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EFFECT OF LONG TERM ORGANIC AND CONVENTIONAL FERTILIZATION METHOD ON CHOSEN SOIL CHEMICAL PROPERTIES

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Abstract

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The aim of the study was to compare a long term effect of oppositional fertilization methods, organic vs. conventional, on chosen soil chemical properties. Soil samples were collected from organic farms with at least 10-years history of organic management and from neighboring conventional farms. In total soil samples from 66 farms distributed all over Poland were collected. The following properties were analyzed: organic carbon (C_{org}), total nitrogen (N_{tot}), pH, exchangeable forms of P, K and Mg. In general organic management resulted in slightly higher soil pH. Bigger differences were found in case of C and N content. Thanks to organic fertilization method in loamy and clay soils C content was higher by 13.5% and N content was higher by 20.3%. The same tendency, although not so marked, was found on sandy soils.
Conventional fertilization resulted in higher content of exchangeable P, especially on sandy soils. Almost the same content of exchangeable K was found on both farm types. Higher amounts of exchangeable Mg was found on organic farms on each soil type: sandy, loamy and clay. In the same time bigger disproportions of Mg content were found on organic farms (30–112 mg Mg kg^{-1}) than on conventional farms (30–87 mg Mg kg^{-1}).

organic farming, conventional farming, soil pH, C_{org}, N_{tot}, exchangeable P, K, Mg

Productivity of Polish soils is low. Above all their humus content is insufficient. When assuming the standard of the European Soil Office of 2% C_{org} as a critical value, then 89% of the surface of Polish soils would belong to the category of those of low content of organic matter (Gonet, 2004). Humus has a significant influence on the physical and chemical stability of soil properties, as well as its biological parameters. Moreover in the context of global climate changes, it should be kept in mind that the biggest reserves of carbon are hidden in soils. Proper use can increase significantly the accumulation of carbon in soil, as presently its historic potential in this sphere is utilized only in 50–60% (Lal, 2004).

Soil acidity is a second problem. Organic farmers are sure that the starting point in a long-term process of soil improvement should be checking and optional regulation of its pH (Tyburski, Żakowka-Biemans, 2007). At the same time the researches of the Institute of Soil Science and Plant Cultivation in Puławy show that at present 28% of agricultural land in Poland has high acidity (pH in KCl lower than 4.5), and 31% is acid (pH in KCl from 4.5 to 5.5). The biggest part of very acid and acid soils (65–85%) occurs in central eastern and south eastern Poland, while lower share (30–50%) occupies western and south western Poland.

Moreover the content of Polish soils of macro elements is insufficient. According to the researches of the Institute of Soil Science and Plant Cultivation in Puławy, the very low and low content of K has 49%, of P 38% and of Mg 35% of soils (Igras *et al.*, 2003). In this situation good effects in crop production can be obtained only after a pH correction and soil nutrient status. In creating the soil content of nutritive elements and its fertility, the increasingly bigger significance plays the usage of mineral and organic fertilizers (Mattson, 1999; Mazur, 1999; Cwojdziński

and Nowak, 2000). Unbalanced fertilization can lead to soil degradation and greatly lowers its productivity – mainly as a result of acidity and disturbance of the ion equilibrium in soil environment (Mercik *et al*., 2000a; Mercik *et al*., 2000b; Richter *et al*., 2000). The biggest changes influenced by fertilization are observed in soil acidity and in the content of exchangeable forms of P, K and Mg, and to a lesser extent in the content of organic carbon and total nitrogen. Various systems of crop production, among it fertilization, can significantly reshape chemical properties of soils.

In this context, a question can be asked whether the change of farming system for organic might improve the situation. In fundamental principles of organic farming by International Federation of Organic Farming (IFOAM, 2005), the second principle is that of environment protection, which emphasizes recycling and predominantly that of fertilizers. Does organic farming really affect favorably soil fertility in Poland? The aim of the present researches was examination of the content of exchangeable form of P, K, Mg and C_{org} and N_{tot} as well as soil's pH after several years of cultivation in the systems of organic and conventional farming.

MATERIALS AND METHODS

In order to determine the influence of conventional and organic farming systems on chemical properties of soils, in the years of 2005–2007 there were samples taken on 66 farms situated in all regions of Poland. Researched were only those organic farms, which had been run in this system for at least 10 years. While the conventional farms were always situated in close neighborhood of the organic farms in order to ensure the possibility of taking soil samples which did not differ significantly in basic properties (parent rock, content of particles $\varnothing \leq$ 0.02 mm, etc.).

The farm types (organic vs. conventional) differed in:

a) land use structure (more legume crops were grown on organic farms; the proportion of cereals was ca. 55% on organic and 80% on conventional farms);
b) regular use of farm yard manure or compost on organic farms. The manures were usually applied to a field every 2nd or 3rd year (for row crops, including maize, and also for cereals) with a rate of 20–30 t per ha;
c) on conventional farms farm yard manure was applied for row crops (potatoes, sugar beet, rape or maize), so the soil was fertilized every 4th or 5th year with a rate of 30–40 t per ha;
d) until 2004 there was no official state positive list of mineral fertilizers approved for organic farms (run by Institute of Soil Science, Tillage and Fertilization in Pulawy), so only compost, farm yard manure and green manures were applied by Polish organic farmers (although in some organic farms soil minerals deficiency, especially with K, were noticed);
e) conventional farms differed in degree of their intensity – they were both low and high input. Usually conventional farms on good quality soils (i.e. high productive – medium and heavy soils) tend to be more intensive, and on pour, sandy soils – tend to be extensive – low input. On light soils high-inputs do not pay back – gave not adequate financial returns). So typical mineral fertilization on conventional farms with heavy soils was: 161–212 kg of N, 59–97 kg of P_2O_5 and 123–178 kg of K_2O and on farms with light soils was: 39–87 kg of N, 23–46 kg of P_2O_5 and 32–73 kg of K_2O.

The representative soil samples were obtained from the ploughing level (0–20 cm) using Egner's cane. The taken material was dried to the state of air dry, ground and sieved by a sieve of 1mm mesh. Such prepared samples of soil underwent a chemical analysis and there were measured:

- potentiometically pH in suspension of 1 mol KCl.dcm^{-3} solution,
- content of form of P & K were determined by method of Egner-Riehm,
- content of assimilable Mg by Schachtschabel's method,
- content of organic carbon by Turin's method,
- content of N_{tot} after mineralization by distillation.

The obtained research results were worked out statistically by *Statistica* computer program.

RESULTS AND DISCUSSION

The researches made proved that the organic farming system affects more favorably than the conventional one the amount of organic carbon in soil (Tab. I). The favorable influence of organic farming on C_{org} was stronger in soils containing more than 20% colloidal fraction. Probably to lighter soils (less than 20% of colloidal fraction) came less organic matter because of their smaller productivity. It can be also assumed that in light soils mineralization was more intensive than in heavy soils. The histograms of the C_{org} content show clearly different conditions of cultivation (Fig. 3).

In literature of the problem there are majority of reports affirming the favorable influence of organic farming methods on the content of humus in soil. It was reported among others by Hepperly *et al.* (2006) in a relation of many years' researches conducted in Pennsylvania, USA. Also from the USA comes a paper summarizing the results of many experiments conducted in different regions of that country that also indicate more favorable influence of organic methods than conventional ones on amount of humus in soil (Marriott & Wamder, 2006). Similar relationships were obtained by Sokołowska *et al.* (1998) in researches made in Poland. In the oldest and the most known DOK trial in Therwil in Switzerland started in 1978, it was concluded that the most

advantageous for the content of humus is the biodynamic system, followed by organic and conventional with manure fertilizing, whereas definitely negative impact had mineral fertilizing (Mäder *et al*., 2002).

Yet in many years' researches conducted in Minnesota, USA, by Porter & co-authors (2006) and in Poland by Meysner & co-authors (2006) no relation was found between the system of farming and the amount of humus.

Similarly to the content of C_{org} also the concentration of N_{tot} was on a bit higher level in soils cultivated in the organic system, and in heavier soils (Tab. I). It is worth noticing the bigger disparity of N_{tot} in heavier soils of organic farming system than in the same category of soils in conventional system. It could be caused by the agro-technological differences on organic farms e.g. by crop rotation and influx of organic matter to soil. In the case of light soils such a big disparity of N_{tot} content as influenced by the system of farming was not reported. The distribution of N_{tot} concentration in soils fertilized organically and conventionally to the high degree was identical to that of C_{org} (Fig. 2). Similarly to our own researches, more N in organically cultivated soils was reported in many years' researches in the USA by Hepperly & co-workers (2006), whereas in researches conducted in Poland Meysner *et al.* (2006) did not report a favorable influence of this system on accumulation of N in soil.

One of the most important factors of soils quality is their pH reaction, which influences directly assimilation of nutritive elements. In conditions of the conducted researches there was stated a very strong diversity of soils' pH as fixed in suspension of the solution of 1 mol KCl·dm^{-3} (Tab. I). The lowest pH values both for light and heavy soils occurred in the case of conventional system and the highest ones in the organic system. The changeability of pH of the examined soils was also significantly bigger for the soils fertilized conventionally.

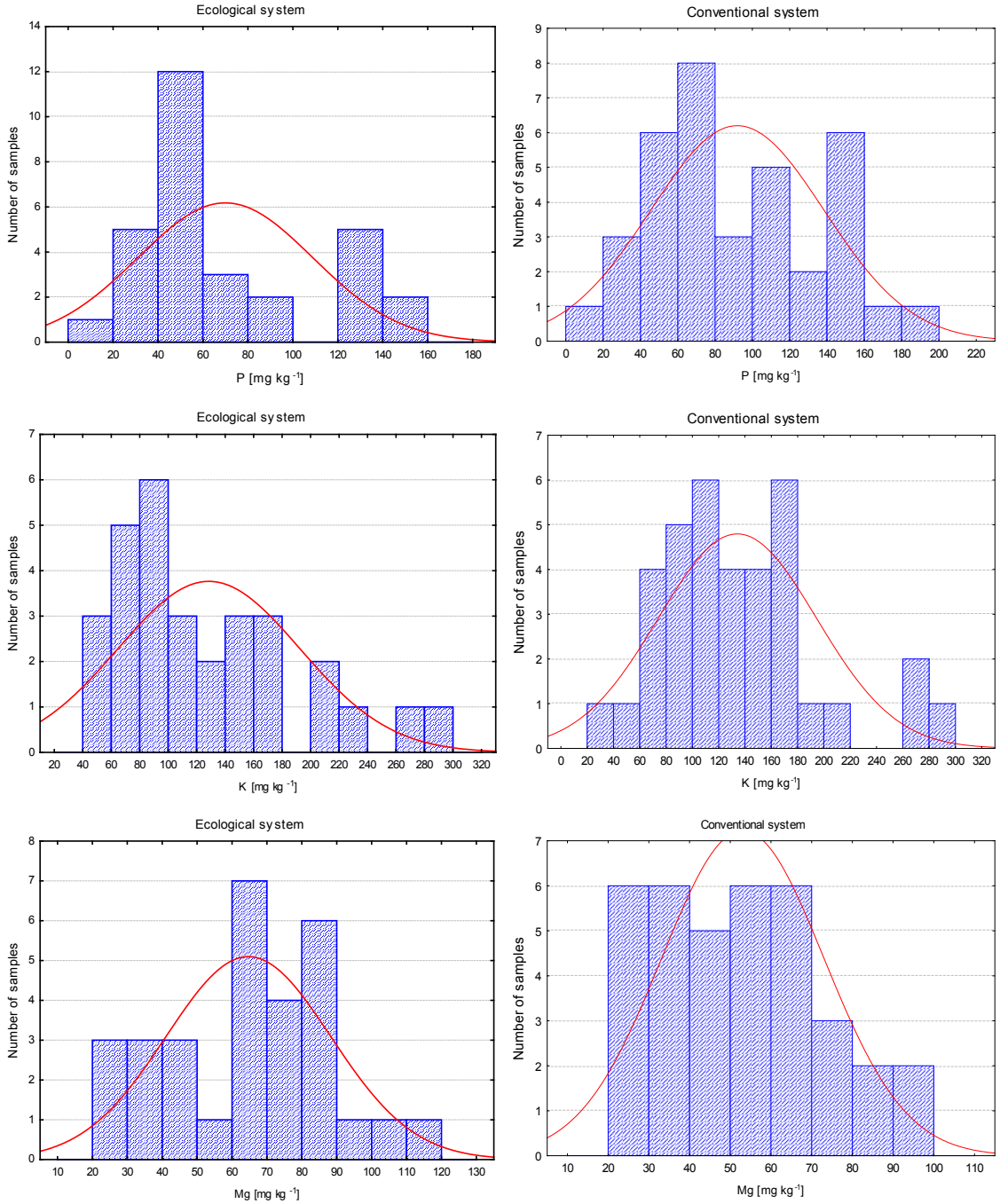
We think that soils fertilized in organic system are less prone to acidity due to elimination of acidifying mineral fertilizers (esp. N and K), and thanks to generally and often used organic fertilizers as well

I: *Chemical properties of heavier (> 20% of content of particles ∅ ≤ 0.02 mm particles) and light (< 20% content of particles ∅ ≤ 0.02 mm) soils depending on a farming system*

Soil's feature	The lowest value	The highest value	Mean value	Standard deviation	Standard error
Heavy soil (> 20% content of particles ∅ ≤ 0.02 mm) – organic system					
P (mg·kg^{-1})	19.64	153.64	77.01	40.70	8.88
K (mg·kg^{-1})	49.83	290.70	140.01	70.39	15.36
Mg (mg·kg^{-1})	30.00	112.00	72.67	21.13	4.61
pH (1 mol KCl·dm^{-3})	5.04	7.24	6.41	0.61	0.13
$C_{org.}$ (mg·kg^{-1})	7.95	32.31	12.04	6.19	1.35
$N_{tot.}$ (mg·kg^{-1})	0.90	2.80	1.24	0.49	0.11
Heavy soil (> 20% content of particles ∅ ≤ 0.02 mm) – conventional system					
P (mg·kg^{-1})	28.37	190.31	96.85	46.62	8.97
K (mg·kg^{-1})	66.45	282.39	148.27	58.89	11.33
Mg (mg·kg^{-1})	30.00	97.00	58.78	17.89	3.44
pH (1 mol KCl·dm^{-3})	4.55	7.15	6.23	0.75	0.14
$C_{org.}$ (mg·kg^{-1})	7.25	18.79	10.61	2.96	0.57
$N_{tot.}$ (mg·kg^{-1})	0.70	1.60	1.03	0.21	0.04
Light soil (< 20% content of particles ∅ ≤ 0.02 mm) – organic system					
P (mg·kg^{-1})	25.32	123.09	52.18	28.53	9.51
K (mg·kg^{-1})	53.99	149.50	99.94	31.67	10.56
Mg (mg·kg^{-1})	21.00	63.00	45.11	16.86	5.62
pH (1 mol KCl·dm^{-3})	5.00	7.15	5.69	0.61	0.20
$C_{org.}$ (mg·kg^{-1})	6.79	13.51	9.56	2.30	0.77
$N_{tot.}$ (mg·kg^{-1})	0.80	1.30	1.04	0.17	0.06
Light soil(< 20% content of particles ∅ ≤ 0.02 mm) – conventional system					
P (mg·kg^{-1})	33.17	151.90	82.17	41.42	14.64
K (mg·kg^{-1})	37.38	153.65	94.06	37.95	13.42
Mg (mg·kg^{-1})	25.00	72.00	35.63	15.31	5.41
pH (1 mol KCl·dm^{-3})	4.03	6.85	5.59	0.90	0.32
$C_{org.}$ (mg·kg^{-1})	5.92	11.25	8.85	1.90	0.67
$N_{tot.}$ (mg·kg^{-1})	0.70	1.30	0.91	0.21	0.07

as to use of crop rotation with legumes. The proof of this thesis are histograms of the distribution of pH of soils fertilized organically & conventionally (Fig. 2). Acidity of soils often grows up along with the increase of mineral fertilization, whereas organic fertilizers, which form the base of fertilization in organic farming, can prevent to a high degree that disadvantageous phenomenon (Sienkiewicz, 2003). Data obtained in the researches prove the above stated thesis.

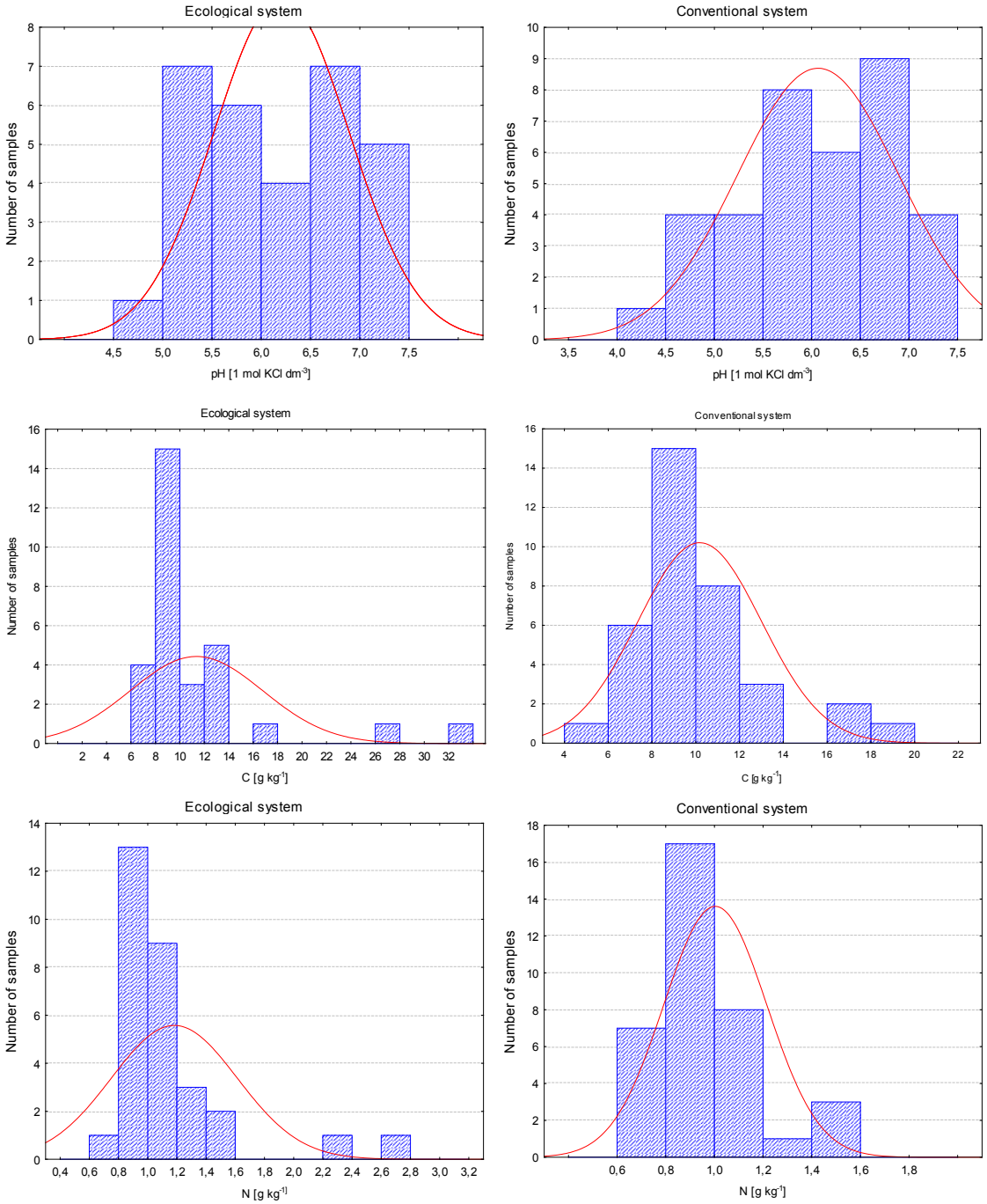
Analyses showed a very strong changeability of the content of exchangeable forms of P, K and Mg in light and heavy soils regardless the farming system (Tab. I). Bigger differences of concentration of available P for plants occurred in soils cultivated in conventional system as compared to those cultivated in organic one. It can indicate a bigger stability of this P form in soils which were cultivated organically for many years. In this context it is worth citing the results of Mader's *et al.* researches (2006), who in the framework of Therwil experiments re-



1: *Histogram of the content of exchangeable form of P, K and Mg in soil depending on the farming system (organic and conventional)*

ported a higher degree of mycorrhiza occurrence on crop roots grown in organic system. It should be emphasized though that in the conventional system accumulation of exchangeable P in soils was significantly higher than in the organic system. This relation was stronger in the case of light soils. Definitely more P available to plants was to be found in heavier soils as compared to light ones. The variability of the discussed P form in soils fertilized conventionally was less marked and closer to the normal distribution (Fig. 1).

Generally it is believed that P is an element which does not limit production in organic farming. In nutrients balances this element sometimes gets slightly negative values (–2 ÷ –3 kg per ha per year), but it comes quite often that it shows positive values. It was proved among others by the researches of Granstedt *et al.* (2004), Granstedt (2006), IKC (1997), Hülsbergen *et al.* (1997), Granstedt *et al.* (2007). Yet the tendency to mining of soil abundance in P was recorded among others in Therwil in Switzerland



2: *Histogram of pH of soils and the content of organic carbon and nitrogen depending on the farming system (organic and conventional)*

(Mäder *et al.*, 2006) and in Pote's *et al.* researches (2006) in the USA.

As for the content of exchangeable K in soil a bit different relations occurred. The strongest disparity was observed in the case of heavy soils fertilized ecologically (Tab. I). – the soils were slightly less rich in the discussed element than comparable soils fertilized conventionally. Inversely though there was the case with light soils – slightly more exchangeable K was found in condition of organic farming and a stronger difference occurred on soils fertilized conventionally. Taking into account the distribution of the content of K available for plants in soils, it should be stated that similarly to the P case it was more favorable in the conventional system – more soils lay in the ranges of higher abundance (Fig. 10). Generally K can be an element in organic farming with a negative balance, because crops bring with yield the most of this element. Thus it depends a lot on a specialization of an organic farm – if it sells more crops, among them vegetables, then the mining of K in soils will be greater (Grandstedt *et al.*, 2007).

The content of exchangeable Mg in turn was the most different in heavy soils cultivated in the organic system (Tab. I). Regardless the farming system in soils containing more than 20% of particles content of particles $\varnothing \leq 0.02$ mm there was also more exchangeable K. Both in heavy and light soils fertilized ecologically more available forms of Mg was recorded than in soils of the same category fertilized conventionally. It can be supposed that farmers running conventional farms fertilized their fields insufficiently in Mg. On the other hand, soils fertilized ecologically, due to input of organic fertilizers, can get Mg in this way. Contrary to the case of exchangeable K, definitely more soils fertilized ecologically lay in the groups of increased content of Mg – more than 70 mg·kg^{-1} (Fig. 1)

In the context of analysis of abundance in macro elements of soils cultivated ecologically, it is worth noticing that organic farmers in Poland have had an access to mineral potassium, magnesium and phosphorus fertilizers permitted in this system only for a few last years.

Cultivated and fertilized soils not necessarily keep their properties; unbalanced or insufficient fertilization leads as consequence to soil depravation from nutritive elements and its impoverishment (Kęsik, 2000; Fotyma, 2000; Fotyma, 2003). The cited authors rightly claim as alarming the impoverishment of Polish soils in exchangeable nutrients. According to Sienkiewicz (2003) organic and mineral fertilization modifies in a wide range abundance of soil in organic carbon and total nitrogen. The opinion that the system of fertilization influence decisively on the above mentioned features of soil is shared by many authors (Mercik *et al.*, 2000b; Murawska *et al.*, 2000; Szulc *et al.*, 1999).

On the grounds of the conducted analyses it was found univocally that organic farming may significantly enrich soil in organic matter and nitrogen and influence favorably soil's pH values and abundance in exchangeable Mg.

SUMMARY

Productivity of Polish soils is low. Above all their humus content is insufficient. Humus has a significant influence on the physical and chemical stability of soil properties, as well as its biological parameters. Soil acidity is a second problem. Organic farmers are sure that the starting point in a long-term process of soil improvement should be checking and optional regulation of its pH (Tyburski, Żakowka-Biemans, 2007). Moreover the content of Polish soils of macro elements is insufficient. In this situation good effects in crop production can be obtained only after a pH correction and soil nutrient status.

The aim of the study was to compare a long term effect of oppositional fertilization methods, organic vs. conventional, on chosen soil chemical properties. Soil samples were collected from organic farms with at least 10-years history of organic management and from neighboring conventional farms. In total soil samples from 66 farms distributed all over Poland were collected. The following properties were analyzed: organic carbon (C_{org}), total nitrogen (N_{tot}), pH, exchangeable forms of P, K and Mg.

In general organic management resulted in slightly higher soil pH. Bigger differences were found in case of C and N content. Thanks to organic fertilization method in loamy and clay soils C content was higher by 13.5% and N content was higher by 20.3%. The same tendency, although not so marked, was found on sandy soils.

Conventional fertilization resulted in higher content of exchangeable P, especially on sandy soils. Almost the same content of exchangeable K was found on both farm types. Higher amounts of exchangeable Mg was found on organic farms on each soil type. In the same time bigger disproportions of Mg content were found on organic farms (30–112 mg Mg kg^{-1}) than on conventional farms (30–87 mg Mg kg^{-1}).

In overall, we can say, that on the grounds of the conducted analyses of soil samples from 66 farms in Poland there was stated that the farming system influences greatly soil chemical properties.

1. Organic farming, as compared to conventional, favors stronger accumulation of organic matter in soil.

2. Organically fertilized soils are less prone to acidity.
3. On organic farms a higher content of exchangeable Mg was recorded.
4. Conventionally fertilized soils are characterized by higher abundance in exchangeable phosphorus and potassium in comparison to ecologically fertilized soils.

SOUHRN

Vliv metod dlouhodobého ekologického a konvenčního hnojení na vybrané chemické vlastnosti půdy

Produktivita polské půdy je nízká. Především její obsah humusu je nedostatečný. Humus má významný vliv na fyzikální a chemickou stabilitu půdních vlastností, stejně jako její biologické parametry. Kyselost půdy je druhý problém. Ekologičtí zemědělci mají jistotu, že výchozím bodem v dlouhodobém procesu zlepšování půdy by měla být kontrola a efektivní regulace jejího pH (Tyburski, Żakowka-Biemans; 2007). Navíc obsah makro prvků v polských půdách je nedostatečný. V této situaci je možné dosáhnout dobrých výsledků v rostlinné výrobě pouze správnými zásahy, jako např. korekcí pH a obsahu půdních živin.

Cílem studie bylo porovnat dlouhodobý efekt protichůdných systémů hospodaření, organické vs. konvenční, na vybrané chemické vlastnosti půdy. Půdní vzorky byly odebrány z ekologických zemědělských podniků s nejméně desetiletou historií ekologického hospodaření a ze sousedících konvenčních farem. Celkem byly odebrány vzorky z 66 farem rozmístěných po celém Polsku. Byly analyzovány tyto vlastnosti: obsah organického uhlíku (C_{org}), celkový dusík (N_{tot}), pH, výměnné formy P, K a Mg. Obecně přinesl ekologický způsob hospodaření mírně vyšší pH půdy. Větší rozdíly byly zjištěny u obsahu C a N. Díky ekologickému hnojení, na hlinitých a jílovitých půdách, byl obsah C vyšší o 13,5% a N o 20,3%. Stejná tendence, i když ne tak výrazná, byla zjištěna také na písčitých půdách. Klasické konvenční hnojení mělo za následek vyšší obsah výměnného P, a to zejména na písčitých půdách. Téměř stejný obsah výměnného K byl zjištěn na obou typech zemědělských podniků. Vyšší obsah výměnného Mg byl zjištěn na ekologických farmách na všech půdách. Zároveň byla zjištěna větší disproporce obsahu Mg na ekologických farmách (30–112 mg $Mg.kg^{-1}$) než na konvenčních farmách (30–87 mg $Mg.kg^{-1}$).

Na základě provedených analýz půdních vzorků od 66 zemědělských podniků v Polsku bylo zjištěno, že způsob hospodaření výrazně ovlivňuje chemické vlastnosti půdy.

1. Ekologické zemědělství, v porovnání s konvenčním, podporuje silnější akumulaci organické hmoty v půdě.
2. Organicky hnojené půdy jsou méně náchylné ke kyselosti.
3. Na ekologických farmách byl zaznamenán vyšší obsah výměnného Mg.
4. Konvenčně hnojené půdy jsou charakteristické vyšším obsahem vyměnného fosforu a draslíku ve srovnání s ekologickým hnojením.

ekologické zemědělství, konvenční zemědělství, půdní pH, obsah C_{org}, N_{tot}, výměnný P, K, Mg

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