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THE EFFECT OF ANNUAL APPLICATION OF NATURAL FERTILIZERS AND STRAW ON THE YIELDING OF MAIZE GROWN FOR GRAIN IN MULTIPLE MONOCULTURE

Summary

The purpose of the work was to evaluate the effects of agricultural use of natural fertilizers and rye straw in the cultivation of maize for grain. The research was carried out using the variety PR39G12, on the field after a 6-year-old maize monoculture. In the years 2005-2008, two mono-factorial experiments were established on two soil complexes: rye and good wheat. It was shown, that the use of natural fertilizers and straw limited the negative effects of maize cultivation in monoculture. The application of a full dose of manure on a good wheat complex and plowing of rye straw with the addition of 40 $m^{3\cdot} ha^{-1}$ slurry on a rye complex resulted in an increase in grain yield.
***Key words**: manure, slurry, rye straw, maize, monoculture*

WPŁYW COROCZNEGO STOSOWANIA NAWOZÓW NATURALNYCH I SŁOMY NA PLONOWANIE KUKURYDZY UPRAWIANEJ NA ZIARNO W WIELOLETNIEJ MONOKULTURZE

Streszczenie

Celem pracy była ocena efektów rolniczego wykorzystania nawozów naturalnych oraz słomy żytniej w uprawie kukurydzy na ziarno. Badania przeprowadzono z wykorzystaniem odmiany PR39G12, na polu po 6-letniej monokulturze kukurydzy. W latach 2005–2008 założono dwa jednoczynnikowe doświadczenia na dwóch kompleksach glebowych: żytnim oraz pszennym dobrym. Wykazano, że stosowanie nawozów naturalnych oraz słomy ograniczało ujemne skutki uprawy kukurydzy w monokulturze. Zastosowanie pełnej dawki obornika na kompleksie pszennym dobrym oraz przyoranie słomy żytniej z dodatkiem 40 $m^3 \cdot ha^{-1}$ gnojowicy na kompleksie żytnim prowadziło do wzrostu plonu ziarna.
***Słowa kluczowe**: obornik, gnojowica, słoma żytnia, kukurydza, monokultura*

1. Introduction

Maize *(Zea mays* L.*)* belongs to the most cultivated plants in the world. The last few decades for maize cultivation in Poland was groundbreaking. From a plant of marginal importance, it has become one of the most important cereal species in our country [5]. Such an intense growth of interest owes to the huge biological progress with which we have faced in recent years. New hybrids were grown during this period, more adapted to production [15], with yields of grain reaching 10-12 tons per hectare, which is over twice as high as for other cereals [9]. The growing interest in this plant among farmers, according to Michalski [8], results, among others, from its high efficiency, good grain price, and thus high profitability of production. According to Sulewska [14], maize does not have high soil requirements and successfully succeeds at weaker sites belonging to class IVb rye complexes, which dominate in Poland.

Corn is an undemanding species as forecrop, tolerating cultivation in monoculture [7]. In recent years, the share of cereals in the structure of crops has been systematically growing, which results in the lack of a correct sequence of plants in the crop rotation. This resulted in limiting the availability of suitable positions for cereal crops, including for maize, forcing cultivation in monoculture [2]. Such cultivation has adverse effects on the plant and the natural environment [16]. Contraindications to growing plants in monoculture result, among the others, from the deterioration of phytosanitary status of plants, soil use, the accumulation of pathogens and allelopathic compounds, which in turn lead to deterioration of habitat conditions [2]. Integrated methods of plant protection applicable from 2014 allow the use of monoculture in the cultivation of maize. As the methods limiting the risk of yield decrease in monocultures, there is mentioned increased mineral fertilization, chemical protection of plants, intensive soil management, cultivation of catch crops for green fertilizer and the use of organic and natural fertilization [4]. As reported by Wiater and Kozera [17], the yielding effect of natural and organic fertilizers is observed in later years due to the effect of their cumulative effects, through the growth and stabilization of soil fertility. The use of fertilization based only on mineral fertilizers is insufficient to maintain soils in appropriate fertility, and especially to keep a favorable balance of organic matter. Organic and natural fertilizers are an important source of humus in the soil and their use softens the negative impact of unbalanced mineral fertilization and acidification and is almost the sole source of micronutrients [3].

The aim of the research was to assess the effect of natural fertilization and straw application on the yield of maize cultivated for grain. In addition, it was intended to indicate which fertilizer combination reduces the risk of a decrease in the yield of maize cultivated in a multi-annual monoculture.

2. Materials and methods

In the years 2005-2008, in the fields of Experimental Station Gorzyń, branch in Swadzim belonging to the University of Life Sciences in Poznań, two series of strict field trials were conducted with maize variety PR39G12 grown in monoculture for grain harvest. The trials were established in the fields where maize was cultivated in monoculture for a period of six years. The first series of experiments was conducted in the years 2005-2007 on soil class IVb, good rye complex, while the second one was established in 2006-2008 on soil belonging to the IIIa bonitation class - good wheat complex. Both experimental fields were in close distance to each other. In each of the locations described above, mono factorial experiments were carried out in a randomized blocks design in four trial replicates. The experimental factor included the type of fertilization applied (natural or with the use of straw) with the following levels: control plant (mineral fertilization NPK), full manure dose (30 $t \cdot ha^{-1}$), half manure dose (15 $t \cdot ha^{-1}$), straw + 5 kg N/t fresh straw weight and straw +40 $m^3 \cdot ha^{-1}$ of slurry. The effects of using natural fertilizers were evaluated against the background of the mineral fertilized control object in the following doses: N - 110 $kg \cdot ha^{-1}$, phosphorus - 35 $kg \cdot ha^{-1}$ and potassium - 100 $kg \cdot ha^{-1}$. Every year, after grain harvest, the straw remaining on the crop (6.5-7 $t \cdot ha^{-1}$), was crushed and plowed down. Straw with an amount of 5 $t \cdot ha^{-1}$ was applied on the object with straw plowing-down. Every year, on the same experimental plots, in the autumn before pre-winter plowing, natural fertilization was applied. Immediately prior to the spring pre-sowing cultivation, additional mineral fertilization was applied to these objects to supplement the amount of nutrients found in the soil with natural fertilizers and straw. For this purpose, urea, single granulated superphosphate and potassium salt were used. Maize was sown with a precision pneumatic seed drill Monosem, in 4 rows with a spacing between rows of 0.7 m and the distance of plants in a row 15.5 cm to a depth of 5 cm. The area of the trial plots on the sites located on soil class IVb was 42 m^2 (21 m^2 for harvest), while in the second location (soil class IIIa), the plot area was 22.4 m^2 (11.2 m^2 for harvest). During the trial period, the plant greenness index [SPAD] was determined, in the flowering phase of the ear and maize tassels (BBCH 61-67) on the leaf below the ear, using the Hydro N-Tester, in three replicates. In the phase of full grain maturity (BBCH 89) samples to determine harvest components were taken. The moisture content of the grain at harvest was determined on a random sample of 250 g of grain using an automatic grain moisture meter. Grain yield was converted to 15% moisture.

The collected research results were analyzed statistically using the analysis of variance (ANOVA) for mono factorial experiments. All calculations were performed using an Excel spreadsheet in a Windows environment using the STATISTICA 10 package. Significance of differences between the tested factor levels was assessed by Fisher's test at the significance level of $P < 0.05$ (*) and $P < 0.01$ (**) to form homogeneous groups marked as a, b, c. In addition, Pearson's linear correlation coefficients were calculated.

3. Results and discussion

The applied fertilization significantly diversified plant density in the initial period of maize growth (Table 1) and in the majority of cases it influenced the density of plants after emergence. This was particularly evident on soil class IIIa, where significantly the highest number of plants after emergence was found after using the full dose of manure ($30 t \cdot ha^{-1}$) or rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of slurry. Obtaining such effects indicates improved water and air conditions at these sites, which helped the growth and rapid development of young seedlings. It can be assumed that the addition of organic matter, which was applied as natural fertilizers, led to an intensive development of beneficial soil microflora, thanks to which a faster decomposition of post-harvest residues took place. This is confirmed by the results of research carried out by Buraczyńska and Ceglarek [1]. Niewiadomska et al. [10] in research on the dynamics of the development of proteolytic and ammonifying bacteria in the cultivation of maize indicates that the development of soil microorganisms is determined among other things by the type of organic fertilization. The author noted the highest amount of ammonifying bacteria after fertilization of maize with a full dose of manure. Statistical analysis of the quantitative status of plants before harvest in both locations showed no significant changes under the influence of the applied fertilization. It should be emphasized, however, that the positive effect of the applied fertilization on the values of this feature was observed on the majority of objects. According to the literature on reduction of maize density during the growing season, a number of factors interfering with the course of life processes may influence, which leads to the dying of young plants. In our own studies, the percentage of plant disappearance during the growing season was small and was related to the type of applied fertilization and the soil class (Table 1). The lowest number of plant disappearance, regardless of the type of fertilization applied, was found on the better soil (IIIa) and it was lower by 2.5 $pcs \cdot m^2$ than on the weaker soil (IVb). It can be assumed that on the soil weaker in worse soil conditions seedlings died during the sunrise or died later. It should also be noted that on soil class IVb there was a significant increase in the disappearance of plants compared to the control object, after the use of rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of slurry. However, on the better soil (IIIa), the use of half the manure dose and rye straw + mineral nitrogen allowed to reduce the disappearance of plants, which had a beneficial effect on obtaining a satisfactory plant density.

The size of the maize grain harvested was changing under the influence of the applied fertilization, which was especially evident in the weaker soil (IVb), where the application of natural fertilizers and straw was able to compensate for worse soil conditions leading to a grain yield increase compared to the control object (Table 2) . The increase in grain yield after application of rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of slurry, compared to the control amounted to 8.6 $dt \cdot ha^{-1}$ (13.0%), while after the full of manure dose was slightly lower, but still statistically significant and amounted to 5.6 $dt \cdot ha^{-1}$ (8.5%). It should also be emphasized that the use of other fertilizer combinations, as compared to the control object, also led to an increase in grain yield. Similar relations were also found on the better soil (IIIa), where the application of natural fertilizers allowed to limit the negative effects of maize cultivation in monoculture. The highest increase in grain yield was recorded after application of full dose of manure (5.4 $dt \cdot ha^{-1}$) and rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of manure (3.3 $dt \cdot ha^{-1}$), differences in relation to the control object were not statistically proven. Similarly in the cultivation of peas fertilized with organic fertilizers (straw or intercrop) with application of mineral fertilization proved the best production results (seed and protein yields) [6]. The relations found in our study has been confirmed in the results obtained by Sulewska et al. [13] concerning the cultivation of silage maize. In these studies, the author indicates strong stimulating effect of straw with N mineral on the yield of stems. The author believes that the achievement of such effects was associated with the rate of straw mineralization and high availability of nutrients for maize, especially in the first period of growth and stem formation. In our own experiments, the fertilizing effect of straw was dependent on the type of soil. On the weaker soil (IVb), straw fertilization stimulated yielding more strongly, which was not so visible on soil class IIIa. Such a reaction of maize plants to this additive could have been caused by the formation of an insulating layer obstructing the soaking of water from deeper soil layers. The negative effect of straw fertilization on the yields volume was also found by Spiak and Piszcz [11], especially in conditions of moisture deficiency. On the other hand, research carried out by Sulewska et al. [12] proved that the highest yields of maize grain cultivated on class IIIa soil were collected after applying 30 tonnes of manure or 40 m^3 of pig slurry. These studies also indicate that the productivity of natural fertilizers and straw expressed by the level of maize grain yield was higher on soil class IIIa than on soil class IVb. Differing results were obtained in the own research, where the higher grain yield on average by 4.2% was obtained on the weaker soil (IVb).

Extension of plant vegetation, expressed in the increase of grain moisture in harvest (Table 2) took place on soil class IIIa, after the use of rye straw with the addition of mineral nitrogen. The grain moisture increase has been statistically proven, and compared to the control object it was 1.2%. However, on the weaker soil (IVb), the influence of the applied natural fertilizers on the moisture content of the grain during harvesting has not been proved. Sulewska et al. [12] indicate that the use of a full manure dose for maize can lead to slight grain moisture increases. Own research also showed that regardless of the soil class, the ear volume on the control object on which only mineral fertilization was applied was worse than after using the full dose of manure on class IIIa soil and rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of slurry on soil class IVb (Table 2).

The natural fertilization and straw application applied in both locations was favorable for the setting of ears by maize plants and the filling of kernels with a higher TKW (Table 3). Irrespective of the type of soil, the tendency to set up more ears was found on sites where a full dose of manure or rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of slurry was used. On the other hand, the development of kernels with a larger thousand weight (TKW) was supported mainly by rye straw with the addition of mineral nitrogen or slurry. The weight of thousand kernels on these objects, compared to the control, was higher by an average of 14.6 g. The obtained relations were confirmed by studies carried out by Sulewska et al. [12]. Also, later studies conducted by Sulewska et al. [13] show that after ploughing down a full dose of manure or straw with slurry it is possible to obtain an increase in the number of productive ears by as much as 0.8 units$\cdot m^2$. The use of rye straw with the addition of slurry and the full manure dose on the weaker soil (IVb) also led to a significant increase in the number of kernels in the corn ear (Table 3). However, on the better soil (IIIa) the largest increase in the number of kernels in the ear was visible after the introduction of rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of slurry and it was 10.4% compared to the control.

Table 1. Plants number (pcs$\cdot m^2$) and plants losses (%) depending on the applied fertilization
Tab. 1. Liczba roślin (szt$\cdot m^2$) oraz zaników roślin (%) w zależności od zastosowanego nawożenia

Combination	Plants number after emergence		Plants number before harvest		Plants losses	
	Soil class		Soil class		Soil class	
	III a	IV b	III a	IV b	III a	IV b
Control (NPK min.)	7.51 bc	7.64 a	7.63 a	7.53 a	0.74 ab	2.26 b
Manure 30 $t\cdot ha^{-1}$	7.78 a	7.77 a	7.74 a	7.57 a	1.61 a	2.28 b
Manure 15 $t\cdot ha^{-1}$	7.57 abc	7.73 a	7.62 a	7.56 a	0.38 b	2.69 b
Straw + N min.	7.35 c	7.67 a	7.60 a	7.51 a	0.36 b	3.41 ab
Straw + slurry	7.76 ab	7.78 a	7.90 a	7.36 a	1.67 a	6.48 a
Mean	7.59	7.72	7.70	7.51	0.95	3.42
p value	0.009^{**}	0.396_{ns}	0.438_{ns}	0.550_{ns}	0.048^{*}	0.003^{**}

* – statistically significant differences (p <0.05), ** – statistically highly significant differences (p<0.01), ns – no statistically significant effect on tested trait (p>0.05), a, b, c – homogeneous groups (NIR Fisher's test, p<0.05)

Source: own study / Źródło: badania własne

Table 2. Grain yield ($dt\cdot ha^{-1}$) and moisture (%) as well as maize ears capacity (cm^3) depending on the applied fertilization
Tab. 2. Plon ($dt\cdot ha^{-1}$) i wilgotność ziarna (%) oraz pojemność kolb kukurydzy (cm^3) w zależności od zastosowanego nawożenia

Combination	Grain yield		Grain moisture		Ears capacity	
	Soil class		Soil class		Soil class	
	III a	IV b	III a	IV b	III a	IV b
Control (NPK min.)	64.4 a	65.9 c	26.1 b	25.5 a	179.8 b	178.3 c
Manure 30 $t\cdot ha^{-1}$	69.8 a	71.5 ab	26.4 b	25.1 a	208.8 a	190.8 b
Manure 15 $t\cdot ha^{-1}$	66.8 a	68.6 bc	26.3 b	25.5 a	190.3 ab	186.6 b
Straw + N min.	66.6 a	69.0 b	27.3 a	25.3 a	198.5 ab	186.4 b
Straw + slurry	67.7 a	74.5 a	26.6 b	25.1 a	197.9 ab	198.9 a
Mean	67.1	69.9	26.5	25.3	195.1	188.2
p value	0.715_{ns}	0.000^{**}	0.003^{**}	0.711_{ns}	0.049^{*}	0.000^{**}

* – statistically significant differences (p <0.05), ** – statistically highly significant differences (p<0.01), ns – no statistically significant effect on tested trait (p>0.05), a, b, c – homogeneous groups (NIR Fisher's test, p<0.05)

Source: own study / Źródło: badania własne

Table 3. Yield components depending on the applied fertilization

Tab. 3. Komponenty plonowania w zależności od zastosowanego nawożenia

Combination	Ears number (pcs·m^{2})		Grains number in ear (pcs)		TKW (g)	
	Soil class		Soil class		Soil class	
	III a	IV b	III a	IV b	III a	IV b
Control (NPK min.)	6.95 a	6.45 a	427.7 a	443.8 bc	287.5 a	313.1 a
Manure 30 t·ha^{-1}	7.03 a	6.73 a	465.0 a	456.8 ab	295.5 a	324.4 a
Manure 15 t·ha^{-1}	6.87 a	6.12 a	452.6 a	438.5 bc	298.5 a	317.1 a
Straw + N min.	6.68 a	6.48 a	457.0 a	416.6 c	302.2 a	318.2 a
Straw + slurry	7.06 a	6.58 a	472.4 a	474.1 a	300.2 a	327.7 a
Mean	6.92	6.47	455.0	446.0	296.8	320.1 a
p value	0.454_{ns}	0.814_{ns}	0.396_{ns}	0.000^{**}	0.541_{ns}	0.062_{ns}

* – statistically significant differences (p <0.05), ** – statistically highly significant differences (p<0.01), ns – no statistically significant effect on tested trait (p>0.05), a, b, c – homogeneous groups (NIR Fisher's test, p<0.05)

Source: own study / Źródło: badania własne

The highest stability in years for the grain yield on soil class IIIa, was found after using the full dose of manure, and the coefficient of variation (CV) was 36.1% (Table 4). In turn, the highest variability of this feature in years (CV = 43.4%) was found after using half the manure dose and ploughing rye straw with the addition of 40 m^3·ha^{-1} slurry. Analysis of the correlation between maize grain yield and yielding components showed that there are a number of significant relationships between them (Table 4). The yield of grain was most strongly related to the number of kernels in the ear on all the tested objects. The strength of this relationship depended on the type of fertilization used, and the strongest relationship between the tested features occurred on the control object (0.955**). On the soil of class IVb, the yield variability was slightly lower than on soil class IIIa (Table 5). In this location the highest yield stability was characteristic for maize plants, which were grown after plowing rye straw with the addition of 40 m^3·ha^{-1} of manure. On this object the coefficient of variation was the lowest and amounted to 26.3%. On the other hand, the least stable yielding of maize in the years was found on objects where half the manure dose was applied and only mineral fertilization (control). Obtained results of own research do not confirm the research carried out by Sulewska et al. [13] on silage maize. The authors assessing the fertilizer value of natural fertilizers on different types of soil indicated that greater yield stability in the years was obtained on better soil (IIIa) than on weaker soil (IVb). In our own research, the analysis of grain yield correlation with its components showed that on the control object where only mineral fertilization was applied, there was a strong positive correlation between the grain yield and the number of kernels in the ear (0.966**). However, on other objects where different variants of natural fertilizers and straw were used, the yield of maize grain was strongly correlated positively with the number of ears per 1 m^2 and the number of grains in the ear. The strength of these dependencies varied and the correlation coefficients calculated ranged from 0.684* to 0.965**, respectively.

The application of diversified natural fertilization in the conducted own experiment regardless of the soil class was favorable to better nitrogen plant nutrition (Table 6).

Table 4. Correlation coefficients and statistical characteristics of grain yield and yield components depending on the applied fertilization on class soil IIIa

Tab. 4. Współczynniki korelacji oraz charakterystyki statystyczne plonu ziarna i jego składowych w zależności od zastosowanego nawożenia na glebie klasy IIIa

Factor levels	Specification	1	2	3	CV %	Values min-max
Control (NPK min.)	Ears number (1)	1.000			10.6	6.0 – 8.3
	Grains number in ear (2)	0.781**	1.000		15.3	365.3 – 531.0
	TKW (3)	0.424	0.202	1.000	13.3	198.9 – 318.3
	Grain yield	0.843**	0.955**	0.284	40.7	39.6 – 106.2
Manure 30 t·ha^{-1}	Ears number (1)	1.000			11.4	5.1 – 7.7
	Grains number in ear (2)	0.431	1.000		8.9	394.0 – 527.0
	TKW (3)	0.640*	0.242	1.000	15.5	202.8 – 341.5
	Grain yield	0.443	0.792**	0.081	36.1	43.1 – 103.2
Manure 15 t·ha^{-1}	Ears number (1)	1.000			11.6	5.3 – 8.1
	Grains number in ear (2)	0.570	1.000		14.9	303.0 – 525.0
	TKW (3)	0.296	0.752**	1.000	13.2	215.7 – 339.6
	Grain yield	0.694*	0.747**	0.374	43.5	33.9 – 101.1
Straw + N min.	Ears number (1)	1.000			10.9	5.3 – 8.0
	Grains number in ear (2)	0.593*	1.000		10.6	380.0 – 562.0
	TKW (3)	0.738**	0.342	1.000	13.7	206.7 – 338.4
	Grain yield	0.706*	0.597*	0.273	41.2	32.6 – 102.3
Straw + slurry	Ears number (1)	1.000			9.0	6.2 – 8.1
	Grains number in ear (2)	0.584*	1.000		11.2	400.6 – 532.8
	TKW (3)	0.373	- 0.122	1.000	10.6	237.5 – 333.7
	Grain yield	0.696*	0.905**	0.046	43.3	32.7 – 100.4

*statistically significant differences (p < 0.05); **statistically highly significant differences (p < 0.01)

Source: own study / Źródło: badania własne

Table 5. Correlation coefficients and statistical characteristics of grain yield and yield components depending on the applied fertilization on class soil IVb
Tab. 5. Współczynniki korelacji oraz charakterystyki statystyczne plonu ziarna i jego składowych w zależności od zastosowanego nawożenia na glebie klasy IVb

Factor levels	Specification	1	2	3	CV %	Values min-max
Control (NPK min.)	Ears number (1)	1.000			37.1	0.3 – 9.0
	Grains number in ear (2)	0.571	1.000		17.7	320.8 – 538.6
	TKW (3)	- 0.257	- 0.024	1.000	4.9	280.3 – 333.5
	Grain yield	0.564	0.966**	0.059	35.5	35.2 – 93.1
Manure 30 t·ha^{-1}	Ears number (1)	1.000			30.7	1.5 – 8.9
	Grains number in ear (2)	0.508	1.000		16.0	354.1 – 569.8
	TKW (3)	- 0.356	- 0.338	1.000	3.2	299.4 – 338.1
	Grain yield	0.708**	0.923**	- 0.300	33.9	36.3 – 97.1
Manure 15 t·ha^{-1}	Ears number (1)	1.000			42.9	0.4 – 8.8
	Grains number in ear (2)	0.764**	1.000		21.9	294.9 – 588.4
	TKW (3)	0.029	0.082	1.000	3.3	300.3 – 332.2
	Grain yield	0.833**	0.941**	0.019	35.7	30.9 – 94.0
Straw + N min.	Ears number (1)	1.000			34.3	1.3 – 8.7
	Grains number in ear (2)	0.757**	1.000		22.8	275.6 – 511.0
	TKW (3)	- 0.095	- 0.230	1.000	3.8	292.5 – 334.6
	Grain yield	0.740**	0.965**	- 0.270	34.9	31.7 – 95.0
Straw + slurry	Ears number (1)	1.000			32.7	1.0 – 9.2
	Grains number in ear (2)	0.742**	1.000		17.6	325.1 – 597.0
	TKW (3)	- 0.330	- 0.587*	1.000	4.1	309.0 – 344.5
	Grain yield	0.684*	0.928**	- 0.513	26.3	46.9 – 99.3

*statistically significant differences ($p < 0.05$); **statistically highly significant differences ($p < 0.01$)

Source: own study / Źródło: badania własne

Table 6. Biometric traits of maize plants depending on the applied fertilization
Tab. 6. Cechy biometryczne roślin kukurydzy w zależności od zastosowanego nawożenia

Combination	Plant height (cm)		Height of ear establishing (cm)		Greenness index (SPAD)	
	Soil class		Soil class		Soil class	
	III a	IV b	III a	IV b	III a	IV b
Control (NPK min.)	263.7 a	201.4 bc	95.4 a	86.3 b	466.7 b	636.4 b
Manure 30 t·ha^{-1}	236.8 a	203.8 b	94.3 a	89.5 ab	551.6 a	666.6 ab
Manure 15 t·ha^{-1}	237.7 a	196.0 c	97.1 a	86.0 b	535.8 a	663.8 ab
Straw + N min.	237.5 a	211.4 a	99.7 a	93.1 a	564.1 a	687.8 a
Straw + slurry	235.7 a	206.2 ab	94.9 a	86.9 b	583.7 a	682.3 a
Mean	262.3	203.8	96.3	88.3	540.4	667.4
p value	0.442_{ns}	0.000^{**}	0.298_{ns}	0.000^{**}	0.000^{**}	0.001^{**}

* – statistically significant differences (p <0.05), ** – statistically highly significant differences (p<0.01), ns – no statistically significant effect on tested trait (p>0.05), a, b, c – homogeneous groups (NIR Fisher's test, p<0.05)

Source: own study / Źródło: badania własne

This was particularly evident in the better soil (IIIa), where on the control object where only mineral fertilization was applied, the nitrogen nutritional status of maize plants was significantly worse. In both locations, ploughing of rye straw with the addition of mineral N or 40 m^3·ha^{-1} of slurry led to a significant increase in the value of the SPAD units in comparison to the control. On average, for these objects, this increase amounted to 76.6 SPAD units. Also according to Sulewska et al. [12] the use of fertilizer in the natural cultivation of maize for grain favored better greenness of plants. These studies indicate that the best effect can be obtained after using the full dose of manure. On the other hand, the positive effect of using slurry on the greenness status of maize plants depended on the type of soil on which it was grown. In turn, later studies conducted by Sulewska et al. [13] concerning the cultivation of maize silage inform about the relationship between the height of the SPAD index and the type of soil on which the maize was cultivated. These authors showed higher values of the leaf greenness index on the weaker soil (Cl. IVb). Similar relationships were also found in our own research. The height of plants and the height of setting corn ears cultivated in monoculture on soil class IIIa were not significantly modified by the type of natural fertilization applied (Table 6). However, on weaker soil (IVb) plowing of rye straw with the addition of N mineral or 40 m^3·ha^{-1} of slurry, led to a significant increase in plant height compared to the control object. In turn, the plowing of rye straw with the addition of mineral N or the use of a full dose of manure favored the setting of ears at a higher height and the obtained differences were statistically proven.

4. Conclusions

1. The use of natural fertilizers and straw in the cultivation of maize for grain limited the negative effects of its cultivation in monoculture. The use of a full dose of manure on class IIIa soil and plowing of rye straw with the addition of 40 m^3·ha^{-1} of slurry on soil class IVb resulted in a grain yield increase of 8.4% and 13%, respectively.

2. The plowing of rye straw with the addition of N mineral or 40 $m^3 \cdot ha^{-1}$ of slurry, regardless of the soil class, led to a better greenness of maize plants, expressed in units of SPAD as compared to the control object.
3. The influence of the tested natural fertilizers and straw on individual yield components was different. Regardless of the soil class, the fertilizers that most strongly stimulated ear formation included manure used at full dose. In contrast, plowing of rye straw with the addition of 40 $m^3 \cdot ha^{-1}$ of manure or mineral nitrogen promoted the production of a larger number of grains in an ear with a higher weight per thousand.

5. References

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