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THE EFFECT OF ANNUAL APPLICATION OF NATURAL FERTILIZERS, STRAW OR INTERCROP ON THE YIELD OF MAIZE CULTIVATED FOR SILAGE IN LONG-TERM MONOCULTURE

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Abstract. The study was conducted in the years 2005-2008 in the fields of the Experimental Station Swadzim (52°26' N; 16°45' E) belonging to ZDD Gorzyń, property of the Poznań University of Life Sciences. Two experiments with PR 39G12 maize cultivar were conducted in fields, where previously maize was sown in a six-years monoculture. The aim of the study was to evaluate the effects of natural fertilizers, straw or intercrop applied together with mineral fertilizers. We investigated whether this approach can reduce the negative effects of maize cultivation in monoculture system and at the same time help to increase the silage yield. The assessment of plant response was made on two soil classes. It has been shown that the use of natural fertilizers, straw or an intercrop (rye with vetch), reduced the negative effects of maize growing in monoculture and led to a significant increase in the dry mass yield of whole plants on IIIa soil class.

Key words: farmyard manure, maize for silage, mineral fertilization, monoculture, rye straw, slurry, winter intercrop

INTRODUCTION

In Poland, area for maize cultivation for silage in 2014 was 624,000 ha, maize for grain was harvested from 412,000 ha, while maize for biofuel from 10,000 ha [GUS 2015].

Since 1 January 2014, professional producers in Poland are obliged to use principles of an integrated plant protection, which results from the provision of article 14 of the Directive 2009/128/WE as well as from the Regulation, no 1107/2009. However, the

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Common Agricultural Policy of EU for the years 2014-2020 included maize into fodder plants, in which no obligatory use of crop rotation is required.

So far, crop rotation has been the best system in plant cultivation, which stabilizes yields on a particular level. Monocultural cultivation system leads to a deterioration in habitat conditions [Deryło and Szymankiewicz 1999], and it also increases weed infestation and compensation of burdensome weed species, characteristic of a particular plant [Gawrońska-Kulesza *et al.* 2005]. Blecharczyk and Pudełko [1997] indicated that maize cultivated alternately with other plants gives yields higher by 10-30% than in monoculture.

Wiater and Kozera [2000] indicate increased rates of nutrients used in mineral, natural and organic fertilizers as a factor reducing the risk of decreasing crop yield in monoculture. The yield-producing effect of natural or organic fertilizers manifests itself also in later years, due to a cumulative effect which leads to an increase in soil fertility. Organic and natural fertilizers are an important source of humus in the soil, they improve many of its properties, among other things: structure, water capacity, density [Piechota *et al.* 2000]. Moreover, they are a source of nutrients and energy for soil microorganisms. Organic and natural fertilizers alleviate the negative effect of unsustainable mineral fertilization and soil acidification [Jaskulska 2003], moreover, they are an almost exclusive source of microelements [Ceglarek and Płaza 2000].

In Polish soils it often occurs deficiency of humic compounds, and to sustain biodiversity of agroecosystems, natural environment protection and improvement in soil fertility, it is important to select and properly incorporate an appropriate organic fertilization [Niewiadomska *et al.* 2010].

Intensity of maize cultivation as well as lack of an obligation to apply crop rotation caused that on many fields maize is still cultivated in monoculture.

The aim of the study was evaluation of the effects of incorporating, beside mineral fertilization, also natural fertilizers, straw or an intercrop. It was studied if such an activity will allow to reduce negative effects of maize cultivation in monoculture, and at the same time contribute to an increase in the yield of the raw material for ensiling. The evaluation of plant response was carried out on two soils differing in bonitation class.

In the research hypothesis it was assumed that incorporation of natural fertilizers, straw or an intercrop, together with an application of mineral fertilizers, will allow to reduce the risk of a decrease in the yield of maize cultivated in a long-term monoculture.

MATERIAL AND METHODS

The research was carried out in Swadzim in the years 2005-2008, on the fields of the Experimental Station in Gorzyń, property of the Poznań University of Life Sciences. Maize cv PR 39G12 was cultivated in two experimental series after 6-year monoculture. In the years 2005-2007 the experiments were conducted on soil, class IVb, of a good rye complex, with the following content of available forms of nutrients in $mg \cdot kg^{-1}$ of the soil: 33.2-41.5 P, 111.2-117.0 K, 58.5-60.3 Mg and pH within the range of 5.9-6.2.

The second experimental series was carried out in the years 2006-2008 on soil class IIIa, good wheat complex, on a field 1250 m away from the first location. The content of available forms of nutrients in $mg \cdot kg^{-1}$ of soil was: 56.3-63.7 P, 117.9-166.0 K, 30.8--37.4 Mg, respectively, and pH ranged within 6.9-7.0.

In each location, one-way experiments were conducted in randomized blocks design in four field replications with maize cultivated for silage in monoculture.

The experimental factor was application of an organic matter and mineral fertilization (Table 1). Annually, in autumn natural fertilizers and rye straw as well as mineral fertilizers were ploughed in on the same plots according to the experimental design, at a rate balancing the doses incorporated in the control plot. The intercrop of rye, cv Fernando F1, with villous vetch were sown with their proportion in the mixture being 50%. Sowing was carried out with an Amazone seeder, with a row spacing of 15 cm, to a depth of 4 cm.

Table 1. Comparison of combinations used in the experiment

	Combination	Rate per 1 ha	Rates incorporated in mineral fertilizers $kg{\cdot}ha^{-1}$		
			N	P	K
1	control (NPK min)	130 kg N, 34.9 kg P, 116.2 kg K	0	0	0
2	manure	30 Mg	77.2	25.1	0
3	manure	15 Mg	103.3	30.0	55.2
4	rye straw	5 Mg + 5 kg Nmin.$\cdot$1 Mg^{-1} słomy	129.5	34.9	116.2
5	rye straw + slurry	5 Mg + 40 m^3	73.6	7.0	11.0
6	winter intercrop	10-15 Mg	129.5	34.9	116.2
7	slurry	40 m^3	73.6	7.0	11.0

The experimental plot area on plots located on soil of poorer class IVb was 42 m^2, while for harvest it was 21 m^2. Plots located on soil class IIIa, were smaller and had an area of 22.4 m^2, and for harvest 11.2 m^2.

All agronomic treatments were conducted according to the principles of good practice for the cultivation of maize for silage.

In spring, right before presowing tillage, an intercrop of rye was ploughed in with winter vetch, and a spiked roller was used behind the plough. At that time, mineral fertilizers were incorporated at doses balancing the applied ones on the control plot. When establishing the doses, the use of nutrients from natural fertlizers was taken into account (Table 2). They included: urea, triple superphosphate and potassium salt 60%.

Sowing of maize was carried out with a precision seeder, Monosem, with row spacing of 0.7 m, into a depth of 5 cm, while the assumed grain spacing in a row was 15.5 cm. Plant density in all the years was similar and ranged from 8.0 to 9.5 plant$\cdot m^{-2}$. Plant harvest was carried out manually.

In all years of research, at the stage BBCH 60-70 (flowering – grain filling), maize leaf greenness index was measured (SPAD) on leaves belove the ears with the Hydro N-Tester.

Characteristics of weather conditions was conducted based on the data from the meteorological station in Swadzim. The years when the experiments were carried out were characterized by various weather conditions (Figs. 1-5). In the region of central Greater Poland, maize yield is determined by rainfall distribution at the time of plants' vegetation. Every year of research, there occurred periods with water deficiency. In 2005, drought occurred in June and at the end of September; in 2006, in June and July, and also in mid- and late September; in 2007 in early and mid- April and in August; on the other hand in 2008: in May, June and early July and in mid- September. The most unfavorable conditions for plant development occurred in the growing season of 2006, as water deficiencies in the flowering stage determined low yields. On the other hand, the most favorable weather conditions for maize occurred in the growing season of 2007.

Table 2. The dry mass content and the main macronutrients applied in natural fertilizers, winter intercrop and rye straw in the years 2005-2008, $g \cdot kg^{-1}$ D.M.

Year	Combination	Dry mass content	Total N	P	K
2005	manure	349.2	8.2	4.0	16.6
	slurry	51.8	8.3	5.9	160.2
	winter intercrop	153.0	34.2	2.8	16.8
	rye straw	843.0	8.0	1.2	9.8
2006	manure	275.1	10.0	6.8	25.0
	slurry	38.0	7.7	10.3	144.2
	winter intercrop	191.0	29.3	3.6	16.0
	rye straw	801.0	7.8	1.6	10.6
2007	manure	295.1	11.4	8.6	22.5
	slurry	59.0	6.9	13.3	71.7
	winter intercrop	163.0	29.0	2.2	15.8
	rye straw	823.0	6.6	1.4	9.0
2008	manure	313.0	11.1	8.8	21.5
	slurry	47.7	8.0	11.0	134.0
	winter intercrop	170.0	25.3	2.4	15.3
	rye straw	844.0	6.9	1.0	10.0

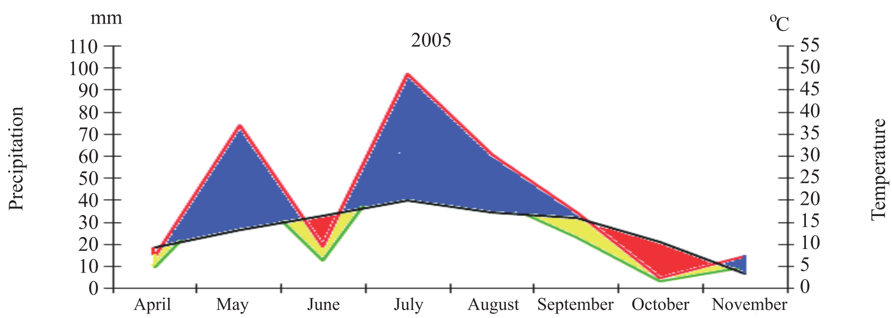

Fig. 1. Weather conditions in Swadzim 2005 (according to Walter [1976])

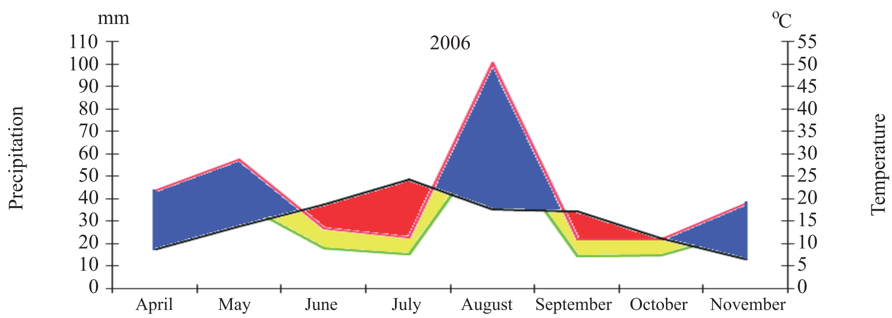

Fig. 2. Weather conditions in Swadzim 2006 (according to Walter [1976])

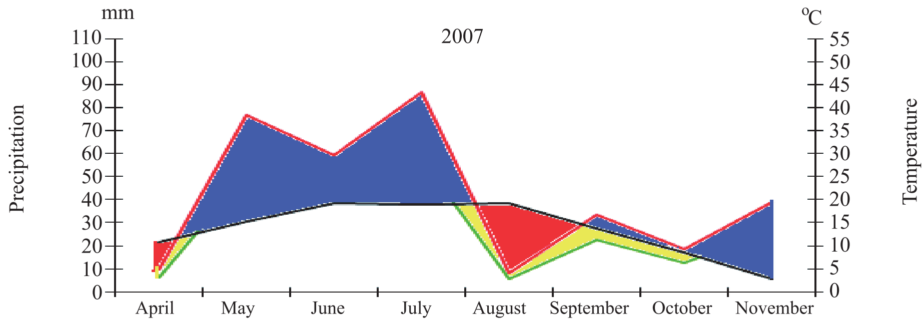

Fig. 3. Weather conditions in Swadzim 2007 (according to Walter [1976])

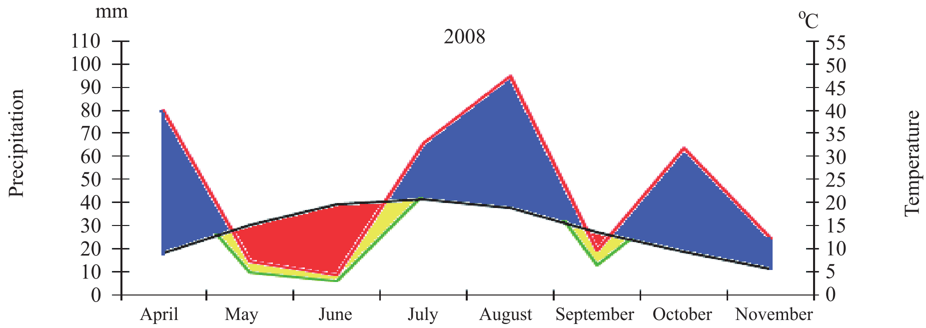

Fig. 4. Weather conditions in Swadzim 2008 (according to Walter [1976])

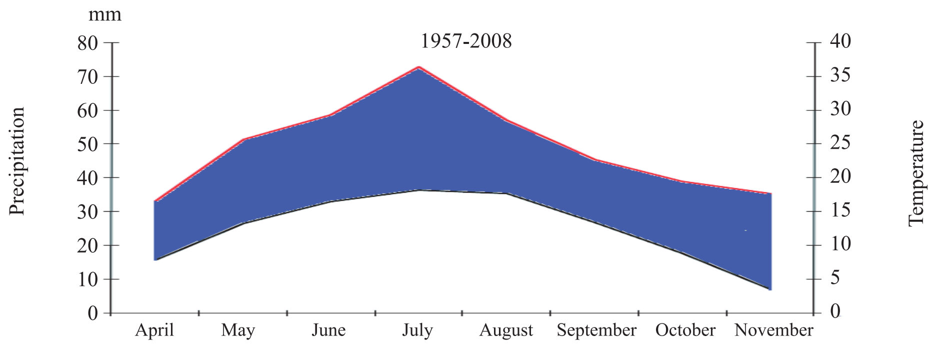

Fig. 5. Weather conditions in Swadzim 2006 from April to November 1957-2008 (according to Walter [1976])

Legend

- semi-drought period
- drought period
- relatively wet period
- temperature, °C
- precipitation, mm
- reduced precipitation

The research results were elaborated statistically with the method of analysis of variance, Anova, and the significance of differences was evaluated with Tukey test, at the level of p = 0.95.

RESULTS

Type of soil on which maize was cultivated determined the number of developed ears. On plots located on soil class IIIa, on average more ears, by 0.9, were obtained per 1 m^2 than on soil class IVb (Table 3). An application of all the studied combinations of incorporating organic matter, except winter intercrop on poorer soil (decrease by 0.9 ears·m^{-2}), favorably affected the number of ears per unit of area in both experimental locations. The use of slurry on soil class IVb led to a significant increase in the number of production ears, and the difference compared with the control plot was up to 1.3 ears·m^{-2} (19.1%). On soil class IIIa, the best results were obtained when using each year, beside mineral fertilization, a full dose of manure or straw with slurry (increase by 0.8 ears·m^{-2}).

Table 3. Number of proper ears, the share of proper ears in the yield of the dry mass of whole plants and leaf greenness index

Combination	Soil class IIIa			Soil class IVb		
	ear number	ear share %	leaf greenness index	ear number	ear share %	leaf greenness index
Control (NPK min)	7.8 a	56.7 a	533.7 d	6.8 bc	54.9 c	634.8 d
Manure 30 Mg·ha^{-1}	8.6 a	52.4 b	551.3 c	7.5 ab	57.6 ab	662.6 b
Manure 15 Mg·ha^{-1}	8.1 a	48.3 c	566.6 bc	7.4 ab	53.4 cd	650.7 c
Straw + min N	8.1 a	48.0 c	533.8 d	6.9 bc	51.9 d	663.3 b
Straw + slurry	8.6 a	55.8 a	571.9 b	7.6 ab	57.0 b	644.5 cd
Winter intercrop	8.2 a	49.6 c	623.9 a	6.5 c	54.5 c	703.8 a
Slurry	8.2 a	48.1 c	557.9 c	8.1 a	59.3 a	702.8 a
Mean	8.2	51.3	562.7	7.3	55.5	666.1

a, b… – homogenous groups, values denoted by the same letter do not differ significantly on the level P = 0.05

Moreover, various effect of soil and studied experimental combinations was indicated on the leaf greenness index in maize, expressed as SPAD index. Higher values of this index were obtained on poorer soil (class IVb). On both classes of soil, application of each of the studied combinations of incorporating organic matter caused a significant increase in the value of the leaf greenness index in maize compared with the control plot. However, it should be highlighted that after ploughing in straw on soil class IIIa and straw with slurry on soil class IVb together with mineral fertilization, an increase in the value of this index showed only an increasing tendency. The highest values of SPAD were observed after applying, beside mineral fertilization, a winter intercrop of rye with vetch: 623.9 on soil class IIIa, and 703.8 on class IVb. On soil class IVb after ploughing in the intercrop and slurry, similar values of the above mentioned index were obtained.

Irrespective of the soil conditions, application of each combination of incorporating organic matter led to an increase in the yield of the dry weight of maize plants compared with the control plot (Table 4). On soil class IIIa after applying, beside mineral fertilization, also manure at a rate of 15 Mg·ha^{-1}, straw with mineral N and intercrop, a significant increase in the yield was obtained, which compared with the control plot was 4.01; 3.71 and 3.54 Mg·ha^{-1}, respectively of d.m. of whole plants. The indicated increases in the yield compared with the control plot in a series of experiments carried out on soil class IVb were statistically insignificant. The highest increases in the yield of the dry weight of whole plants occurred after incorporating, beside mineral fertilization, also winter intercrop and straw with slurry, which exceeded the yields obtained from the control plot by 0.67 Mg·ha^{-1} and 0.66 Mg·ha^{-1}, respectively.

Table 4. Yields of the dry mass of stems and whole plants, Mg·ha^{-1}

Combination	Soil class IIIa		Soil class IVb	
	dry mass yield		dry mass yield	
	stems	whole plants	stems	whole plants
Control (NPK min)	6.48 e	14.89 c	6.24 bc	13.96 a
Manure 30 Mg·ha^{-1}	8.53 c	17.40 b	5.94 cd	14.26 a
Manure 15 Mg·ha^{-1}	9.92 a	18.90 a	6.31 abc	14.30 a
Straw + min N	9.91 a	18.60 a	6.63 a	14.05 a
Straw + slurry	7.46 d	16.80 b	6.15 c	14.62 a
Winter intercrop	9.44 ab	18.43 a	6.58 ab	14.63 a
Slurry	9.00 bc	17.39 b	5.73 d	14.33 a
Mean	8.68	17.49	6.23	14.31 a

a, b… – homogenous groups, values denoted by the same letter do not differ significantly on the level P = 0.05

On soil class IIIa annually, application of slurry, and especially straw with slurry together with mineral fertilization, stabilized the yield of the dry weight of whole plants over the years, and the calculated variation coefficients were lower than on the control plot, and were 1.60% and 1.38%, respectively (Table 5). The use of other experimental combinations on this class of soil and all the studied combinations on soil class IVb, led to an increase in yield variation over the years compared with the control plot with mineral fertilization. On the other hand, the lowest yield variation over the years on soil class IVb was obtained from the control plot, and CV was 1.34%.

Table 5. Statistical characterizations of the yields of whole plants' dry mass, Mg·ha^{-1}

Combination	Soil class IIIa				Soil class IVb			
	min.-max. values		SD	CV%	min.-max. values		SD	CV%
Control (NPK min)	12.34	18.95	2.75	18.5	11.56	17.70	1.87	13.4
Manure 30 Mg·ha^{-1}	12.70	22.41	3.48	20.0	11.37	18.11	2.32	16.2
Manure 15 Mg·ha^{-1}	13.37	27.63	5.14	27.2	9.95	19.13	3.33	23.3
Straw + min N	14.01	26.75	5.44	29.3	11.07	18.40	2.86	20.3
Straw + slurry	14.24	20.77	2.31	13.8	10.84	18.50	2.67	18.2
Winter intercrop	14.06	23.83	3.56	19.3	10.67	18.70	2.67	18.3
Slurry	14.83	22.47	2.79	16.0	11.05	17.91	2.36	16.5

The yield of the dry weight of stems on soil class IIIa was higher than on soil class IVb (Table 4). The use of the studied combinations of incorporating organic matter on both soil classes, significantly diversified the yield of stems. On soil class IIIa, stem yield was mostly stimulated by an incorporation of, beside mineral fertilization, also: 15 Mg·ha^{-1} manure, straw + N and intercrop, after whose application, the following values were obtained: 9.92; 9.91 and 9.44 Mg·ha^{-1}, respectively. On soil class IVb, of rye complex, as a result of incorporating straw with an addition of N together with mineral fertilizers, there occurred a significant increase in the stem yield, and this increase compared with the control plot was 0.39 Mg·ha^{-1}. Ploughing in winter intercrop induced a tendency to increase the yield of the dry weight of stems, and the difference compared with the control plot was 0.34 Mg·ha^{-1}. On this soil, a significant decrease occurred in the stem yield by 8.2% compared with the control plot after application of slurry with mineral fertilizers.

The share of ears in the yield of the dry weight of whole plants obtained in both experimental series depended significantly on the applied fertilization (Table 3). On soil class IIIa the group with the highest share of ears included plots with mineral fertilization (control plot) and with an annual incorporation of straw with slurry together with mineral fertilizers. This share was 56.7% and 55.8%, respectively. On soil class IVb, a significantly higher share of ears in the yield of the dry weight of whole plants than on the control plot was obtained after application of a full rate of manure (57.6%), straw with slurry (57.0%) and especially slurry (59.3%) together with mineral fertilizers.

Over the years, the highest stability of ear proportion in the yield of whole maize plants on soil class IIIa was indicated after application of slurry together with mineral fertilizers, and the variation coefficient CV was 5.0% (Table 6). The highest variation in this trait over the years (CV = 12.2%) was obtained after ploughing in mineral fertilizers with straw with N. On soil class IVb, variation in the share of proper ears in the yield of the dry weight of whole plants was slightly higher than on soil class IIIa. In this experimental series, the highest stability of the discussed trait was characteristic of the plot with an annual application of mineral fertilizers with an intercrop, for which the variation coefficient was 8.3%. On the other hand, the least stable share of proper ears over the years was obtained after application of half a dose of manure with mineral fertilizers (CV = 24.2%).

Table 6. Statistical characterizations of the share of proper ears in the yield of the whole plant dry mass, %

Combination	Soil class IIIa				Soil class IVb			
	min.-max. values		SD	CV%	min.-max. values		SD	CV%
Control (NPK min)	51.2	66.2	4.7	8.2	43.7	60.4	5.2	9.4
Manure 30 Mg·ha^{-1}	43.7	61.5	6.1	11.6	46.3	63.3	6.0	10.4
Manure 15 Mg·ha^{-1}	40.1	53.4	4.1	8.5	32.7	67.3	12.9	24.2
Straw + min N	39.8	57.5	5.9	12.2	40.3	60.1	7.7	14.9
Straw + slurry	51.4	64.4	3.7	6.7	44.6	62.9	6.7	11.8
Winter intercrop	39.9	57.6	5.5	11.2	46.3	60.4	4.5	8.3
Slurry	43.7	51.7	2.4	5.0	50.4	66.2	5.7	9.6

Beside the height of yield of the dry weight of whole plants, also the content of ears/grains is very significant in the cultivation of maize for silage. In the experiments carried out on soil class IIIa, it was not possible to indicate any variant of fertilization which would allow to obtain the highest yield of dry weight with at the same time the highest proportion of proper ears. On this soil, annual application of a full rate of manure together with mineral fertilizers was the most favorable, as it allowed to obtain an average in this experimental series yield of dry weight with a higher than average share of proper ears.

On soil class IVb, combinations providing higher yields of the dry weight of whole plants than the means for experiments, with at the same time higher than the average share of ears included: straw + slurry and slurry, applied annually along with mineral fertilizers.

DISCUSSION

The use of the close correlation between nitrogen content and leaf color gives a possibility to measure plant nutrition with this element with the use of SPAD test. An increased nitrogen fertilization is accompanied by an increase in the value of the leaf greenness index, however its value also affects plant nutrition with sulphur and magnesium as well as available water capacity [Machul 2003, Jodełka and Sosnowski 2010]. Incorporation of any of the studied experimental combinations, irrespective of the soil class, increased the value of SPAD index, and the indicated differences compared with the control plot, were statistically significant, except when incorporating beside mineral fertilizers, straw + N on soil class IIIa and slurry on soil class IVb. The higher value of SPAD index was determined on leaves of maize cultivated on soil class IVb. Natywa *et al.* [2014] indicated an increase in the value of SPAD index along with an increasing rate of nitrogen applied in maize cultivation.

Rabikowska and Piszcz [1993] as well as Żarski and Dudek [2003], in their studies indicated a significant effect of soil quality on the level of obtained maize yields. This was confirmed in our studies, as the yields of the dry weight of whole plants obtained on soil of wheat complex (17.49 $Mg \cdot ha^{-1}$) exceeded the yields obtained on a lighter soil (14.31 $Mg \cdot ha^{-1}$).

Combinations used in our studies, irrespective of the soil type, contributed to an increase in the yields of the dry weight of whole maize plants compared with the control plot. In the experimental series on soil class IIIa, the most favorable results were obtained after fertilizing with half a rate of manure along with mineral fertilization (increase in the yield compared with the control plot by 26.9%). Also, the use of straw or intercrop together with mineral fertilizers, strongly stimulated the level of obtained yields of the dry weight of plants (increase by 24.9% and 23.8%, resectively). On the other hand, Rabikowska and Piszcz [1993] as well as Sienkiewicz [1998] obtained a lower increase in maize yields as a result of fertilizing with manure, which increased by 12% and 6.7%, respectively. Similar tendencies concerning the favorable effect of manure on the maize yield were indicated by Mercik and Stępień [1996] as well as Cwojdziński and Majcherczyk [1996].

On soil class IVb, application of an intercrop or straw with slurry together with mineral fertilizers, turned out to be the most favorable variant, although the differences compared with the control plot have not been statistically confirmed.

Mazur *et al.* [2002] observed an over 100% increase in the yield of maize cultivated in monoculture on light soil as a result of applying slurry. However, under conditions of our experiments, increases in the yield after applying slurry along with mineral fertilizers were visibly lower, and were 16.8% on soil (class) IIIa, and only 2.6% on soil class IVb. Sienkiewicz [1998] highlights that the combined application of mineral and organic fertilization is significantly favorable for the plant yield. On the other hand, Deryło and Szymankiewicz [2001], while comparing the yield-producing effect of manure, green fertilizers and straw, evaluated straw value the lowest. This result was confirmed as a tendency in the experimental series carried out on soil class IVb.

While analyzing the yields of the dry weight of whole plants obtained on soil class IIIa, it was observed that an increase in the yield after incorporating half the rate of manure, straw or intercrop together with mineral fertilizers, occurred through an increase in the yield of the dry weight of stems. Koc [1993] as well as Grzebisz *et al.* [1993] prove that the combined application of mineral fertilization with slurry, stimulates an increase in the yield of leaves and stems more, and to a lesser degree in ears, which is similar to the results of our studies. Fertilizing value of slurry in the studies of these authors, revealed in a 32% increase in the yield of the dry weight of plants compared with the control plot, while in the variant with the combined application of mineral and organic fertilization, this increase even reached 90%. In our studies, favorable effect of this fertilizer was also indicated, especially on soil class IIIa, and the yield increase compared with the control plot was 16.8%, and was statistically insignificant, although the effect was lower than with other fertilizers. Rabikowska and Piszcz [1993] state that slurry contains all nutrients necessary for the growth of maize plants.

In the conducted research, irrespective of the soil class, a strong stimulating effect of straw with mineral nitrogen used along with mineral fertilizers was indicated on the yield height of stems. It may be assumed that it was connected with the rate of straw mineralization and high availability of nutrients, especially in the first stage of growth and stem formation.

In our studies on soil class IIIa, plants developed on average one ear each (from 0.9 to 1.1 ear·plant^{-1} depending on the experimental combination), while on soil of rye complex 0.9 ear (from 0.8 to 0.9). Application of each of the studied combinations, beside ploughing in an intercrop on soil class IVb, induced an increasing tendency in the number of ears per unit of area compared with the control plot. An increase in the number of production ears by as much as 0.8 ear·m^{-2} was obtained on soil class IIIa after applying a full rate of manure or straw with slurry together with mineral fertilization. Similar, favorable effect of mentioned combinations, was found on soil class IVb, however, in this case, the strongest effect had slurry used along with mineral fertilizers, causing an increase in the number of ears compared with the control plot by 19.3%. Kubiak and Kruczek [1992], however, indicated lack of the effect of using straw on plant density and numer of production ears per unit of area. In the experiment with sweet maize cultivation, Rosa *et al.* [2012] indicated that formation of ears after applying manure and an intercrop of phacelia and amaranth was similar.

In the experiments carried out on soil class IVb, the lowest numer of ears was obtained after applying winter intercrop (rye with vetch) along with mineral fertilizers. In the studies on wheat cultivated in monoculture, Lepiarczyk *et al.* [2005] proved favorable effect of papilionaceous plants on ear density.

Share of ears in the harvested yield, to a large extent determines the quality of silage, because the yield of energy, protein and other nutrients, is basically concentrated in the grain. On the other hand, stems contain lower amounts of nutrients, and because of a large proportion of fiber, they constitute roughage. In our studies it was proven that raw material obtained on soil class IVb was characterized by a more favorable share of proper ears that on soil class IIIa, and this difference was 4.2%. Previously, Michalski and Bieliński [2008] indicated that under less favorable habitat conditions, maize first of all reduces development of vegetative organs, which results in an increase in the proportion of ears in the harvested silage yield; this was confirmed in our studies.

Positive effect of using the studied combinations of incorporating organic matter, revealing in a high share of proper ears in the yield of the dry weight, on soil class IVb was observed after using slurry (59.3%), manure (57.6%) and straw with slurry (57%) together with mineral fertilizers. Application of these combinations on soil class IIIa, led to a decrease in the share of ears in the yield of the dry weight within the range from 0.9 pp (straw + slurry) to 8.7 pp (straw + N) compared with the control plot. Application of the studied combinations on soil class IIIa caused a significant increase in the yield of whole plants, in which there prevailed stems. Significant fluctuation in the share of ears in the yield depending on the type of soil, was also obtained by Żarski and Dudek [2003], and the share of ears in the total yield on very light soil was 35.2%, while on light soil 56.8%.

CONCLUSIONS

1. Application of manure, slurry, straw or an intercrop of rye with vetch together with mineral fertilizers, irrespective of the soil class, reduced negative effects of maize cultivation in monoculture.
2. On soil class IIIa, a significant increase in the yield of the dry weight of whole plants, was obtained after an application of half of the rate of manure, straw with mineral N or winter intercrop along with mineral fertilization. On soil class IVb a tendency to increase the yield was indicated after using straw with slurry as well as winter intercrop.
3. Share of proper ears in the dry weight of plants cultivated on soil class IVb was higher than on soil class IIIa. The highest share of ears in the dry weight of whole plants cultivated on soil class IIIa provided systematic ploughing in straw with slurry along with mineral fertilization, while on soil class IVb the use of slurry or a full rate of manure.
4. Over the years, annual ploughing in winter intercrop, irrespective of the soil class, stimulated and stabilized the yield of the dry weight of whole plants of maize, however proportion of ears was similar to the one obtained after using mineral fertilizers.
5. On soil class IVb, a higher yield of the dry weight of whole plants was obtained than the average one for experiments, with at the same time higher than the average share of ears, after annual application of straw with slurry as well as slurry together with mineral fertilizers. On soil class IIIa, the most favorable was annual incorporation of the full rate of manure.

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WPŁYW COROCZNEGO STOSOWANIA NAWOZÓW NATURALNYCH, SŁOMY LUB MIĘDZYPLONU NA PLON KUKURYDZY UPRAWIANEJ NA KISZONKĘ W WIELOLETNIEJ MONOKULTURZE

Streszczenie. W latach 2005-2008 w Swadzimiu, na polach Zakładu Doświadczalno--Dydaktycznego Gorzyń, należącego do Uniwersytetu Przyrodniczego w Poznaniu, prowadzono badania nad kukurydzą odmiany PR 39G12. Celem badań była ocena efektów wprowadzania obok nawożenia mineralnego nawozów naturalnych, słomy bądź międzyplonu. Badano, czy takie postępowanie pozwoli ograniczyć ujemne skutki uprawy kukurydzy w monokulturze i jednocześnie przyczyni się do wzrostu plonu surowca do zakiszania. Po okresie sześcioletniej monokultury założono dwie serie doświadczeń: jedną na glebie klasy IIIa, drugą na glebie klasy IVb. Wykazano, że stosowanie nawozów naturalnych, słomy lub międzyplonu żyta z wyką ozimą ograniczało ujemne skutki uprawy kukurydzy w monokulturze i wpłynęło na istotne zwiększenie plonu suchej masy całych roślin uprawianych na glebie klasy IIIa.

Słowa kluczowe: gnojowica, kukurydza na kiszonkę, międzyplon ozimy, monokultura, nawożenie mineralne, obornik, słoma żytnia

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