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EFFECT OF STRAW AND SOIL TILLAGE WITH THE APPLICATION OF EFFECTIVE MICROORGANISMS ON SOIL MOISTURE AND COMPACTION FOR WINTER WHEAT MONOCULTURE

Summary

The effect of using straw and the application of effective microorganisms on soil moisture and compaction in plowing tillage and direct sowing is presented. Data were collected during the spring growing season during the three-year monoculture of winter wheat. Soil moisture and compaction at four levels to a depth of 40 cm were measured. Plowing tillage in comparison to direct sowing resulted in a reduction of average soil moisture at all depths, and soil compaction at the 10-40 cm levels. The application of effective microorganisms in plowing tillage caused an increase in soil compaction at all depths and moisture content of the deepest layer. The effective microorganisms used in direct sowing resulted in higher moisture content primarily in the surface layer. The use of straw did not affect significantly soil moisture but resulted in a reduction in compaction under direct sowing conditions. Straw, soil tillage method, application of the effective microorganisms and the interaction among those factors significantly affected soil moisture and compaction. The influence of the effective microorganisms on soil moisture is the most significant in plowing tillage, while the effect of straw on soil compaction is the most evident for direct sowing.
***Key words**: soil moisture, soil compaction, monoculture, winter wheat, soil tillage, straw*

WPŁYW SŁOMY I UPRAWY ROLI Z APLIKACJĄ EFEKTYWNYCH MIKROORGANIZMÓW NA WILGOTNOŚĆ I ZWIĘZŁOŚĆ GLEBY W MONOKULTURZE PSZENICY OZIMEJ

Streszczenie

Właściwości fizyczne gleby są ważnym czynnikiem produkcyjności roślin. W trzyletniej monokulturze pszenicy ozimej określono wpływ stosowania słomy oraz zróżnicowanej uprawy roli (uprawa płużna, siew bezpośredni) wraz z aplikacją efektywnych mikroorganizmów na wilgotność i zwięzłość gleby do głębokości 40 cm w okresie wiosennej wegetacji. Wilgotność i zwięzłość wierzchnich warstw gleby do głębokości 20 cm były bardzo zmienne w czasie i silnie ujemnie ze sobą skorelowane. Stosowanie słomy nie wpłynęło istotnie na wilgotność gleby, spowodowało natomiast zmniejszenie jej zwięzłości w warunkach wykonywania siewu bezpośredniego. Płużna uprawa roli w porównaniu z siewem bezpośrednim spowodowała zmniejszenie średniej wilgotności gleby do głębokości 40 cm, a zwięzłości gleby na głębokości 10-40 cm. Wnoszenie efektywnych mikroorganizmów do gleby uprawianej płużnie wywołało tendencję wzrostu zwięzłości wszystkich jej warstw do głębokości 40 cm, a wilgotności zwłaszcza warstwy najgłębszej – 30-40 cm. W przypadku siewu bezpośredniego efektywne mikroorganizmy nie spowodowały wzrostu zwięzłości gleby, a większa wilgotność wystąpiła głównie w warstwie powierzchniowej.
***Słowa kluczowe**: wilgotność gleby, zwięzłość gleby, monokultura, pszenica ozima, uprawa roli, słoma*

1. Introduction

The physical properties of soil can affect its microbiological activity as well as the quantity and transformations of organic matter, which are critical factors shaping the production potential of soil [23, 31, 42]. Soil properties are the product of pedogenesis, and depend on the mineralogy and particle-size distribution of the soil as well as on the topography, ground water level and climatic conditions. Agriculture also contributes, especially those factors involved in the production of plants: crop rotation, fertilization and tillage [4, 7, 33].

The organizational and economic considerations of modern agriculture promote simplification of the classic elements of agricultural practices, both with regard to soil tillage and crop rotation [2, 32]. Rotations of crop are short, with 2-3 plants or even monocultures. Crop structure is dominated by cereals whose cultivation results in a negative organic matter balance in the soil [11]. The production and application of natural fertilizers is on the decrease, while cereal biomass, straw and other types of biomass are becoming common energy sources [3, 39]. Simplification in soil tillage refers to the elimination of plowing, shallower tillage, tool aggregation or fully abandoning tillage and substituting it with direct sowing [36]. In addition to the economic aspect, the field production of plants has an environmental aspect that should help to eliminate the adverse effects of climatic changes and extreme weather phenomena. In Central Poland such phenomena include a decreasing precipitation trend and ground water deficit. This leads to a process of organic matter mineralization dominating the process of humification and a decrease in the organic matter content of soils [27]. Maintaining the content of organic carbon in farming soils requires a continuous supply of organic matter and an increase in moisture content. Under conditions of intensive farming, mulch such as cereal straw can play that role. Plant biomass left on the field has a beneficial effect on the retention of water in the soil, depending on the physical and chemical properties and degree of decomposition [15]. The microbiological activity of soil is determined by air and water conditions [29], and straw mulch not only improves soil properties but also increases the length, volume, weight and density of the plant roots [9].

The results of previous research indicate that the introduction of straw or other sources of organic carbon to the soil increases the biological activity of the soil and reduces the loosening of the soil during tillage, which can help to achieve the environmental and production goals of plant production in the field [1, 8, 21, 37, 41]. The elimination of tillage and direct sowing both have beneficial effects for the biological, chemical and physical properties of the soil, especially when the crop residue is left on the field following the harvest of the forecrop [6, 13, 17, 25, 38, 40]. Reducing the number of soil loosening treatments can, however, cause compaction, a decrease in rainwater filtering [21], as well as limitations in sprouting and the growth of plant root systems [12, 18]. The structure of the root system is crucial for water and nutrients acquisition by plants and their productivity [9]. Reduced root systems limit biomass production and plant yields [24]. Thus the hypothesis stating that "zero tillage" directly increases soil moisture content needs to be verified. Soil moisture can be higher due to the lower transpiration of plants producing less biomass. The results of previous research also do not offer a clear answer to the question as to whether microbiological preparations containing effective microorganisms (EM) applied to the soil have beneficial effects on the soil properties and health of plants, especially for winter wheat monocultures and under conditions of simplified tillage [5, 14, 43].

The purpose of the study was to determine the effect of straw and soil tillage with the application of effective microorganisms on soil moisture content and soil compaction in winter wheat monocultures.

2. Materials and Methods

The investigation of soil moisture content and compaction was carried out as part of a field experiment involving the three-year monoculture of winter wheat on a phaeozem soil in Chełmce, Kujawsko-Pomorskie province, northern Poland (52^{o}61'N; 18^{o}44'E). Soil texture is that of sandy silt, with the following fractions: sand (2.0-0.05 mm) - 46%; silt (0.05-0.02) - 15%; silt and clay fraction (<0.02) - 39% [26]. The whole field featured high uniformity of texture. The content of organic carbon in a soil sample taken directly prior to commencement of the study was 23.1 $g \cdot kg^{-1}$ of soil (Tiurin method: [10]), the content of available forms of P, K and Mg were, respectively, 161, 218, 48 $mg \cdot kg^{-1}$ of soil (Egner-Riehm method acc. to PN-R-04023:1996, PN-R-04022:1996 and Schucht Schabel method acc. to PN-R-04020:1994), and the pH_{KCl} value was 7.6 (PN-ISO 10390:1997). Every year the wheat was fertilized with phosphorus and potassium in the following amounts: 36 kg $P_2O_5 \cdot ha^{-1}$ and 92 kg $K_2O \cdot ha^{-1}$, applied on the forecrop stubble. Nitrogen fertilization in the order of 160 kg $N \cdot ha^{-1}$ was applied in spring in split doses.

The field experiment involved eight test objects, in a random sub-unit arrangement, in four repetitions: 32 test units, 32.0 m^2 each.

In order to reduce the effects of monoculture, straw was introduced to the soil every year, which constitutes factor one (two levels: disintegrated straw left on the field, without straw). Effective microorganisms (EM) were applied during soil tillage, which constitutes factor two (four levels: plowing tillage, plowing tillage+EM, no tillage – direct sowing, no tillage – direct sowing +EM). Measurement points for the determination of soil moisture content and compaction were determined, one per each object. Those features were measured at four soil levels: 0-10, 10-20, 20-30 and 30-40 cm. In the assessment of the results, this was considered to be factor three.

The plowing tillage of soil, carried out in September 2012, included post-harvest tillage with a grubber to a depth of 8-10 cm, pre-sow plowing to 20 cm and sowing using a tillage and sowing unit fitted with an active cyclotiller section and a sowing machine with disk coulters. Soil moisture content during soil tillage (10-20 cm layer) was in the range: 18.7 – 21.2%. Direct sowing was carried out in the stubble-field, using a Horsch Pronto 4DC sowing machine. The preparation containing the effective microorganisms, "EmFarma Plus^{TM}" by ProBiotics^{TM} Polska, was applied on the disintegrated straw or stubble-field, in the dosage recommended by the manufacturer, i.e. 40 $dm^3 \cdot ha^{-1}$, directly before post-harvest tillage or direct sowing.

In the autumn of 2012, after the emergence of the wheat, measurement points were determined in each object (8 in total), based on similarities in soil compaction and moisture content. In each a thin-walled tube was inserted to measure the soil moisture using a profile probe (PR2/4 Delta-T Devices LTD). This type of probe was chosen because of the convenient installation method in access tubes, low salinity and temperature sensitivity, low cost and ability to measure moisture content at four depths using a single device. The application of a TDR measurement system [34], although more accurate and not sensitive to soil salinity, would have been more expensive and more disruptive to soil profile. In spring 2013, between 17 April and 2 July, measurements of soil moisture content were carried out every 5-8 days (12 dates in total), at each point. On the same dates and at the same places (approx. 20 cm from the tubes), soil compaction was measured using a hand-operated hydraulic penetrometer (Eijkelkamp).

The results were statistically analysed using three-way ANOVA without replication. The data for the listings in tables 2 and 5 were prepared by adopting the following factors in ANOVA analysis: A – straw management method, B – soil tillage method, and C – soil layer. The statistical analysis of the data on the soil moisture content in the dynamic aspect (Fig. 1 and 2) was conducted by ANOVA analysis, with the following factors: A – straw management method, B – soil tillage method, and C – determination dates (12 levels). A separate analysis was conducted for each layer of soil. The Least Significant Difference (LSD) was determined for each significant factor and their interactions (Tukey test, p=0.05) in order to assess the significance of the average values of soil moisture content and compaction. As regards interactions, two LSD values were calculated for two directions: comparisons between values in columns and rows. In addition, the coefficients of soil moisture content and soil compaction variation (CV) were determined during the spring vegetation period of winter wheat under the effect of straw and diversified tillage of soil with the application of effective microorganisms. The CV coefficients were calculated according to formula (1):

$$CV = \frac{S}{\bar{x}} \cdot 100\%, \quad (1)$$

where S is the standard deviation and is the mean.

3. Results and Discussion

The total precipitation in the period preceding the investigation of soil moisture content and compaction approximated the many-year average value. In each decade, from January to the early second half of April, the rainfall was 2.3 to 18.8 mm (Table 1). Precipitation in May was higher than average and in June lower than average. The lowest total precipitation was observed in the first decade of May (4.6 mm) and in the second decade of June (2.1 mm).

Soil moisture content during the spring vegetation of winter wheat underwent significant changes, especially in the surface layer and the layers in which the major root mass was developing. A significant decrease in soil moisture content was observed in the 10-20 cm and 20-30 cm layers, irrespective of tillage method and use of straw, in the first and second decades of May and June (Fig. 1). A precipitation deficit was observed in the first decade of May and then in the second decade of June; this and the high transpiration of plants explains the relatively low soil moisture content. The straw and tillage method resulted in the smallest change in soil moisture content in the 10-20 cm layer, which is expressed in the closeness of the lines representing soil moisture content in this layer during the spring vegetation of winter wheat. Soil moisture content in the surface layer of the soil underwent the greatest change.

The effect of straw on soil moisture content was not large and, on average, not significant throughout the whole period (Fig. 1). It only increased the soil moisture content in the individual soil layers which were not tilled before sowing the winter wheat (direct sowing method) as compared with plowing tillage, but only at the beginning of the spring vegetation period. Later, the soil moisture content in soil with introduced straw and in soil without straw was similar for individual methods of tillage. Also Shen et al. [30] observed in corn crops that wheat straw mulch initially increased soil moisture content in the soil layer in the 20-80 cm layer, and that the beneficial effect improved with increases in straw quantity. However, the soil moisture content equalized after 50 days. A similar effect was observed in the present study, where winter wheat straw remaining on the soil surface increased water retention only during the beginning of the vegetation period. Soil moisture diversification under the effect of tillage occurred mostly in the surface layer (0-10 cm); it was smaller in the deepest layers (20-30 cm and 30-40 cm), and it was the least in the layer where the major root mass was developing (10-20 cm).

Direct sowing (no tillage) had a beneficial effect on soil moisture content, as compared with plowing tillage, especially in the surface layer. The application of the effective microorganisms reduced the adverse effect of plowing tillage on soil moisture content throughout the winter wheat vegetation period, mostly in the deeper layers. The effect of the effective microorganisms on soil moisture content in the no tillage soil was rather small, which may be related to the lack of microorganism penetration into the deeper soil layers and consequently lack of their activity at those depths. Therefore, the application of microbiological preparations while carrying out tillage, as proposed by Krysztofiak et al. [19], seems to be justified.

As in studies by other authors [9, 30], the average soil moisture content between 17 April and 2 July increased with depth. The largest difference (10.4 percentage points) was observed between the 0-10 cm layer and the 10-20 cm layer. Among all the agricultural treatments, only soil tillage with the application of effective microorganisms had an effect on soil moisture content. However, the straw showed no effect on soil moisture content (Table 2)..

Table 1. Decade total precipitations (mm)
Tab. 1. Dekadowe sumy opadów atmosferycznych (mm)

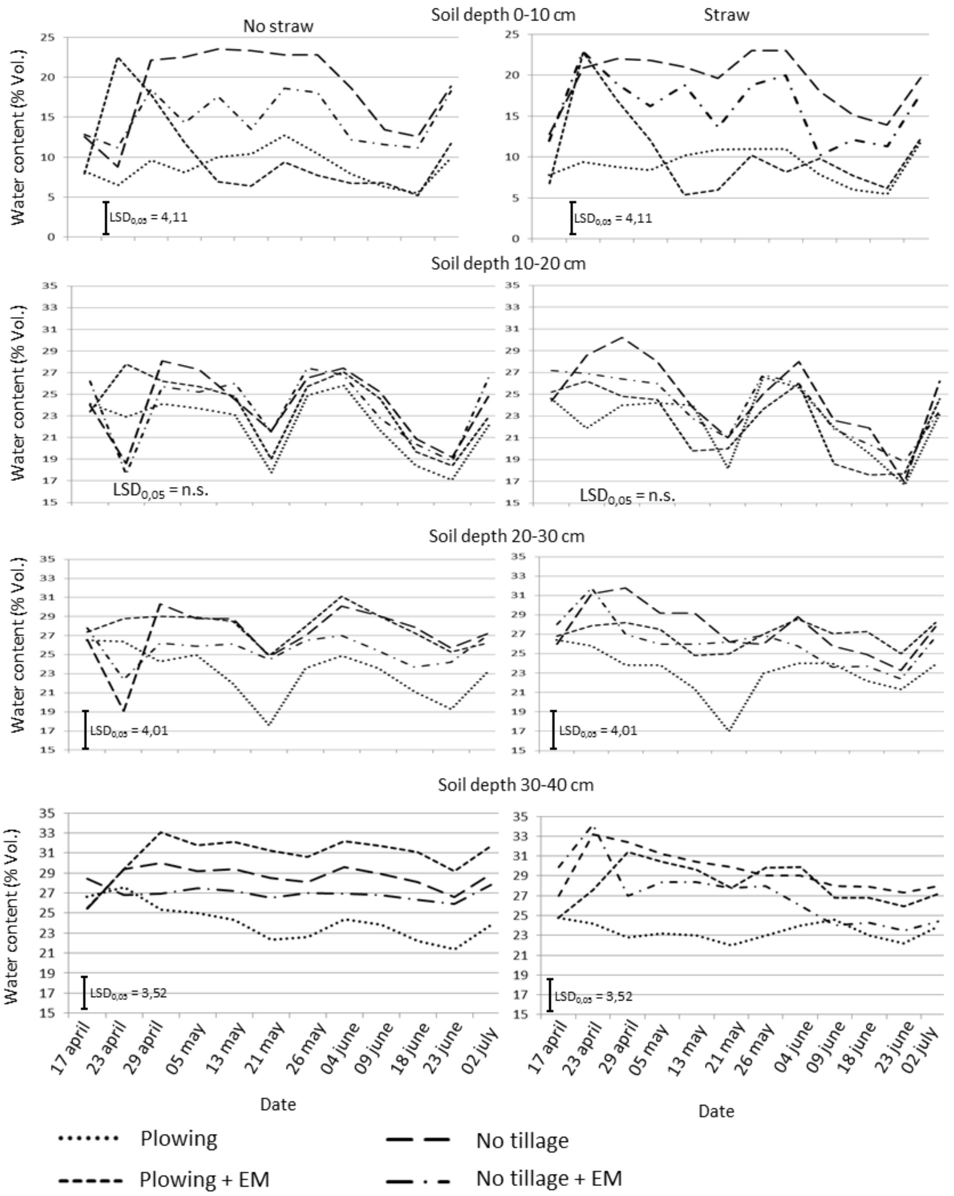
Year	Decade	Month						
		I	II	III	IV	V	VI	VII
2013	I	18.8	10.3	3.3	2.3	4.6	22.6	35.6
	II	6.5	10.6	4.7	4.1	24.7	2.1	48.9
	III	13.6	2.8	13.6	14.8	45.2	26.6	27.4
	I-III	38.9	23.7	21.6	21.2	74.5	51.3	111.9
Mean 1967-2012		25	21	28	27	52	69	81

Source: Głębokie meteorological station (52°64'N; 18°44'E) / Źródło: stacja meteorologiczna Głębokie

Table 2. Average soil moisture content [% vol.] during the spring vegetation of winter wheat, depending on soil tillage method and the application of effective microorganisms
Tab. 2. Wilgotność warstw gleby [% vol.] średnio w okresie wiosennej wegetacji pszenicy ozimej w zależności od sposobu uprawy roli z aplikacją efektywnych mikroorganizmów

Soil depth	Tillage method				Mean
	plowing	plowing + EM	no tillage	no tillage + EM	
0-10	9.0	10.9	16.0	19.7	13.9
10-20	23.1	24.1	24.7	25.3	24.3
20-30	23.5	27.4	26.3	27.7	26.2
30-40	24.1	29.8	27.7	29.4	27.7
Mean	19.9	23.0	23.7	25.5	
$LSD_{0.05}$ for	tillage =1.29	soil depth = 1.21	soil depth/tillage = 1.76	tillage/soil depth = 1.44	

Source: own work / Źródło: opracowanie własne



Source: own work / Źródło: opracowanie własne

Fig. 1. Changes in moisture content in soil profile depending on the use of straw, soil tillage method and the application of effective microorganisms

Rys. 1. Zmiany zawartości wody w profilu glebowym w zależności od stosowania słomy i sposobu uprawy roli z aplikacją efektywnych mikroorganizmów

Following plowing tillage, soil moisture content throughout the soil profile especially after the application of effective microorganisms, was significantly less than soil moisture content following direct sowing. This demonstrates the adverse effect of intensive tillage on soil moisture content. Moraru and Rusu [22] underline that total untilled soil had higher moisture content than that of plowing tillage and zero-tillage soil. Similar conclusions can be drawn from results of the study by Sławiński et al. [35], who observed higher soil moisture contents in the soil 5-30 cm layer throughout the whole winter wheat vegetation period due to reduced soil tillage, as compared with traditional tillage. The application of the EM to plowing tillage soil caused an increase in soil moisture content to the level occurring after direct sowing. In the case of no tillage and direct sowing, the application of effective microorganisms also caused a significant increase in soil moisture content. However, the beneficial effect of EM to soil moisture content in individual layers with both tillage methods was varied. Under the effect of the EM, the soil moisture content in plowing tillage soil increased in the deepest layer (30-40 cm) and, following direct sowing, only in the surface layers

Soil moisture content in the surface layer of the soil was not only the lowest but also the most varied throughout the winter wheat spring vegetation period. The soil moisture content variation coefficient decreased with increases in depth (Table 3). In the absence of soil tillage (no tillage) and the use of direct sowing, the application of straw and effective microorganisms also did not cause significant changes to the soil moisture content variation coefficient. Following the application of the EM to the plowing tillage soil, the susceptibility to changing weather conditions increased, resulting in an increase in the variation of soil moisture content in the surface layer.

Table 3. Soil moisture content variation coefficients (CV) [%] during the spring vegetation of winter wheat, depending on the use of straw, soil tillage method and the application of effective microorganisms

Tab. 3. Współczynniki zmienność CV [%] wilgotności gleby w trakcie wiosennej wegetacji pszenicy ozimej w zależności od stosowania słomy i sposobu uprawy roli z aplikacją efektywnych mikroorganizmów

Soil depth	Tillage method				Mean
	plowing	plowing + EM	no tillage	no tillage + EM	
			no straw		
0-10	20.3	52.0	21.1	27.1	31.1
10-20	13.0	13.4	14.3	13.5	13.6
20-30	11.7	6.3	6.2	11.2	8.1
30-40	7.7	6.5	2.5	4.7	5.6
Mean	13.2	19.6	11.0	14.1	14.6
			straw		
0-10	24.2	49.6	25.5	18.4	33.1
10-20	13.4	15.0	12.3	15.3	13.6
20-30	10.6	8.1	9.2	9.4	9.3
30-40	3.9	7.2	11.2	6.8	7.4
Mean	13.0	20.0	14.5	12.5	15.8

Source: own work / Źródło: opracowanie własne

The literature shows a lack of results obtained using the same methodology that could be compared with those from the present study. However, Ismail [16] observed an increase in water retention in soil under the effect of effective microorganisms (EM1), including when applied in combination with plant biomass (green fertilizer). He explains the beneficial effect of EM1 in terms of changes in other soil properties, such as volumetric density. According to Sangakara [28], the increase in soil moisture content under the effect of effective microorganisms, although less than under the effect of organic matter, occurred also during wet and dry vegetation seasons and lasted from sowing to harvest.

Changes in soil compaction throughout the winter wheat vegetation period were nearly identical in objects with and without straw. Therefore, the average data from those objects are presented, depending on the tillage method and application of microorganisms (Fig. 2). In April, May and early June the compaction of soil in the 0-10 cm layer for all objects varied between 0.23 and 1.20 MPa, and differences between the objects did not produce any correlations that could be explained by the application of experimental factors. Only in early June did the compaction of the soil surface layer begin to increase for all tillage methods, the least for plowing tillage. In the beginning of the spring vegetation period, the observed compaction of the 10-20 cm soil layer in objects with direct sowing – no tillage was higher by approx. 1.5 MPa than in tillage objects. Later, the differences decreased. This was probably related to a large extent with the change in soil moisture.

On average, throughout the study period, soil compaction increased with depth. Its value depended on the application of straw and the soil tillage method (Table 4). Significant decreases in soil compaction occurred only after leaving straw on the ground and direct sowing, and did not occur after the plowing tillage. On average, during the spring vegetation of winter wheat, below a depth of 10 cm the soil compaction in the objects subject to plowing tillage was less than in the direct sowing objects. Due to the application of effective microorganisms, soil compaction in the plowing tillage objects increased more than in the direct sowing objects, although such increases were not statistically significant.

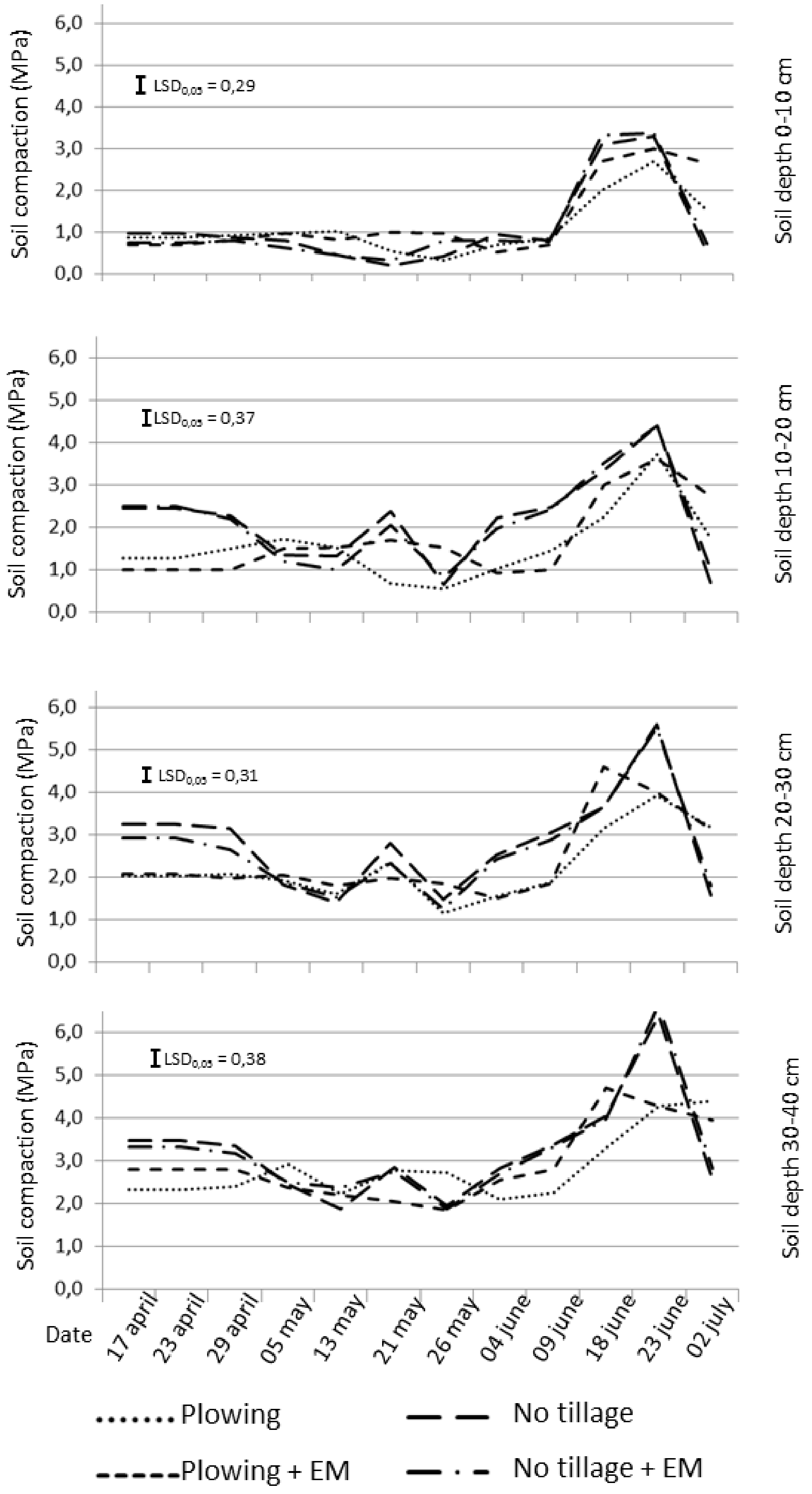
The least increase in soil compaction in plowing tillage objects, by approx. 0.4 MPa, was observed between the 0-10 cm and 10-20 cm layers, whereas in direct sowing objects the highest change in soil compaction (1.01-1.05 MPa) was observed between those layers (Table 4). Following plowing tillage, the application of effective microorganisms triggered an increasing trend in soil compaction in all examined layers, while for direct sowing no clear vector of changes was observed.

Table 4. Soil compaction [MPa] depending on the use of straw, soil tillage method and the application of effective microorganisms

Tab. 4. Zwięzłość gleby [MPa] w zależności od stosowania słomy i sposobu uprawy roli z aplikacją efektywnych mikroorganizmów

Soil depth	Tillage method				Mean
	plowing	plowing + EM	no tillage	no tillage + EM	
0-10	1.11	1.30	1.11	1.12	1.16
10-20	1.51	1.71	2.16	2.13	1.88
20-30	2.23	2.40	2.79	2.64	2.52
30-40	2.83	2.93	3.22	3.23	3.05
mean	1.92	2.08	2.32	2.28	
no straw	1.93	2.12	2.50	2.43	2.25
straw	1.91	2.05	2.15	2.13	2.06
$LSD_{0.05}$ for: straw=0.04; tillage=0.2; soil depth=0.14; straw / tillage=0.12; tillage / soil depth =0.22;					

Source: own work / Źródło: opracowanie własne



Source: own work / Źródło: opracowanie własne

Fig. 2. Changes in soil compaction depending on soil tillage method and the application of effective microorganisms
Rys. 2. Zmiany zwięzłości gleby w zależności od sposobu uprawy roli z aplikacją efektywnych mikroorganizmów

Soil compaction decreased in all objects with increases in soil moisture content, although statistically confirmed correlations occurred only in the two topmost soil layers (Table 5). The most variable compaction of soil was observed in the 10-20 cm layer, and stabilized with depth (Table 6). The largest coefficients of variation were observed for soil compaction values under directly sown wheat, especially when straw was left on the surface of soil. This can be connected with the decomposition process of the straw mulch.

Table 5. The values of soil moisture and soil compaction correlation coefficients depending on the use of straw, soil tillage method and the application of effective microorganisms
Tab. 5. Wartości współczynnika korelacji między zawartością wody w glebie a jej zwięzłością w zależności od stosowania słomy i sposobu uprawy roli z aplikacją efektywnych mikroorganizmów

Soil depth	Tillage method			
	plowing	plowing + EM	no tillage	no tillage + EM
	no straw			
0-10	**-0,701**	-0,289	-0,564	**-0,576**
10-20	**-0,576**	**-0,791**	**-0,703**	**-0,600**
20-30	-0,540	-0,544	-0,500	-0,221
30-40	-0,535	-0,100	-0,566	-0,493
	straw			
0-10	**-0,672**	-0,207	-0,448	**-0,596**
10-20	**-0,618**	**-0,576**	-0,572	**-0,586**
20-30	-0,207	-0,158	-0,329	-0,451
30-40	-0,320	-0,535	-0,350	-0,343

Bold face - statistically significant

Source: own work / Źródło: opracowanie własne

Table 6. Coefficients of soil compaction variation CV [%] during the spring vegetation of winter wheat, depending on the use of straw, soil tillage method and the application of effective microorganisms
Tab. 6. Współczynniki zmienności CV [%] zwięzłości gleby w trakcie wiosennej wegetacji pszenicy ozimej w zależności od stosowania słomy i sposobu uprawy roli z aplikacją efektywnych mikroorganizmów

Soil depth	Tillage method				Mean
	plowing	plowing + EM	no tillage	no tillage + EM	
	no straw				
0-10	18.1	13.3	27.2	21.1	19.5
10-20	26.2	15.2	25.9	27.9	22.4
20-30	16.6	8.3	26.6	20.9	17.2
30-40	13.1	11.3	20.8	14.1	15.1
mean	18.5	12.0	25.1	21.0	18.6
	straw				
0-10	23.5	11.4	26.9	13.7	20.6
10-20	26.4	21.3	38.7	36.9	28.8
20-30	15.5	7.8	28.7	27.4	17.3
30-40	9.9	14.1	19.2	18.0	14.4
mean	18.8	13,7	28.4	24.0	20.3

Source: own work / Źródło: opracowanie własne

4. Conclusions

Straw, soil tillage method, application of the effective microorganisms and the interaction among those factors significantly affected soil moisture content and soil compaction during the spring vegetation of a winter wheat monoculture. The extent of the changes in the physical properties of soil under the effect of such factors depended on the soil layer and phase of the vegetation period. Several years of straw introduction to the soil resulted in a reduction in soil compaction, especially in no tillage soil and the use of the direct sowing method. The effect of straw on soil moisture content occurred only in early spring. Later the effect disappeared and was, on average, insignificant throughout the whole vegetation period, irrespective of soil tillage method. Plowing tillage, in comparison to direct sowing, resulted in the reduction of the average soil moisture content to the depth of 40 cm, and the compaction of the soil in the 10-40 cm layer. The application of effective microorganisms in the plowing tillage soil caused a slight increase in compaction of all soil layers, and especially the moisture content of the deepest layer (30-40 cm). In no tillage soil the effective microorganisms did not cause an increase in soil compaction and a higher moisture content was observed primarily in the surface layer.

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