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ASSESSMENT OF THE IMPACT OF SELECTED AGRICULTURE FACTORS ON MAIZE NUTRITIONAL STATUS IN CRITICAL GROWTH STAGES USING THE PLANT ANALYSIS METHOD. PART II. FLOWERING STAGE (BBCH 61)

Summary

The study presents the results of a 3-year field study, whose aim was to assess the effect of sowing and NP fertilizer application method on the content of nutrients in leaf blades of two different types of maize varieties (traditional and stay-green) in the BBCH 61 stage. The selection of the variety in combination with row NP fertilization is a factor supporting the nutritional status of maize at this stage. The "stay-green" variety showed a positive reaction to the row NP application, which was caused by a better supply of P and K. The content of N, P, K, Mg in maize leaves at the BBCH 61 stage may be an indicator of the size of maize grain yield, regardless of the type of maize hybrid.
Key words: *maize, nutrients, flowering stage, leaf below ear*

OCENA WPŁYWU WYBRANYCH CZYNNIKÓW AGROTECHNICZNYCH NA STAN ODŻYWIENIA KUKURYDZY W KRYTYCZNYCH FAZACH WZROSTU METODĄ ANALIZY ROŚLINNEJ. CZĘŚĆ II. FAZA KWITNIENIA (BBCH 61)

Streszczenie

W pracy przedstawiono wyniki 3-letnich badań polowych, których celem była ocena wpływu sposobu siewu i aplikacji nawozu NP na zawartość składników pokarmowych w blaszkach liściowych w fazie BBCH 61 przez dwa różne typy odmian kukurydzy (tradycyjna i stay-green). Czynnikiem wspomagającym stan odżywienia kukurydzy w tym stadium jest dobór odmiany w połączeniu z rzędowym nawożeniem NP. Pozytywna reakcja na rzędowe stosowanie NP wykazała odmiana „stay-green", co wynikało z lepszego zaopatrzenia w P, K. Zawartość N, P, K, Mg w liściach kukurydzy w stadium BBCH 61 może być indykatorem wielkości plonu ziarna kukurydzy, niezależnie od typu mieszańca kukurydzy.
Słowa kluczowe: *kukurydza, składniki pokarmowe, faza kwitnienia, liść przykolbowy*

1. Introduction

Knowledge of varieties and their proper selection for cultivation is one of the most important skills of a modern producer. Older hybrids (varieties) are constantly replaced by new ones with a higher yielding potential and greater resistance to diseases, pests and environmental stresses. Therefore, one needs to be up-to-date on the subject of the problem, because maize breeding progress is very significant and only a few varieties will be profitable in the long term. For several years, hybrids of the "stay-green" type can be encountered in the selection of maize varieties, in which the grain matures at full greenness of the whole plant [1, 2]. Stay-green varieties delay aging and can retain photosynthetic processes during the grain filling stage, while maintaining assimilate supply to the generative crop [3, 4]. This feature is very advantageous from an agricultural point of view, because keeping the stand green (plant photosynthetic apparatus) for a long time is one of the most effective methods of increasing the yield of plants [4]. The aim of the field study was to determine the effect of soil preparation for maize sowing and the method of NP fertilizer application on changes in the chemical composition of the leaf below the ear of two types of maize varieties (*Zea mays* L.) at the BBCH 61 stage.

2. Materials and Methods

2.1. Experimental field

Experimental factors and their levels, experimental design and the characteristics of the experimental field are included in the first part of the work.

2.2. Weather conditions

The characteristics of the weather conditions during the research period were based on data from the meteorological station belonging to the Agronomy Department of the Poznań University of Life Sciences, located at the Experimental and Educational Unit in Swadzim (52º26' N; 16º45' E). Thermal conditions during maize cultivation in the experimental years were similar and amounted on average to 15.4°C in 2012, 15.6°C in 2013 and 16.1°C in the warmest year of 2014. Definitely greater differences between years occurred in the amount of precipitation. The highest sum of rainfall was recorded in 2012, 473.6 mm, which was 76.2 mm higher than the precipitation in 2013, and 121.8 mm higher from the amount of rainfall in 2014 (Tab. 1).

Table 1. Average monthly air temperature and total precipitation in Swadzim for the growing season
Tab. 1. Średnia miesięczna temperatura powietrza i miesięczna suma opadów atmosferycznych w Swadzimiu dla sezonu wegetacyjnego

Years	Temperature [°C]							
	IV	V	VI	VII	VIII	IX	X	Average Total
2012	9.3	16.3	17.0	20.0	19.8	15.0	8.6	15.4
2013	8.9	15.6	18.4	22.0	20.2	13.2	10.8	15.6
2014	11.4	14.6	17.9	23.2	18.8	16.0	11.2	16.1
Years	Precipitation [mm]							
2012	17.4	84.4	118.1	136.2	52.7	28.4	36.4	473.6
2013	10.5	95.5	114.9	52.9	32.4	75.9	15.3	397.4
2014	50.3	80.7	44.6	51.5	56.5	39.2	29.0	351.8

Source: own study / Źródło: opracowanie własne

2.3. Plant material

The analysis of mineral contents in dry matter of plants was performed in the laboratory of the Agronomy Department of the Poznań University of Life Sciences, according to the methods described by Gawęcki [5]. In addition, potassium was determined using a "Flapho 40" flame spectrophotometer, and phosphorus and magnesium using a "Specol 11" colorimeter.

2.4. Statistical analysis

One-year results were subjected to a univariate analysis of variance, followed by a synthesis for multiple experiments. The significance of the differences was estimated at the level of $\alpha = 0.05$ using the Student's t-test. A polynomial curvilinear regression was determined for the means from the individual years. The interaction between grain yield and its structure elements was determined using simple correlation analysis and analysis of path coefficients based on the equation from the study of Douglas et al. [6] using Excel 1997 spreadsheet. The interaction between grain yield and nutrient content in maize leaf blades at BBCH 61 was determined using simple correlation analysis.

3. Results

3.1. Changes in the chemical composition of the leaf below the ear during the flowering phase (BBCH 67)

3.1.2. Nitrogen content in leaf dry matter

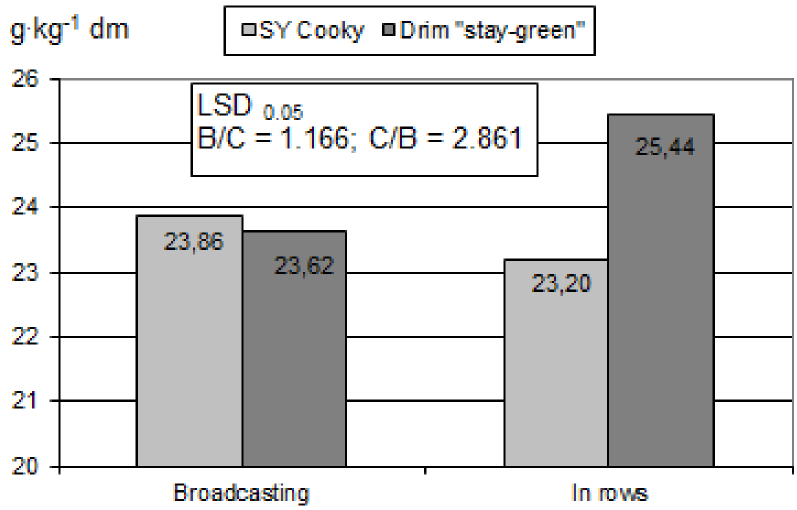
In general, none of the studied factors significantly influenced nitrogen content in leaf dry matter (Tab. 2). The interaction was found only for the variety and the method of NP fertilizer application in relation to the content of this component in maize leaves (Fig. 1). Broadcast fertilization did not significantly differentiate this trait independently of the studied varieties. The Drim "stay-green" hybrid showed a significantly higher nitrogen content in leaf dry matter as a result of row fertilization compared to the traditional variety SY Cooky (Fig. 1). The fertilization method did not differentiate the studied trait in the variety SY Cooky.

Table 2. N content at the BBCH 61 stage ($g{\cdot}kg^{-1}$ dm)
Tab. 2. Zawartość N w fazie BBCH 61 ($g{\cdot}kg^{-1}$ sm)

Experimental Factors		Years			Average
		2012	2013	2014	
Methods of sowing maize **(A)**	sowing in traditionally cultivated soil	24.98	25.22	23.87	24.69
	direct sowing	23.80	22.95	23.35	23.37
LSD $_{0.05}$		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Varieties **(B)**	SY Cooky	24.12	24.07	22.40	23.53
	Drim „stay-green"	24.66	24.11	24.82	24.53
LSD $_{0.05}$		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Methods of sowing NP fertilizer **(C)**	broadcasting	23.72	24.02	23.49	23.74
	in rows	25.06	24.16	23.73	24.32
LSD $_{0.05}$		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Average		24.39	24.09	23.61	24.03

n.s. – non-significant difference

Source: own study / Źródło: opracowanie własne



Source: own study / Źródło: opracowanie własne

Fig. 1. Nitrogen content in leaf dry matter depending on the interaction of the variety with the method of NP fertilizer application. (2012-2014)
Rys. 1. Zawartość azotu w suchej masie liści w zależności od współdziałania odmiany ze sposobem wysiewu nawozu NP. (2012-2014)

3.1.3. Phosphorus content in leaf dry matter

Phosphorus content in leaf dry matter was significantly affected by the variety and method of NP fertilizer application (Tab 3). When considering variety type, a higher content of this component was found in leaf blades of the Drim "stay-green" variety, compared to the classic variety SY Cooky. The difference between the tested varieties was 0.24 $g{\cdot}ha^{-1}$. With respect to the method of fertilizer sowing, a significantly higher content of phosphorus was recorded in maize leaf blades fertilized in rows compared to the traditional method of the component application. The difference between the tested varieties was 0.12 $g{\cdot}ha^{-1}$ (Tab. 3).

3.1.4. Potassium content in leaf dry matter

Overall, potassium content in dry matter of leaf blades was significantly modified by hybrid type during three study years (Tab. 4). Significantly higher potassium concentration was found in the Drim "stay-green" hybrid compared to the classic variety SY Cooky (Tab. 4). Potassium content in leaf dry matter was modified by the interaction of the variety with the method of NP fertilizer application (Fig. 2). Broadcast fertilization did not significantly differentiate this trait, regardless of the studied varieties. The Drim "stay-green" hybrid showed a significantly higher potassium content in leaf dry matter as a result of row fertilization compared to the traditional variety SY Cooky (Fig. 2). Fertilization method did not differentiate the studied trait in the variety SY Cooky.

Table 3. P content at the BBCH 61 stage ($g{\cdot}kg^{-1}$ dm)
Tab. 3. Zawartość P w fazie BBCH 61 ($g{\cdot}kg^{-1}$ sm)

Experimental Factors		Years			Average
		2012	2013	2014	
Methods of sowing maize **(A)**	sowing in traditionally cultivated soil	2.62	2.59	2.56	2.59
	direct sowing	2.48	2.44	2.43	2.45
LSD 0.05		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Varieties **(B)**	SY Cooky	2.44	2.36	2.40	2.40
	Drim „stay-green"	2.66	2.67	2.59	2.64
LSD 0.05		**n.s.**	**0.054**	**n.s.**	**0.105**
Methods of sowing NP fertilizer **(C)**	broadcasting	2.45	2.49	2.44	2.46
	in rows	2.65	2.54	2.55	2.58
LSD 0.05		**n.s.**	**n.s.**	**0.059**	**0.079**
Average		2.55	2.51	2.49	2.52

n.s. – non-significant difference

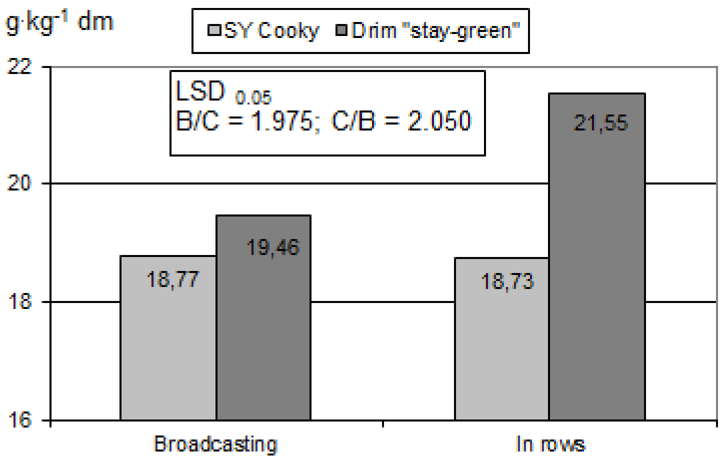
Source: own study / Źródło: opracowanie własne

Table 4. K content at the BBCH 61 stage ($g \cdot kg^{-1}$ dm)
Tab. 4. Zawartość K w fazie BBCH 61 ($g \cdot kg^{-1}$ sm)

Experimental Factors		Years			Average
		2012	2013	2014	
Methods of sowing maize **(A)**	sowing in traditionally cultivated soil	19.02	21.72	20.87	20.54
	direct sowing	18.16	18.80	19.19	18.71
LSD 0.05		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Varieties **(B)**	SY Cooky	17.93	19.17	19.16	18.75
	Drim „stay-green"	19.25	21.35	20.91	20.51
LSD 0.05		**n.s.**	**n.s.**	**n.s.**	**1.347**
Methods of sowing NP fertilizer **(C)**	broadcasting	17.86	19.89	19.60	19.11
	in rows	19.32	20.63	20.47	20.14
LSD 0.05		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Average		18.59	20.26	20.03	19.63

n.s. – non-significant difference

Source: own study / Źródło: opracowanie własne



Source: own study / Źródło: opracowanie własne

Fig. 2. Potassium content in leaf dry matter depending on the interaction of the variety with the method of NP fertilizer application (2012-2014)
Rys. 2. Zawartość potasu w suchej masie liści w zależności od współdziałania odmiany ze sposobem wysiewu nawozu NP. (2012-2014)

Table 5. Mg content at the BBCH 61 stage ($g \cdot kg^{-1}$ dm)
Tab. 5. Zawartość Mg w fazie BBCH 61 ($g \cdot kg^{-1}$ sm)

Experimental Factors		Years			Average
		2012	2013	2014	
Methods of sowing maize **(A)**	sowing in traditionally cultivated soil	2.13	2.14	2.16	2.14
	direct sowing	2.03	2.02	1.95	2.00
LSD 0.05		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Varieties **(B)**	SY Cooky	2.08	2.06	2.09	2.07
	Drim „stay-green"	2.08	2.11	2.02	2.07
LSD 0.05		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Methods of sowing NP fertilizer **(C)**	broadcasting	2.06	2.07	2.02	2.05
	in rows	2.10	2.10	2.09	2.10
LSD 0.05		**n.s.**	**n.s.**	**n.s.**	**n.s.**
Average		2.08	2.09	2.05	2.07

n.s. – non-significant difference

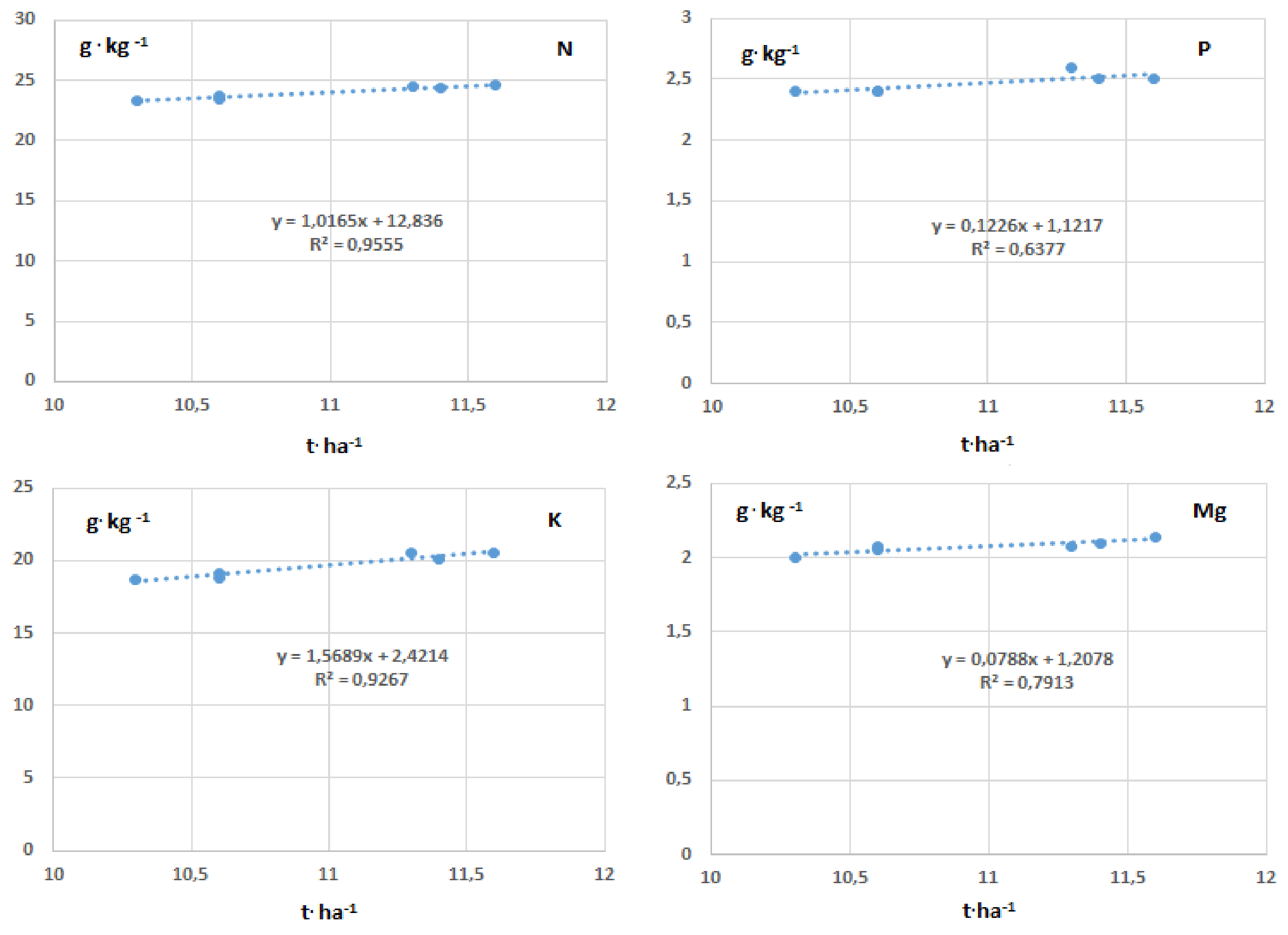
Source: own study / Źródło: opracowanie własne

3.1.5. Magnesium content in leaf dry matter

None of the examined experimental factors significantly influenced magnesium content in dry matter of maize leaf blades (Tab. 5).

4. Discussion

In addition to water, nitrogen fertilization is the basic agriculture factor which determines the quantity and quality of the obtained yield. The application of high nitrogen doses in market economy must be economically justified and should take into account both the ecological and economic aspects. For both of these reasons, it is important to diagnose the status of plant nutrition with nitrogen during the growing season, which allows to correct the applied doses. Assuming that maize tends to take up excessive amounts of nitrogen, it is essential to determine the minimum concentration of the component in the plant material that does not limit maize productivity. Maize leaf during flowering (BBCH 61) is the most frequently used part of the plant to assess maize nutritional status [7]. The greatest advantage of chemical leaf analysis during maize flowering period is the possibility of yield prediction [8]. However, the disadvantage of this method is the low practical usefulness of the obtained models or relationships [9]. Despite the proximity of the flowering period, there is no possibility of correcting maize nutritional status at this stage. This is due to the fact that this is the end of maize vegetative growth [9]. In the present study, nitrogen content in maize leaf blades was significantly determined by the interaction of the fertilization method with the type of maize hybrid. It was shown that the stay-green hybrid fertilized in rows was characterized by a much higher nitrogen content in maize leaves during the flowering period compared to the traditional variety. On the other hand, the difference between the tested varieties was statistically at the same level in the case of standard (broadcast) fertilization. The result obtained in this study demonstrated unequivocally that the “stay-green” variety was characterized by a significantly higher yield potential compared to the classic variety. A similar relationship as described above was noted for potassium content in leaf blades. This clearly proves that the “stay-green” type varieties respond better (positively) to the row application of NP fertilizer [10]. Such behavior of the studied cultivars results from different remobilization of nutrients during maize growth and development [11]. During the period of maize vegetative growth, the flow of nitrogen from the older organs of the plant to the younger ones occurs at a different rate, with soil resources being the dominant source of nitrogen. During the maturation phase, plant nitrogen balance undergoes significant changes. Nitrogen taken up from the soil is only a small part of the nutrient accumulated in the grain. Most of it is derived from the remobilization of this macronutrient from the previously accumulated pool in vegetative organs [12]. Hence, the main nitrogen source for grain in cereal plants, including maize, is the one remobilized from vegetative organs of the plant. In addition, the amount of nitrogen stored in plant vegetative organs during the flowering phase can be used to assess the amount of nitrogen available for this process, which was demonstrated in the present study. The type of plant determines natural dynamics of this element accumulation during the growing season.



Source: own study / Źródło: opracowanie własne

Fig. 3. The relationship between the content of N, P, K, Mg in maize leaves at the BBCH 61 stage and grain yield, regardless of the examined experimental factors (average for 2012-2014)

Rys. 3. Zależność pomiędzy zawartością N, P, K, Mg w liściach kukurydzy w stadium BBCH 61 a plonem ziarna, niezależnie od badanych czynników doświadczenia (średnia 2012-2014)

The classic model of nitrogen accumulation shows that plants accumulate 85-100% of this nutrient during the vegetative growth period, while the processes of re-mobilization of nitrogen organic compounds from the resources accumulated during vegetative growth take place already during the filling phase, and the uptake of nitrogen from soil resources should be considered as complementary. In the previous study [11], the classical model of nitrogen, phosphorus, potassium and magnesium accumulation was observed in the traditional hybrid. The organic compound re-mobilization index was positive in the traditional hybrid, which meant that this variety utilized the components previously accumulated during vegetative growth in the period of grain filling. In turn, a different accumulation model of nitrogen and other mineral components was recorded in the plants of the "stay-green" variety. The remobilization index, nitrogen, phosphorus and magnesium translocation was negative, and only positive for potassium. This indicated that soil resources were the main source of nitrogen accumulation during the generative growth phase. The lack of available forms of nitrogen, phosphorus and magnesium in the soil during the maturation period of "stay-green" maize may limit plants' yield in accordance with the law of J. von Liebig from 1840 [11]. According to this rule, expressing the yielding potential of a cultivated plant is not possible with a deficiency of even a single mineral component. The study also analyzed a simple correlation between the content of nutrients in maize leaf at the BBCH 61 stage and grain yield (Fig. 3). It was found that the higher the content of nutrients in the leaf blades during this development phase, the higher the maize grain yield. The relationship was described by the first degree equation.

5. Conclusions

1. The lack of differentiation in the nitrogen nutritional status of plants at the BBCH 61 stage, despite the considerable diversification of the experimental factor levels, indicated good conditions for the uptake of this nutrient until the flowering period.
2. Selection of the variety in combination with row NP fertilization is the factor supporting the nutritional status of maize at this stage.
3. A positive reaction to the row application of NP was shown by the "stay-green" variety, which resulted from a better supply in P and K.
4. Grain yield is positively correlated with the content of N, P, K and Mg in maize leaf blades at the BBCH 61 stage.

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