Hanna SULEWSKA[1], Karolina RATAJCZAK[1], Jan PIEKARCZYK[2], Alicja NIEWIADOMSKA[3]
[1] Uniwersytet Przyrodniczy w Poznaniu, Katedra Agronomii
ul. Dojazd 11, 60-632 Poznań, Poland
[2] Uniwersytet Adama Mickiewicza, Instytut Geografii Fizycznej i Kształtowania Środowiska Przyrodniczego
[3] Uniwersytet Przyrodniczy w Poznaniu, Katedra Mikrobiologii Ogólnej i Środowiskowej
e-mail: sulewska@up.poznan.pl

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CHANGES OF SELECTED PHYSICAL SOIL PROPERTIES UNDER MAIZE GROWN FOR SILAGE IN MONOCULTURE AS A RESULT OF INTRODUCTION OF INTERCROP, STRAW OR NATURAL FERTILIZERS

Summary

In the years 2005-2008, the trials were established on two soils, rye and wheat complexes in Swadzim, in the fields of the Experimental and Didactic Station Gorzyń, of the Poznań University of Life Sciences. The purpose of the study was to determine changes in selected physical properties of soils under the influence of natural fertilizers, straw or winter intercrop under maize grown for silage in monoculture. It has been shown that the use of slurry on class IIIa soil has reduced soil compactness in all studied layers. The plowing of winter intercrop on both soil classes led to their drying, especially on the lighter soil. Systematic fertilization of straw with slurry of class IIIa soil, and on the IVb soil with a full dose of manure, slurry with straw and winter intercrop increased the field water content of the soil. Lower volumetric density was observed on class IIIa soil after plowing the full dose of manure, and on class IVb soil after the use of winter intercrop.
***Key words**: silage maize, monoculture, natural fertilizers, rye straw, winter catch crop, physical soil properties*

ZMIANY WYBRANYCH WŁAŚCIWOŚCI FIZYCZNYCH GLEBY POD KUKURYDZĄ UPRAWIANĄ W MONOKULTURZE NA KISZONKĘ, JAKO SKUTEK WPROWADZENIA MIĘDZYPLONU, SŁOMY LUB NAWOZÓW NATURALNYCH

Streszczenie

W latach 2005-2008 w Swadzimiu, na polach Zakładu Doświadczalno-Dydaktycznego Gorzyń, należącego do Uniwersytetu Przyrodniczego w Poznaniu, przeprowadzono badania na dwóch kompleksach glebowych, żytnim i pszennym dobrym. Celem badań było określenie zmian wybranych właściwości fizycznych gleb pod wpływem stosowania nawozów naturalnych, słomy bądź międzyplonu ozimego pod kukurydzą uprawianą na kiszonkę w monokulturze. Wykazano, że stosowanie gnojowicy na glebie klasy IIIa zmniejszało zwięzłość gleby we wszystkich badanych warstwach. Przyorywanie poplonu ozimego na obu klasach gleby prowadziło do jej przesuszania, szczególnie wyraźnego na glebie lżejszej. Systematyczne nawożenie słomą z gnojowicą gleby klasy IIIa, a na glebie klasy IVb pełną dawką obornika, słomą z gnojowicą oraz poplonem ozimym zwiększało polową pojemność wodną gleb. Gleba klasy IIIa po przyorywaniu pełnej dawki obornika natomiast gleba klasy IVb po stosowaniu poplonu ozimego charakteryzowały się mniejszą gęstością objętościową.
***Słowa kluczowe**: kukurydza na kiszonkę, monokultura, nawozy naturalne, słoma żytnia, międzyplon ozimy, właściwości fizyczne gleb*

1. Introduction

The key issues in modern agriculture have assumed the reduction of production costs and the protection of soil [9]. Man is putting a lot of pressure on the environment, using simplified rotation and other technologies which expansion is increasingly aggressive [7]. Maize, due to the increasing intensity of its growing and the lack of integrated crop rotation requirement, occupies a key place among plants often grown in monoculture. The decrease of microbial activity of the soil occurring in such fields as a result of deterioration of the phytosanitary conditions of the soil and a significant degradation of microbial life in it [1, 7, 18] negatively affects the stability of soil aggregates, decreasing their physical and water properties [7]. In addition, in Poland light and very light soils account for more than 60% of mineral soils and contain less than 2% of humus in the arable layer, hence the introduction of plant residues or natural fertilizers that are the main source of organic matter [5] becomes very important. Besides the growth of organic matter and humus, they also strongly affect the physical properties of the soil (loosening the soil, improving the structure) as they increase soil fertility and reduce weed infestation, as well as the intensity of diseases and pests.

The aim of the study was to determine changes in selected physical properties of soils under the influence of natural fertilizers, straw or winter intercrop under maize cultivated in monoculture. These studies were carried out on the soils of two quality classes IIIa and IVb.

In the research hypothesis, it was assumed, that the introduction of natural fertilizers, straw or intercrop would improve the selected physical properties of soils used in the multi-annual maize monoculture, thereby reducing the negative effects of such cropping system.

2. Material and methods

The research was carried out in the years 2005-2008 on the soil of class IVb, good rye complex in Gorzyń Experimental and Didactic Department, Swadzim University of Life Sciences in Poznan and in 2006-2008 on soil class IIIa, good wheat complex, of the field at a distance of 1250 m from the farm. The content of available forms of nutrients in the tested soils is presented in Table 1.

Tab. 1. Content of available forms of nutrients in the tested soils ($mg \cdot kg^{-1}$soil)
Tab. 1. Zawartości przyswajalnych form składników w badanych glebach ($mg \cdot kg^{-1}$gleby)

Soil class	P	K	Mg	pH
IV b	33.2-41.5	111.2-117	58.5-60.3	5.9-6.2
III a	56.3-63.7	117.9-166	30.8-37.4	6.9-7.0

Source: own study / Źródło: badania własne

The study covered the soil where maize for silage was grown, using the following fertilizer combinations annually: a) control (130 kg N, 34.9 kg P, 116.2 kg $K \cdot ha^{-1}$, b) manure (30 $t \cdot ha^{-1}$, d) straw + N_{min} (5 $t \cdot ha^{-1}$ + 5 kg $N_{min} \cdot 1 \cdot t$ straw), e) straw + slurry ($t \cdot ha^{-1}$ + 40m^3, f) intercrop of winter rye with vetch (10-15 $t \cdot ha^{-1}$), g) slurry (40 m^3). All objects were additionally fertilized with NPK, which was balanced with control object, taking into account the content of the nutrients and their availability in the first year after plowing. Cultivation treatments were carried out in accordance with the principles of good practice for silage corn. The following soil properties were analyzed: density, volume humidity, field water content and soil compaction. Physical properties of the soil were determined in full vegetation stage of maize plants. The soil temperature was measured in all three replicates of each object at depths of 10 cm and 20 cm using TESTO soil thermometers.

In spring, before the emergence of plants, soil samples were taken from each plot to determine the volume density. A special set was used to obtain unbroken soil, consisting of a hammer and a non-shaking sampler, and 100 cm^3 cylinders with two removable lids. The samples were weighed and dried at 105 °C and then weighed again. The volume density calculation was done using the formula:

$$\rho_{vol} = \frac{b-a}{V_c} (g/cm^3)$$

where:
ρ_{vol} – volume density
b – weigh of cylinder with soil and bottom lid
a – weigh of empty cylinder with bottom lid
V_c – cylinder volume

The soil volumetric humidity was determined by means of a dry-weight method, which determined the difference between the weight of the wet soil sample and its dry mass according to the following formula:

$$W_{vol} = \frac{G_W - G_S}{V} \times 100(\%)$$

W_{vol} – soil moisture in volumetric percentage
G_w – weight of wet soil (g)
G_s – weight of dry soil (g)
V – soil volume (cm^3)

The study was based on the assumption that capillary water, regardless of gravity, moves in all directions and is the main source of water for plants. Field water capacity was determined by the method of water ascension. On the Petri dishes there were placed cylinders with soil dried in 105°C, of unbroken structure, wrapped with stripes of tissue paper of width and length to allow them to wrap. Subsequently, the dishes were placed in cuvettes with water filled to a level that prevented it from pouring into the inside of the dishes, and at the same time allowed the water to be absorbed through the submerged ends of the paper to the parts inside the Petri dish where the soil cylinders were placed with the top lid. After 48 hours of soaking and full saturation of capillary spaces with water, the cylinders were weighed. Based on the obtained results, the maximum capillary water capacity was calculated according to the formula:

$$PPW = \frac{g_w - g_s}{g_s} \times 100\%$$

where:
PPW – capillary water capacity
g_w – soil saturated with capillary water
g_s – soil dried at 105˚C

The compactness of the soil was assessed by the Ejkelkamp hand penetrometer, at depths of 0-10 cm, 10-20 cm and 20-30 cm. The obtained results are presented as the compactness of soil - expressed in MPa resistance.

The results of all tests were statistically analyzed by ANOVA variance analysis for one-factorial experiments in four field repetitions, assuming significant differences at significance level of $p \leq 0.05$.

3. Results

Application of natural fertilizers, straw and intercrops significantly differentiated the compactness of soil in all layers (Table 2). The highest compactness was in the deepest analyzed layers, 20-30 cm, which compactness was more than double that of upper layers and averaged 2.8 MPa on class IIIa soil and 3.7 MPa on lighter soil. Class IIIa soil, regardless of the depth of the analysis, was less compact than that of class IVa soil.

It was found significant influence of the tested fertilization combinations on the compactness of soil class IIIa in the studied layers. In the 0-10 cm layer, the least resistance was found into the soil after application of slurry (1.0 MPa) and winter intercrop of rye with vetch (1.1 MPa), which was also positively influencing lighter soil (0.9 MPa). A different reaction was observed on the soil of class IVb, where the annual application of 40 $m^3 \cdot ha^{-1}$ of slurry led to a statistically significant increase in its compactness compared to the control amounting 0.5 MPa. On class IIIa soil significant growth was observed for layer 10-20 cm after plowing down winter intercrop and 30 tons manure and straw with slurry compared to control compactness. On the other hand, the introduction of slurry significantly reduced soil resistance in this layer. On the soil of class IVb only the plowing of straw with the addition of mineral N tended to decrease the compactness compared to control. Other fertilization variants contributed to a statistically significant increase in soil compactness, the strongest when slurry was applied.

Evaluation of soil compactness in the 20-30 cm layer showed higher values for lighter soil, class IVb. On the soil of class IIIa there was a decrease in compactness following the introduction of straw with slurry and slurry itself. In turn, in experiments on the soil of class IVb, such a response was obtained after ploughing down the manure in both doses and slurry with straw. Significant increase in soil compactness compared to control was observed in both locations after ploughing down the aftrecrop of winter rye with vetch.

The moisture content of the soil, just prior to the emergence of plants, illustrates the effect of tested fertilizer combinations on water retention and the potential amount of water available in the soil for the plants. There were differences in soil moisture content depending on the soil class and a lower value was recorded on the soil of class IVb. The application on the IIIa class soil of both manure doses and straw with the addition of mineral N, significantly increased its moisture content. On the other hand, the application of straw with slurry, winter intercrop and slurry, significantly reduced this value. On soil IVb, a positive effect was observed on the soil saturation with water when fertilized with a full dose of manure, slurry with straw and slurry, and all these values were significantly higher than control.

Research has shown the significant effect of natural and organic fertilization on the field water capacity on tested soils (Table 3). On the soil of class IIIa, the beneficial effect of straw with added slurry was noted, and in the IVb soil a full dose of manure, winter intercrop and straw with slurry.

On soil of class IIIa, the introduction of each of the tested fertilizers caused a decrease of the soil volume density (Table 3), but the decrease in value compared to the control was only proved for both manure doses. On the IVb soil, the use of winter intercrop reduced the volume density compared to the control.

The soil temperature over the whole corn growing season depended on the phase in which the measurements were made, the type of fertilizer and the soil class (Tables 4, 5). Before sowing maize seeds on class IIIa soil, the ploughing of each of tested fertilizers led to increase in soil temperature at 10 cm depth compared to control, while on the IVb soil, on the contrary, led to a significant decrease in soil temperature, except for the objects on which straw with mineral nitrogen were plowed, and the temperature decrease compared to control was not significant and amounted to 0.2°C and 0.1°C, respectively.

Table 2. Soil compactness (MPa) in tested layers depending on applied fertilization and soil class
Tab. 2. Zwięzłość gleby (MPa) w badanych warstwach w zależności od stosowanego nawożenia i klasy gleby

Object	Soil class IIIa			Soil class IVb		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Control - NPK	1.4a	1.7b	2.7c	1.6b	2.0c	3.8b
Manure 30 $t \cdot ha^{-1}$	1.3a	1.9a	2.9b	1.3c	2.3b	3.5c
Manure 15 $t \cdot ha^{-1}$	1.3a	1.7b	2.9b	1.4c	2.3b	3.4cd
Staw +N min	1.3a	1.6b	2.8bc	1.6b	1.9c	4.0a
Straw + slurry	1.3a	1.8a	2.4d	1.1d	2.2bc	3.3d
Winter intercrop	1.1b	1.9a	3.2a	0.9e	2.4ab	4.0a
Slurry	1.0b	1.4c	2.4d	2.1a	2.5a	3.8b
Average	1.2	1.7	2.8	1.4	2.2	3.7

Source: own study / Źródło: badania własne

Table 3. Soil moisture (%) during plants' emergence, field water capacity (PPW) and volumetric density ($g \cdot cm^{-3}$) depending on applied fertilization and soil class
Tab. 3. Wilgotność gleby w okresie wschodów roślin kukurydzy (% obj.), polowa pojemność wodna (PPW) oraz gęstość objętościowa ($g \cdot cm^{-3}$) w zależności od stosowanego nawożenia i klasy gleby

Object	Soil class IIIa			Soil class IVb		
	Moisture %	PPW	Volumetric density ($g \cdot cm^{-3}$)	Moisture %	PPW	Volumeetric density ($g \cdot cm^{-3}$)
Control - NPK	20.8b	26.0b	1.72a	17.8b	25.9b	1.63a
Manure 30 $t \cdot ha^{-1}$	21.0a	26.6b	1.61b	19.3a	27.8a	1.63a
Manure 15 $t \cdot ha^{-1}$	21.6a	25.3b	1.67b	17.8b	25.7b	1.60a
Staw +N min	21.4a	24.8c	1.68a	17.8b	25.7b	1.67a
Straw + slurry	20.1b	27.2a	1.71a	18.9a	27.2a	1.61a
Winter intercrop	20.1c	24.9c	1.69a	15.3c	27.1a	1.56b
Slurry	20.1b	25.8b	1.71a	18.8a	25.3b	1.66a
Average	20.7	25.8	1.68	18.0	26.4	1.62

Source: own study / Źródło: badania własne

Table 4. Soil temperature (ºC) at 10 cm depth depending on maize development phase and fertilization applied on soil class IIIa
Tab. 4. Temperatura gleby (ºC) na głębokości 10 cm w zależności od fazy rozwojowej kukurydzy i stosowanego nawożenia na glebie klasy IIIa

Object	Before sowing	Emergence	3-4 leaves	6-7 leaves	Tillering	Wax maturity	Average
Control - NPK	16.8b	23.6b	27.4bc	27.4a	18.3a	16.6a	21.68ab
Manure 30 $t \cdot ha^{-1}$	17.3ab	23.7ab	27.1c	27.2a	18.3a	16.4ab	21.67ab
Manure 15 $t \cdot ha^{-1}$	17.1b	23.5b	26.7d	27.6a	18.2a	16.1b	21.53b
Staw +N min	17.8a	23.9a	28.1a	27.5a	18.3a	16.3b	21.98a
Straw + slurry	17.5a	23.9a	27.7ab	27.6a	18.2a	16.4ab	21.88ab
Winter intercrop	17.2b	23.5b	27.6b	27.1a	18.0b	16.3b	21.62ab
Slurry	17.3ab	23.9a	26.9c	27.1a	18.0b	16.5a	21.62ab
Average	17.3	23.7	27.4	27.4	18.2	16.5	21.75

Source: own study / Źródło: badania własne

Table 5. Soil temperature (ºC) at 10 cm depth depending on maize development phase and fertilization applied on soil class IVb
Tab. 5. Temperatura gleby (ºC) na głębokości 10 cm w zależności od fazy rozwojowej kukurydzy i stosowanego nawożenia na glebie klasy IVb

Object	Before sowing	Emergence	3-4 leaves	6-7 leaves	Tasseling	Wax maturity	Average
Control - NPK	15.4a	19.3b	26.7a	23.1a	19.0b	16.6bc	20.02c
Manure30 $t{\cdot}ha^{-1}$	15.1b	19.5b	26.7a	23.4a	19.1b	16.7bc	20.08c
Manure15 $t{\cdot}ha^{-1}$	14.9c	19.5b	26.3a	23.0a	18.9b	16.8b	20.73b
Staw +N min	15.2ab	19.5b	26.5a	23.4a	19.0b	16.5c	20.02c
Straw + slurry	15.1b	19.6ab	27.0a	23.1a	19.4a	16.9b	21.03ab
Winter intercrop	15.3a	19.6ab	27.0a	23.3a	18.9b	16.7bc	20.94b
Slurry	15.1b	19.8a	26.7a	23.4a	19.6a	17.4a	21.21a
Average	15.2	19.5	26.7	23.2	19.1	16.8	20.08

Source: own study / Źródło: badania własne

Table 6. Soil temperature (ºC) at 20 cm depth depending on maize development phase and fertilization applied on soil class IIIa
Tab. 6. Temperatura gleby (ºC) na głębokości 20 cm w zależności od fazy rozwojowej kukurydzy i stosowanego nawożenia na glebie klasy IIIa

Object	Before sowing	Emergence	3-4 leaves	6-7 leaves	Tasseling	Wax maturity	Average
Control - NPK	13.9c	20.9a	25.2a	25.5ab	17.6ab	15.7a	19.8a
Manure30 $t{\cdot}ha^{-1}$	14.3b	20.6ab	24.6b	25.3b	17.7a	15.5a	19.7a
Manure15 $t{\cdot}ha^{-1}$	14.8a	20.4bc	24.4b	25.5ab	17.6ab	15.3a	19.7a
Staw +N min	14.4b	20.5bc	24.9ab	25.6a	17.6ab	15.4a	19.7a
Straw + slurry	14.2b	20.6ab	24.5b	25.2b	17.6ab	15.5a	19.6a
Winter intercrop	14.2b	20.2c	24.7ab	25.4ab	17.4b	15.5a	19.6a
Slurry	14.6ab	20.7a	24.1b	25.1b	17.5b	15.5a	19.6a
Average	14.3	20.6	24.6	25.4	17.6	15.5	19.7

Source: own study / Źródło: badania własne

Table 7. Soil temperature (ºC) at 20 cm depth depending on maize development phase and fertilization applied on soil class IVb
Tab. 7. Temperatura gleby (ºC) na głębokości 20 cm w zależności od fazy rozwojowej kukurydzy i stosowanego nawożenia na glebie klasy IVb

Object	Before sowing	Emergence	3-4 leaves	6-7 leaves	Tasseling	Wax maturity	Average
Control - NPK	12.6a	16.7bc	24.3a	22.9b	18.2c	15.5c	18.4bc
Manure 30 $t{\cdot}ha^{-1}$	12.5a	16.7bc	23.7b	23.4a	18.2c	15.5c	18.3c
Manure 15 $t{\cdot}ha^{-1}$	12.4a	16.7bc	23.6b	22.8b	18.1cd	15.4c	18.2c
Staw +N min	12.5a	16.8b	24.3a	23.4a	18.1cd	15.4c	18.4bc
Straw + slurry	12.4a	16.8b	24.4a	23.0b	18.4b	15.8b	18.5b
Winter intercrop	12.5a	16.6c	24.4a	23.2ab	18.0d	15.5c	18.4bc
Slurry	12.7a	17.2a	24.2a	23.5a	18.8a	16.4a	18.8a
Average	12.5	16.8	24.1	23.2	18.3	15.6	18.4

Source: own study / Źródło: badania własne

It has been shown that the use of manure, straw with additional N mineral and slurry application on class IIIa soil resulted in soil temperature increase before maize sowing (Table 6). The applied fertilization variants on class IVb soil did not cause significant changes in the soil temperature measured before planting at a depth of 20 cm. On all objects, except for slurry, there was a tendency to decrease this temperature (Table 7).

4. Discussion

The physical properties of the soils of the two locations were modified in various ways by the fertilization variants. Regardless of the depth of measurement, it was shown that class IIIa soil was characterized by lower compactness than class IVb soil. Moreover, regardless of the type of soil, the tendency to increase the compactness of the soil, along with the increase in depth of measurement, has been shown. The use of most fertilization variants led to a reduction in the soil's compactness in its surface layer. The highest compactness was recorded in the layer of 20-30 cm on the objects after plowing the winter intercrop. The increase in resistance on the objects with intercrop was likely related to additional spring soil tillage. These tillage treatments required additional drives with the tractor, which caused the soil to be compacted, especially in the depth below the tool depth. Tendziagolska and Parylak [19] have shown that skimming and catch crops increase compactness of soil subsurface more than no tillage by up to 15.2%. In turn, Pengthamkeerati et al. [15] showed a decrease in soil compactness as a result of applied agrotechnology, organic fertilization and crop cultivation.

The addition of fresh organic matter decreases soil compactness, especially in its subsurface layer [6]. In our own experience it has been shown that the organic matter added to the soil and the tillage in the surface layer on the object with winter intercrop have loosened the soil particles. On the better soil, manure in full dose and intercrop increased soil resistance while slurry reduced it. Different results are presented by Buczyński et al. [2] who showed a very positive effect of manure applied annually, which loosened the soil much more intensively than agromeliorative doses of lime. Both classes of soil in the 20-30 cm layer showed increased compactness after plowing of winter intercrop. Rasool et al. [17] observed that the positive effect of natural fertilization on the compactness and density of soil is not limited only to the surface layers of the soil. Manure, according to these authors, contributed to a decrease in soil density even to a depth of 65 cm. The compactness of the soil can have a significant effect on root penetration in both plough and no tillage systems, as it depends on the presence of pores in the soil sufficiently broad to accommodate and sufficiently long to ensure the development of long root systems [9]. Many soil researches have shown the increase in soil compactness in case of monoculture crops [4], traditional cultivation systems and direct sowing [20], as well as the related mechanization associated with it [2]. The compactness of the soil is largely dependent on its moisture content, but is also modified by growing crops and wheels of tilling machines [6].

The addition of organic matter can produce an increase in soil moisture. Own research has shown that the soil class has a significant influence on its moisture content measured during plant growth. Class IVb soil was characterized by lower water content compared to class IIIa soil. The negative impact of large amounts of green manure and straw is known to cause the formation of an insulating layer that impedes soil permeability. On the better soil, increase in water content was achieved by plowing manure and straw with nitrogen, whereas on lighter soil the increase in humidity was observed following the application of the full dose of manure, slurry straw and slurry itself. According to Buczyński et al. [2] organic/natural fertilization, especially manure, limits or even completely reduces negative physical processes in soil by loosening the soil to ensure a higher humidity of the tillage layer. Spring ploughing of winter intercrop on both soil classes significantly reduced soil volumetric moisture. It can be assumed that spring tillage treatments on these objects led to soil over-drying and limiting of natural capillary soaking, especially in the early intercrop post-ploughing period. It is known unfavorable effects of catch crop ploughing during spring, especially in dry years, when large amounts of fresh matter entering the soil disturb the water balance in the soil. Tendziagolska and Parylak [19] and Czyż [3] reported that the simplification and reduction of the number of tillage treatments in the soil, result in higher soil moisture. Buczyński et al. [2], Marks et al. [10] emphasized the effect of soil compaction and the disturbance of its structure caused by the wheels of soil tillage machinery, which results in a deterioration of the soil moisture conditions.

Field water capacity is a size that informs about the potential of the soil to meet water needs of plants. The higher it reaches the value, the more the soil can accumulate. On the soil of the wheat complex, ploughing of straw with slurry contributed to the increase of field water capacity, whereas plowing of winter intercrop and straw with mineral N significantly reduced it. Piechota et al. [16] proved the beneficial effect of manure on increasing the capillary water capacity by over 8% and the general soil porosity. Rasool et al. [17] have shown that both organic and mineral fertilization cause an increase in the water capacity of the soil and, in the case of organic fertilization, the positive effect was significant and became more visible as the depth of measurement increased. In turn Majchrzak et al. [18] have shown a decrease in capillary water capacity on objects with simplified tillage and direct sowing.

According to Piechota [16], monoculture caused the increase in soil volumetric density. In turn, Parylak et al. [14] showed insignificant and non-directional changes in volumetric soil density in monocultures. According to these authors, the volumetric density variation is due to the densification of the soil solid phase and the change in soil pore volume. These authors emphasize that the content of organic matter is one of the factors influencing the size of this parameter. In our own trial carried out on class IIIa soil it has been shown that ploughing of manure, independently from the dose, decreased the soil density, while in a lighter soil a similar relationship was observed after the ploughing of winter intercrop. It was also found that the application of straw with mineral N straw led to increase of soil volumetric density compared to control. Similarly, Mosaddeghi et al. [13] showed a decrease in volumetric density after application of manure. Also Mercik et al. [11] found a significant decrease in volumetric density in fields where manure was applied regularly or where legumes were in the rotation. Parylak et al. [14] on the contrary have shown that intercrops and straw can cause the decrease of soil volumetric density. Czyż [3] shown that direct sowing in a three-year corn monoculture caused an increase in soil volumetric density in the upper layer, mainly at a depth of 0-10 cm compared to traditional soil tillage in both monoculture and rotation.

The tillage system and the amount of plant residues on the soil surface modify the rate of its warming up [3, 18]. As the vegetation progresses, the differences in temperature resulting from the growing system and the accumulation of organic matter in the surface layers of the soil disappear. In own trials, the spring temperature measurements right before the sowing maize, on the lighter soil, showed that besides the objects fertilized with straw and mineral N, soil temperature in the surface layer was significantly lower than in the control. It was also found that the temperature decreased after ploughing of winter intercrop on both soil classes. On the IVb soil the plowing of all fertilizers caused an increase in soil temperature measured at a depth of 10 cm. Czyż [3] showed the relationship between soil temperature and yield level. An increase in soil temperature after application of straw with mineral N, slurry straw and slurry was confirmed in both soil classes, also in the corn emergence phase. Numerous authors report limiting influence of low soil temperatures on the uptake of nutrients by young maize plants, especially phosphorus [12]. In addition, at the temperature of 10-15°C the initial development of maize slows down. On the other hand, the increase in temperature results in rapid plant regeneration, but for some time they show a slower rate of leaf growth and accumulation of dry matter. Maize, after disappearing of unfavorable conditions for its development may catch up with faster development in subsequent growth stages. In our own research in later phases of maize development, the effect of different fertilization on soil temperature disappeared. It has been observed from the tasseling phase that some of the fertilizer objects showed lower temperatures than controls. Such a phenomenon was found after plowing of winter intercrop and slurry on class IIIa soil, whereas on soil class IVb, the use of slurry and slurry with straw caused warming of the soil.

5. Conclusions

1. The compactness of the soil in all studied soil layers was higher on the IVb class than the IIIa class, by 0.2, 0.5 and 0.9 MPa, respectively. The application of slurry on class IIIa soil reduced the compactness of soil in all tested layers. On the other hand, on the soil of class IVb no fertilizer can be identified, which would have a similarly loosing effect in each of the analyzed layers.

2. Soil moisture of class IIIa was 2.7% points higher than that of class IVb soil. The ploughing of winter afercrop on both soil classes led to their drying, especially on the lighter soil.
3. The field water capacity of class IVb soil was higher than class IIIa. Significant increase in field water capacity compared to control on class IIIa soil was obtained after systematic application of straw with slurry, and on the IVb soil full dose of manure, slurry with straw and winter intercrop.
4. Soil volumetric density of class IIIa was higher than that of class IVb. Application of each of tested fertilizers reduced the value of this feature on class IIIa soil, and on soil IVb except for the application of straw with mineral N. The most favorable changes on the IIIa soil in this regard occurred after ploughing of the full dose of manure and on the soil of class IVb after application of winter intercrop.
5. The soil temperature at a depth of 10 cm, measured before sowing and in the initial growth phases of the plants, was higher on the soil of class IIIa than on IVb. The application of each of tested fertilizers tested on class IIIa soil led to an increase in the soil temperature determined prior to maize sowing, the largest at the object with ploughing of straw with mineral N. On the other hand, on the soil of class IVb, the effect of using organic matter was unfavorable in this regard.

6. References

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