Jarosław STALENGA, Jerzy KOPIŃSKI
Instytut Uprawy, Nawożenia i Gleboznawstwa – Państwowy Instytut Badawczy
Zakład Systemów i Ekonomiki Produkcji Roślinnej
ul. Czartoryskich 8, 24-100 Puławy, Poland
e-mail: stalenga@iung.pulawy.pl

Received: 2018-06-29 ; Accepted: 2018-09-13

IS IT POSSIBLE IN SPECIALIZED ORGANIC FARMS TO MAINTAIN IN SOIL APPROPRIATE CONTENT OF NUTRIENTS AND ORGANIC MATTER?

Summary

The aim of the research was to assess the soil pH, the content of phosphorus, potassium, magnesium and organic matter in the soil in a group of 30 organic farms of different production profile located in the Lubelskie, Podlaskie and Mazowieckie Voivodeships. The research was carried out in the years 2011-2012. The analyzed farms were divided into three groups: specialized in crop/horticultural production, specialized in animal production and with no specific specialization. There were 10 farms in each group. In specialized farms, the dominant branch had at least 60% share in the total final gross production expressed in PLN. In the farms the surveys were carried out in order to collect data for their organizational and production assessment and calculation of the balance of soil organic matter. On average for 2 years, the balance of soil organic matter in the organic farms was positive and amounted to 1.67 t of DM/ha of arable lands. The negative value of this indicator was recorded only for a group of farms, usually stockless, specialized in crop/horticultural production. There were no statistically significant differences between the compared groups of farms in soil organic carbon, phosphorus, potassium, magnesium content and soil pH. The only statistically significant difference concerned the soil pH between the group of farms with mixed and animal production. The results of chemical analyzes showed low potassium content in soils in all three groups of organic farms.
***Key words**: balance of soil organic matter, soil nutrients content, specialization in agricultural production*

CZY W WYSPECJALIZOWANYCH GOSPODARSTWACH EKOLOGICZNYCH MOŻNA UTRZYMAĆ W GLEBIE ODPOWIEDNIĄ ZAWARTOŚĆ MAKROELEMENTÓW I SUBSTANCJI ORGANICZNEJ?

Streszczenie

Celem prowadzonych badań była ocena odczynu gleby, zawartości fosforu, potasu i magnezu oraz substancji organicznej w glebie w grupie trzydziestu gospodarstw ekologicznych zlokalizowanych na terenie woj. lubelskiego, podlaskiego oraz mazowieckiego o różnym kierunku produkcji. Badania prowadzono w latach 2011-2012. Analizowane gospodarstwa zostały podzielone na trzy grupy: wyspecjalizowane w produkcji roślinnej, wyspecjalizowane w produkcji zwierzęcej oraz bez wyraźnej specjalizacji . W każdej grupie znajdowało się po 10 gospodarstw. W gospodarstwach wyspecjalizowanych dominująca gałąź miała co najmniej 60% udziału w całej produkcji końcowej brutto wyrażonej w PLN. W wybranych gospodarstwach przeprowadzono w latach 2011-2012 badania ankietowe w celu zgromadzenia danych do ich oceny organizacyjno-produkcyjnej oraz wyliczenia bilansu glebowej substancji organicznej. Średnio bilans glebowej substancji organicznej w badanych gospodarstwach ekologicznych był dodatni i wynosił 1.67 t s.m./ha GO. Ujemne wartości tego wskaźnika odnotowano jedynie dla grupy gospodarstw wyspecjalizowanych w na ogół bezinwentarzowej produkcji roślinnej. Nie stwierdzono istotnych statystycznie różnic między porównywanymi grupami gospodarstw w zawartości węgla organicznego, fosforu, potasu, magnezu oraz w odczynie gleby. Jedyna istotna statystycznie różnica dotyczyła odczynu gleby pomiędzy grupą gospodarstw z produkcją o profilu mieszanym a zwierzęcym. Uzyskane wyniki analiz chemicznych wykazały generalnie niską zasobność gleb w potas w ocenianych grupach gospodarstwach ekologicznych.
***Słowa kluczowe:** bilans glebowej substancji organicznej, zasobność gleb, specjalizacja produkcji rolniczej*

1. Introduction

In recent years, a growing specialization in agricultural production has been observed in organic farming. More and more farms, in order to improve their economic situation, decide to strictly direct their production, usually towards the crop production. Currently, in Poland, about 85% of organic farms do not have animal production [14]. There are a number of different problems associated with the progressing specialization of agricultural production in organic farming. The most important ones include difficulties in maintaining the appropriate soil organic matter and nutrient content, especially of phosphorus and potassium [2, 8].

The hypothesis of the research included the statement that difficulties related to maintaining in the soil the appropriate content of nutrients and organic matter may appear in specialized organic farms.

The aim of the research was to assess the soil pH, the content of phosphorus, potassium, magnesium and organic matter in the soil in a group of 30 organic farms of different production profile located in the Lubelskie, Podlaskie and Mazowieckie Voivodeships.

2. Material and methods

The research was carried out in the years 2011-2012. The analyzed farms were divided into three groups: specialized in crop/horticultural production (crop farms), specialized in animal production (animal farms) and with no specific specialization (mixed farms). There were 10 farms in

each group. In specialized (crop or animal) farms, the dominant branch had at least 60% share in the total final gross production expressed in Polish złoty (PLN). In the non-specialized farms (mixed farms) the share of a particular branch (crop or animal) ranged from 40 to 60%. In all 30 farms the surveys were carried out in order to collect data to assess their organizational and production status and calculate the balance of soil organic matter (SOM).

Crop productivity of farms was expressed in cereal units (CU) [6]. A cereal unit is a measure that allows to bring to the common denominator the value of crop and animal products. 1 CU corresponds to 100 kg of cereal grain.

The livestock density was expressed in the Livestock Units (LU), which is a unit of abundance of livestock on the farm. According to Polish standards, 1 LU corresponds to one cow weighing 500 kg [16].

In order to calculate the SOM balance for arable lands special coefficients of SOM reproduction and degradation for light soils proposed by Eich and Kundler modified by Fotyma and Mercik [4] were used (Table 1).

Table 1. Reproduction (+) and degradation (−) coefficients of SOM for light soils [4]
Tab. 1. Współczynniki reprodukcji (+) i degradacji (−) glebowej substancji organicznej dla gleb lekkich [4]

Specification	Coefficient value [t· ha^{-1}]
Cereals and oil crops	−0,49
Maize and leaf vegetables	−1,12
Root crops	−1,26
Grain legumes	+0,32
Fodder legumes	+1,95
Grasses	+1,05
Catch crops for green manure	+0,70
Manure (25% of DM)	+0,35
Straw (85% of DM)	+0,21

Analyzes of soil pH and phosphorus, potassium, magnesium and organic carbon content in the soil were carried out at the Central Laboratory for Chemical Analyzes in Puławy. Soil pH was measured in KCl by electrometric method. P and K content was determined by Egner-Riehm method and Mg by atomic absorption spectrometric method, whereas organic carbon content by Tiurin's method. The results of the analyzes were related to the optimal ranges of pH and the nutrients in conditions of light soils given in Table 1.

Table 1. Optimal pH and average phosphorus, potassium and magnesium content for light soils [9, 10, 11, 12]
Tab. 1. Optymalny odczyn oraz średnie zawartości fosforu, potasu i magnezu dla gleb lekkich [9, 10, 11, 12]

Parameter	Optimal range for light soils
Soil pH	>5.6
Phosphorus content (in mg/100 g of soil)	10.1-15
Potassium content (in mg/100 g of soil)	10.1-15
Magnesium content (in mg/100 g of soil)	3.1-5

Number of combined soil samples taken to measure the SOM content depended on the total area of arable lands in a particular farm. It was assumed that one combined sample was taken at a maximum of 4 ha. One combined sample consisted of 20 primary samples [13]. The presented values are shown as averages of measurements of SOM content for one farm.

3. Results and discussion

3.1. Organizational and production characteristics of organic farms depending on their profile

Most of the compared farms had both crop and animal production. However, in the crop production oriented farms, seven ones did not keep farm animals at all, and fruit and vegetable production was the dominant branch there (Table 2). It should be noted, however, that some of the crop farms tried to improve the balance of SOM by importing manure from the neighboring conventional farms, which is in accordance with official regulations in organic farming [15].

Among the compared groups of organic farms, the crop farms were characterized by the smallest area of agricultural land (AL). The average area of AL in this group was about twice smaller than in the mixed and animal farms (Table 2).

The structure of land use in particular groups of farms reflected the dominant profile of their agricultural production. In crop farms permanent plantations and vegetables on arable lands dominated, while on animal farms meadows and pastures had a significant share. Permanent grasslands had in this group 32% share in the structure of the land use and it was almost 3 times higher than in the other two groups (Table 2). Soil quality in all groups of farms was similar. However, the productivity expressed in CUper ha of AL was quite diversified. The lowest productivity of 18.3 CU was identified in the crop farms, whereas in animal and mixed farms this value was higher and similar (Table 2). The low productivity on the vegetable farms was a consequence of low yields of vegetables and berry crops, mainly strawberries and raspberries.

The structure of crops on arable lands in particular groups of organic farms reflected the dominating profile of their agricultural production. On crop farms, almost half of the arable lands were covered by vegetables. Cereals dominated in the cropping structure of the animal and mixed farms. In contrast, in crop farms cereals accounted for less than 40% (Table 3). It is worth to indicate at over 10% share of buckwheat on arable lands in the crop farms. This cereal is becoming more and more popular among organic farmers, mainly due to the growing demand for products made from buckwheat, mainly groats, but also due to its phytosanitary properties. In all analyzed farms there was the lack of crops requiring the use of intensive technologies, i.e. sugar beet and rapeseed.

In the group of animal farms, mainly fodder species such as cereal mixtures, oat and triticale as well as mixtures of cereals and grain legumes were cultivated with a very small share of grain legumes cultivated in pure sowing. The livestock density expressed in the Livestock Units (LU) per 100 ha of AL was very diverse in the compared groups of organic farms. In the crop farms, where 7 ones did not keep farm animals at all, the livestock density was very low and amounted to less than 10 LU 100 ha^{-1} of AL (Table 4). In the group of farms with mixed production, the livestock density was close to the average for all farms. The highest livestock density, as expected, was found in the group of animal farms (65 LU ha^{-1} AL). The share of particular groups of animals in mixed and animal farms was at a very similar level.

Table 2. Key characteristics of three groups of organic farms
Tab. 2. Potencjał produkcyjny w trzech grupach gospodarstw ekologicznych

No.	Specification	Agricultural profile of farms		
		Crop	Mixed	Animal
1	Number of farms, of which	10	10	10
	stockless	*7*	*0*	*0*
2	Area of agricultural lands (AL) (ha/farm)	7.8	15.4	16.8
3	Share of arable lands (%)	49	78	67
4	Share of permanent plantations (%)	39	11	1
5	Share of premanent grasslands (%)	12	11	32
6	Soil quality index* (1 ha of IVa class = 1)	0.68	0.67	0.66
7	Agricultural production in CU ha/AL	18.3	30.8	32.0

* - soil quality index according to Main Statistical Office, 1 ha of arable lands of IVa class = 1

Source: own study / Źródło: opracowanie własne

Table 3. Cropping structure (in %) on arable lands in three groups of organic farms
Tab. 3. Struktura upraw (w %) na gruntach ornych w trzech grupach gospodarstwach ekologicznych

No.	Specification	Agricultural profile of farms		
		Crop	Mixed	Animal
1	Cereals – total	38.6	63.7	60.0
	of which:			
2	*Rye*	*5.1*	*12.9*	*10.9*
3	*Common wheat*	*0*	*3.9*	*6.0*
4	*Spelt wheat*	*0*	*1.1*	*0*
5	*Triticale*	*5.6*	*7.8*	*12.8*
6	*Barley*	*0*	*0*	*1.6*
7	*Oat*	*2.9*	*4.6*	*8.2*
8	*Mixture of cereals*	*13.9*	*29.1*	*20.4*
9	*Buckwheat*	*11.0*	*4.3*	*0*
10	Mixtures of cereals with grain legumes	8.4	5.1	21.3
11	Potato	1.2	4.4	3.8
12	Sugar beet	0	0	0
13	Grain legumes	2.5	4.9	0.9
14	Oilseed crops	0	0	0
15	Fodder crops	4.6	17.8	13.4
16	Vegetables	44.7	4.2	0.6

Source: own study / Źródło: opracowanie własne

Table 4. Livestock density and its structure in three groups of organic farms
Tab. 4. Obsada inwentarza żywego i struktura pogłowia w analizowanych grupach gospodarstw

No.	Specification	Agricultural profile of farms		
		Crop	Mixed	Animal
1	Livestock density in LU·100 ha^{-1} AL	9.8	48.6	65.4
2	Share of cattle in %	49.6	70.0	66.7
3	*of which cows in %*	*13.2*	*49.8*	*32.4*
4	Share of pigs in %	1.6	23.6	21.5
5	Share of goats and sheep in %	0	0	0
6	Share of poultry in %	0	4.1	6.0
7	Share of horses in %	48.8	2.2	5.8

Source: own study / Źródło: opracowanie własne

Cattle, mainly dairy cows, had about 70% share in the population structure of animals, while pigs accounted for approx. 20-25% of the total livestock population (Table 4). A definitely different structure of the share of particular groups of animals was recorded in the crop farms, where pigs were practically not kept, and the main direction in animal production was cattle for beef production and horses kept mainly for recreational purposes. Both of these groups of animals had a very similar share in the structure of the farm animal population.

3.2. Soil organic matter balance

SOM balance in all compared farms calculated on the basis of Körschens et al. [7] coefficients, taking into account the impact of arable crops as well as organic fertilizers, was positive and amounted to an average for 2 years of 1.69 t of dry matter (DM) · ha^{-1} of arable lands. This indicates the high potential of organic farms for the reproduction of organic matter and indirectly for its ability to sequester CO_2. However the compared groups of farms were

characterized by a very diversified balance of SOM (Table 5).

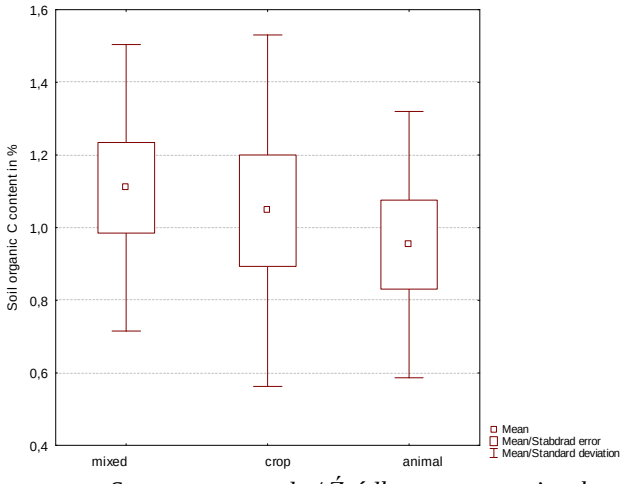
Table 5. Soil organic matter balance average for 2 years (in t DM·ha^{-1} of arable lands) in three groups of organic farms
Tab. 5. Bilans glebowej substancji organicznej (w t s.m.·ha^{-1} GO) w trzech grupach gospodarstw ekologicznych

Agricultural profile of farms	Impact of crops	Impact of organic fertilizers	**Balance**
Crop	-2.03	1.30	**-0.73**
Mixed	1.70	1.94	**3.64**
Animal	-0.35	2.62	**2.27**
Average	**-0.29**	**1.98**	**1.69**

Source: own study / Źródło: opracowanie własne

On farms specialized in crop production, especially in the production of vegetables, a negative balance of SOM, amounting to -0.29 t DM·ha^{-1} of arable lands, was calculated. This, in the long term, may lead to the increased mineralization of soil humus and decrease in soil fertility. It should be noted that the obtained result for this group could have been even less favorable, if not for that some of these farms purchased manure from the neighboring conventional farms, which is in accordance with official regulations on organic farming. In the studies conducted by Schultz et al. [17] it was shown a significant decrease in SOM content in the group of stockless organic farms with a high share of market crops and with no ley in the crop rotation. In this group of farms the content of SOM decreased significantly by as much as 8.4% compared to the initial value. In general, the positive balance of SOM in the group of mixed and animal organic farms was due to 15% share of fodder crops in the sowing structure (Table 3), as well as higher than in a crop farms livestock density (Table 4).

The organic carbon content in the soil is a good indicator of the status of SOM. The results of the soil analyzes did not show any statistically significant differences between the compared groups of farms (Fig. 1).



Source: own study / Źródło: opracowanie własne

Fig. 1. Soil organic carbon content (in %) in 3 groups of organic farms
Rys. 1. Zawartość węgla organicznego (w %) w 3 grupach gospodarstw ekologicznych

This content on an average for all farms amounted of 1.04% (Table 6). This value was lower as compared to the average contents for this type of soils ranging from 1.5 to 1.9% [18]. The lowest content of soil C_{org} was measured in the animal farms (Fig. 1) which is the opposite to the calculated value of soil organic matter balance (Table 5). The explanation for this might be the lowest value of soil quality index in the group of animal farms as given in Table 2.

3.3. Evaluation of soil pH and the content of phosphorus, potassium, magnesium in soil

In the majority of organic farms the content of phosphorus and magnesium was at or near optimal level (Table 6). On the other hand, the soil pH and potassium content was usually low, which would indicate a lack of sustainable calcium and potassium management (an important component especially in periods of drought) in the compared farms and would raise the need for application of potassium and calcium mineral fertilizers allowed in organic farming. In general, there were no statistically significant differences in the considered soil fertility coefficients between the compared groups of farms (Figs. 2-5, Table 6). The only statistically significant difference concerned the soil pH in the mixed and animal groups of farms (Fig. 2, Table 6).

The low soil pH found in the group of animal farms may have resulted from the lowest value of soil quality index as given in Table 2. compared to other groups. In the majority of farms, soil pH (pH in KCl) was low (Fig. 2) and on average slightly over 5. It should be noted that in all farms sandy soils dominated. Nevertheless, with such a low pH, there is an urgent need for liming.

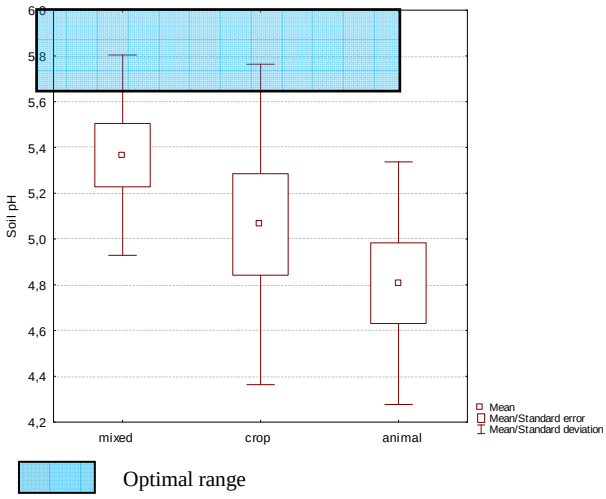


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Fig. 2. Soil pH (pH in KCl) in 3 groups of organic farms
Rys. 2. Odczyn gleby (pH w KCl) w trzech grupach gospodarstw ekologicznych

The average content of phosphorus in the soil in the compared organic farms amounted to about 11 mg of P_2O_5/100 g of soil (Table 6) and for all three groups it was within the range of optimal values (Fig. 3).

In the compared organic farms, the potassium content in the soil on average amounted to 8.68 mg K_2O · 100-1 g of soil (Table 6). For all farms it was slightly below the lower limit of the optimal range. In all three types of farms, the potassium content in soil was similar, however, in the crop farms the content was the highest (Fig. 4). It should be noted that in the crop farms there were several ones specializing in the cultivation of berry plants and vegetables.

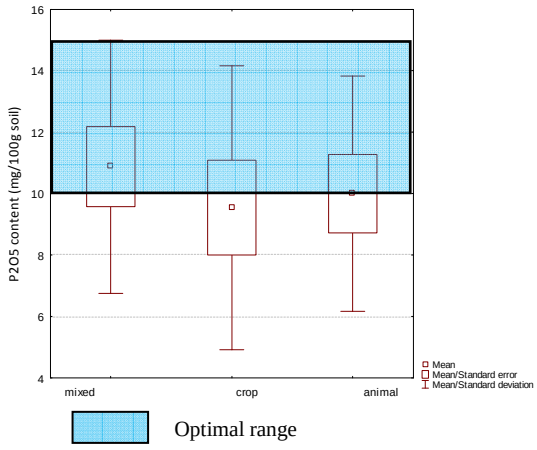
Table 6. Comparison of soil pH, the content of phosphorus, potassium, magnesium and organic carbon in soil in 3 groups of organic farms

Tab. 6. Porównanie odczynu, zasobności gleb w makroelementy oraz zawartości C org w trzech grupach gospodarstw ekologicznych

Agricultural production profile of the farms	pH in KCL	P_2O_5 (mg·100^{-1} g soil)	K_2O (mg100^{-1} g soil)	Mg (mg·100^{-1} g soil)	C org. (%)
Mixed farms	5.37a	10.88a	8.65a	6.66	1.11a
Crop farms	5.06ab	9.54a	8.90a	7.17	1.05a
Animal farms	4.81bc	10.00a	8.50a	6.64	0.95a
Mean	*5.08*	*10.84*	*8.68*	*6.82*	*1.04*
LSD	*0.39*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

Source: own study / Źródło: opracowanie własne

These farms quite often used their own organic fertilizers or manure from purchase, which finally could improve the soil's potassium content. The few results of foreign research [1, 3, 5] indicate that problems related to the maintenance of appropriate phosphorus and potassium level in the soil may appear in organic farms, especially located on light soils.



Source: own study / Źródło: opracowanie własne

Fig. 3. Content of phosphorus in soil (in mg P_2O_5/100 g of soil) in 3 groups of organic farms

Rys. 3. Zasobność gleby w fosfor (w mg P_2O_5/100 g gleby) w 3 grupach gospodarstw ekologicznych

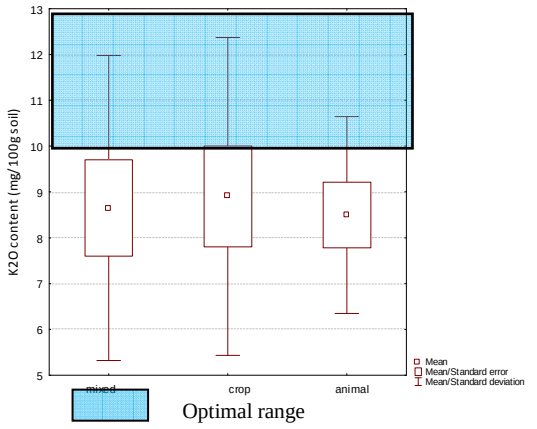


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Fig. 4. Content of potassium in soil (in mg K_2O /100 g of soil) in 3 groups of organic farms

Rys. 4. Zasobność gleby w potas (w mg K_2O/100 g gleby) w 3 grupach gospodarstw ekologicznych

In the compared organic farms, the average soil fertility in magnesium amounted to 6.82 mg Mg100g^{-1} of soil (Table 6). The highest was on the crop farms, while in the other two groups it was at a slightly lower and similar level. In each case, the average values were in the range of high content of this component. There was no low or very low magnesium concentration in the researched farms (Fig. 5).

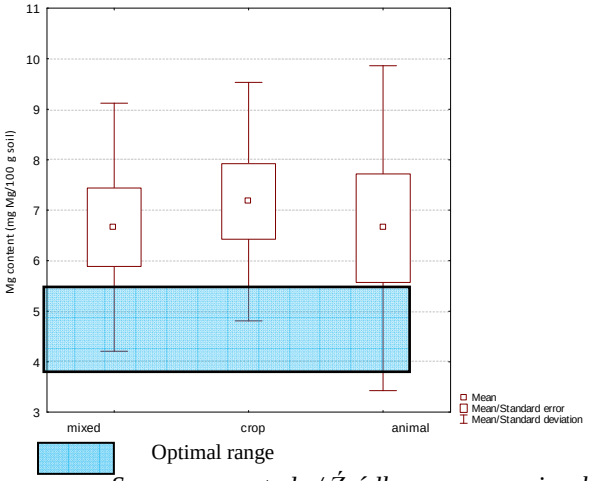

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Fig. 5. Content of magnesium in soil (in mg Mg /100 g of soil) in 3 groups of organic farms

Rys. 5. Zasobność gleby w magnez (w mg Mg·100^{-1} g gleby) 3 grupach gospodarstw ekologicznych

4. Conclusions

1. On average for 2 years, the balance of soil organic matter in the organic farms was positive and amounted to 1.67 t of DM/ha of arable lands. The negative value of this indicator was recorded only for a group of farms, usually stockless, specialized in crop production.
2. There were no statistically significant differences between the compared groups of farms in soil organic carbon, phosphorus, potassium, magnesium content and soil pH. The only statistically significant difference concerned the soil pH between the group of farms with mixed and animal production.
3. The results of chemical analyzes showed low soil pH and potassium content in soils in all three groups of organic farms.
4. A specialization in organic agricultural production towards crop production may lead to problems with maintaining the appropriate content of soil organic matter.

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The study was conducted under the statutory project of IUNG-PIB no 3.07 "Evaluation of nutrient management and soil fertility in organic farms of different production profiles" (2010-2013).
Badania zostały sfinansowane z tematu z działalności statutowej IUNG-PIB nr 3.07 „Ocena gospodarki nawozowej i żyzności gleby w gospodarstwach ekologicznych o różnym kierunku produkcji" (2010-2013).