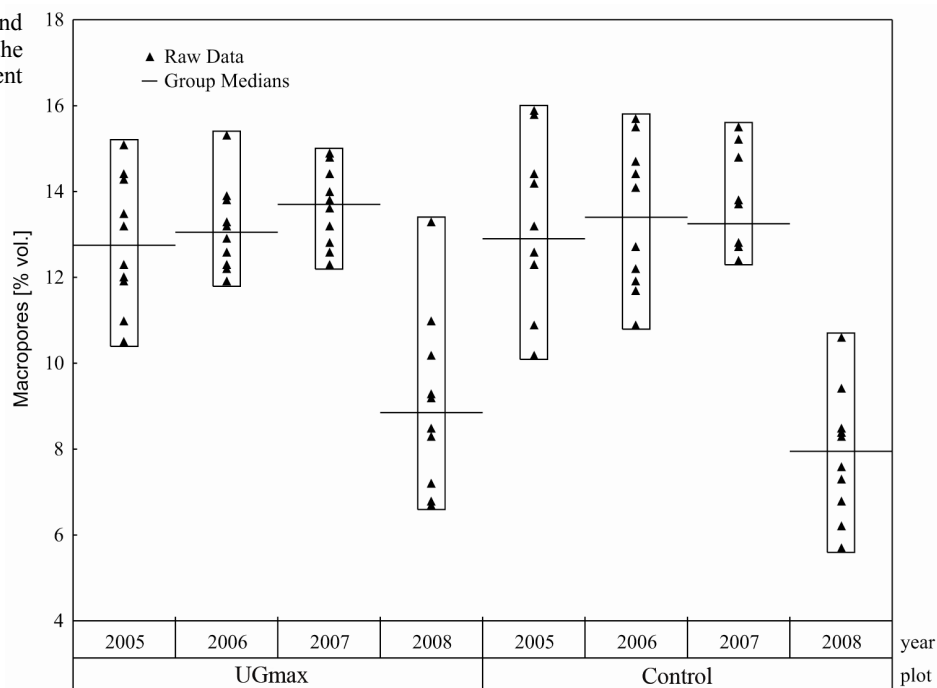
FIGURE 3. Soil total porosity during the experiment

TABLE 3. Significance of differences between soils enriched with UGmax and control for various confidence intervals

Year	Physical and water properties						
	Bd	TP	Macropores	AWC	RAWC	SAWC	Micropores
2005	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.
2006	0.0002***	0.0109*	n. s.	0.0068**	0.0066**	n. s.	n. s.
2007	0.0009***	0.1690*	n. s.	0.0002***	0.0000****	n. s.	n. s.
2008	0.0000****	0.0004***	n. s.	0.0000****	0.0000****	0.0047**	0.0470*

* – for confidence of $\alpha = 0.05$, ** – $\alpha = 0.01$, *** – $\alpha = 0.001$, **** – $\alpha = 0.0001$; description of symbols given in Table 2.

FIGURE 4. Soil macro and micropore content during the experiment



b

The results of studies available in the literature indicate that the impact of microbiological specimens on structure and physical properties of soils is ambiguous (Dziamba et al. 2009, Kordas and Zbroszczyk 2012) or insignificant (Gajewski 2016, Łachacz et al. 2017). Research of Baran et al. (2014) on water resistance of soil aggregates has shown that the use of EM technology significantly impairs the quality of soil structure. Whereas Gajewski et al. (2010, 2011), Kaczmarek et al. (2007, 2008), Kocoń and

Gałązka (2015), Mrugalska et al. (2009) reported that the use of effective EM-A microorganisms in incubation experiments contributed to the significant improvement of structure of soil humus horizons and improvement of soil physical properties.

Water retention properties and air-water relations in mineral soils depend mainly on granulometric composition, content of humus, soil density and position in a relief (Rawls et al. 1991, Walczak et al. 2002). Analysis of the content of various types of soil pores,

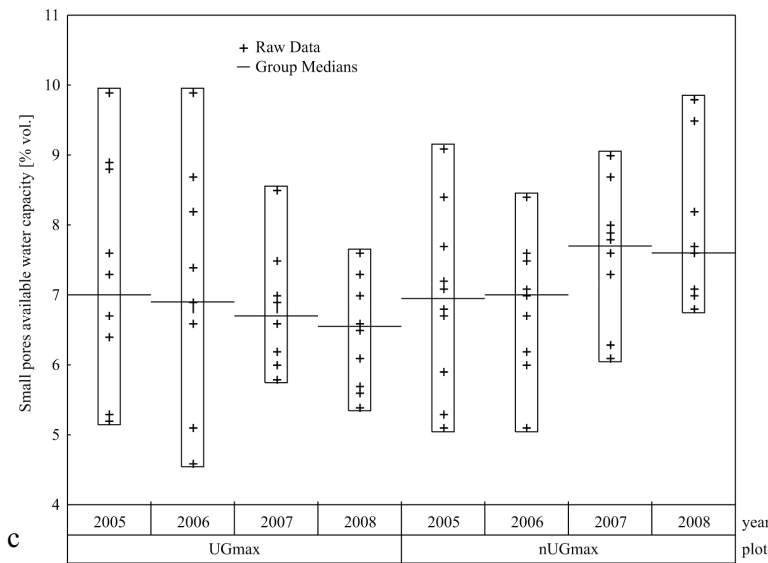
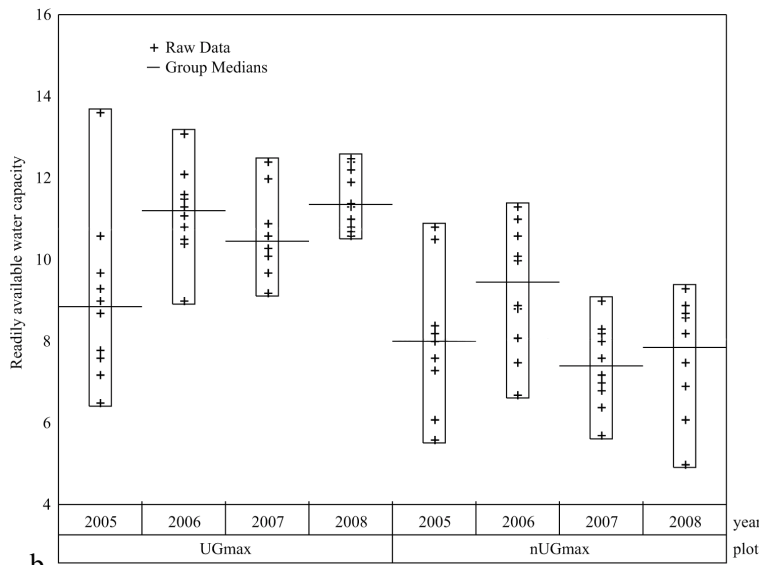
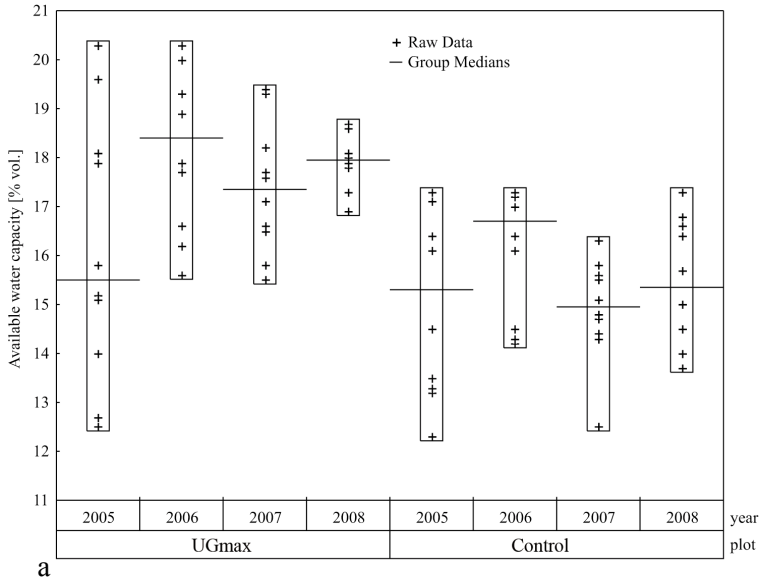


FIGURE 5. Soil AWC, RAWC and SAWC during the experiment

and thus various types of water retention abilities, showed a significant decrease of the volume of macropores in studied soils in 2008 as compared to 2005, 2006 and 2007 (Table 2, Fig. 4). The greatest average decrease of volume of macropores, by 5.3 percentage points, was observed in Ap horizons of control soils when the years 2005 and 2008 were compared. In the soils where UGmax was applied, the decrease amounted to 3.7 percentage points. The decrease of air pores content (macropores) below 10% in the studied soils may limit the growth and development of plants, because mainly these pores are responsible for the volume of soil air and oxidation-reduction properties of soils (Stepniewski 1980).

Analysis of the volume of mesopores, showed a clear increase of AWC in Ap horizons in soils enriched with UGmax. In Ap horizons, AWC increased, on average, by 1.9 percentage points after 4 years of using the enricher, as compared to 2005, while in the Ap horizons of control soils the increase was small and amounted to 0.5 percentage point (Table 2, Fig. 5). Between 2006 and 2008, RAWC increased by 1.5–2.5 percentage points only in soils enriched with UGmax. In control soils, only in 2006 the volume of water readily available for plants increased, on average, by 1.2 percentage point in relation to 2005. However, in 2007 and 2008, the RAWC values decreased by 0.4–0.7 percentage point. Analysis of SAWC showed a decrease of the volume of water hardly available for plants by 0.6 percentage points in the soils enriched with UGmax and its increase by 0.7 percentage points in control soils (Table 2, Fig. 5) during the experimental period. A similar tendency was observed for the content of water unavailable for plants. Average volume of micropores in Ap horizons of enriched soils did not change significantly, and the differences in values varied

within 0.5 percentage point, while in control soils at the end of the experiment, the volume of micropores increased by 1.2 percentage points (Table 2, Fig. 4). The increase of RAWC (at the area enriched with UGmax) was mainly due to the decrease of SAWC and volume of micropores. The mentioned capacities are extremely important in this type of soils, because they modify soil water infiltration capacity. The statistical calculation of water retention parameters showed a significant variation between the soils where UGmax was applied and control in 2007 and 2008 for AWC and RAWC (Table 3).

CONCLUSIONS

1. A significant decrease in soil bulk density was observed in the first and second year in the soils where UGmax was applied.
2. A slight but statistically significant increase of available water capacity and readily available water capacity was observed in the field where the UGmax was applied between 2006 and 2008.
3. The use of UGmax enricher on loamy soils used as arable lands in the temperate climate of north-eastern Poland influenced soil physical and water properties.

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Wpływ użyźniacza UGmax na właściwości fizyczne i retencyjne gleb

Streszczenie: W pracy przedstawiono wpływ działania preparatu UGmax na właściwości fizyczne, powietrzno-wodne i retencyjne gleby. Doświadczenie założono w 2005 roku na polu produkcyjnym o powierzchni 2 ha położonym w odległości 9 km od Lidzbarka Warmińskiego we wsi Budniki. Na badanym obszarze występują gleby zaliczane do Cambisols i Luvisols (IUSS Working Group WRB 2015) wytworzone z utworów glacialimicznych. Zastosowanie użyźniacza UGmax na glebach gliniastych użytkowanych płuźnie w klimacie umiarkowanym Polski północno-wschodniej spowodowało statystycznie istotne zmniejszenie gęstości objętościowej i wzrost zawartości wody dostępnej dla roślin (AWC), w tym wody łatwo dostępnej dla roślin (RAWC). Statystycznie istotne różnice pomiędzy badanymi właściwościami gleby stwierdzono w większości badanych lat.

Słowa kluczowe: użyźniacz UGmax, zagęszczenie gleby, gęstość objętościowa, woda dostępna dla roślin