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REGULAR ARTICLE

Grain yield and yielding components of different types of corn cultivars (*Zea mays* L.) depending on method of nitrogen fertilizer application

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ABSTRACT

The paper presents the results of field tests intended to assess the yields of corn (*Zea mays* L.) with different genetic profiles, depending on the method of nitrogen fertilizer application. According to results of our study the corn grain moisture at harvest time was affected by variation in air temperature as well as amount of rainfall. It was demonstrated that start fertilization affected the grain yield beneficially, as compared to spread fertilization, both when employed exclusively and in combination with partial top dressing. The "stay-green" ES Paroli variety provided greater grain yield in comparison to the traditional variety (ES Palazzo) in all trial years and regardless of the year or fertilizing method. The number of produced cobs per unit of area, and the weight of 1000 grains were markedly higher for the stay-green hybrid. Variety had an opposite effect on the number of grains per cob.

Key Words: *corn; stay-green; type of nitrogen fertilizer; method of fertilization.*

INTRODUCTION

Grain yield size, apart from proper hybrid selection for cultivation, is influenced by nitrogen fertilization with maintaining a proper proportion of this macroelement and other mineral elements, e.g. phosphorus, potassium or magnesium (Costa et al. 2002). Corn (*Zea mays* L.) exhibits high nutritional and fertilization requirements, particularly in terms of nitrogen, and at the same time has low sensitivity to over-fertilization with this macroelement (Sinclair and Vadez, 2002). When nitrogen is applied before sowing, mainly by spread fertilization, there is a risk of this biogen being lost by leaching during long periods between sowing and corn emergence, what may contribute to nitrogen eutrophication of soil (Al-Kaisi and Yin 2003). Also according to Księżak et al. (2012), using high doses of nitrogen, particularly on light soils, creates a hazard for the environment. For this reason, multi-directional studies and tests are carried out on the possibilities of increasing the efficiency of the mineral fertilization used in corn growing, as well as rationalising the nitrogen management of this plant (Szulc et al. 2012, Szulc and Bocianowski 2012a). Aside from farming where obtaining hybrids with lower nitrogen demands is desirable (Presterl and Groh 1994), major possibilities of reducing the doses of this component and limiting its losses are presented by placing the fertilizer in direct vicinity of the corn grains (Tlustos et al. 1997, Kruczek 2005). Such application of the nutrient is called row, or starter fertilization (Kruczek and Szulc 2006). The lower volume of the fertilised soil in the case of row fertilization is compensated by the higher nutrient concentration, so consequently its intake per unit of fertilised soil volume is markedly higher in comparison to classical, spread application of fertilizer (Murphy 1984).

In the study hypothesis, it was assumed that the type of nitrogen fertilizer, method of its distribution and the genetic profile of the variety can significantly affect the range of corn grain yield. Therefore, field trials were established to determine the effects of nitrogen fertilizer application methods on the yields of two types of corn hybrids: traditional and stay-green, grown for grain.

MATERIALS AND METHODS

The field experiments were performed at the Department of Agronomy of Poznań University of Life Sciences, Institute for Education and Experiment in Swadzim (2009-2011). They were set up as 3-factor experiments in the "split-split-plot" system (random sub-blocks method), in 4 repetitions. The studied factors were: A - type of nitrogen fertilizer: ammonium saltpetre (NH_4NO_3), Canwil nitro-chalk (NH_4NO_3+$CaCO_3$+$MgCO_3$); B - method of fertilizer application: spread (entire nitrogen dose before corn sowing), row (entire nitrogen dosage at the time of corn sowing), row supplemented with top dressing [50 kg $N{\cdot}ha^{-1}$ of row fertilization at the time of corn sowing + 50 kg $N{\cdot}ha^{-1}$ of top dressing during the 5-6 leaves phase (BBCH 15/16)]; and C - corn hybrid type: traditional ES Palazzo and "stay-green" ES Paroli. In each year of the study, before the sowing, the same mineral fertilizers were applied to the entire experimental field in the following amounts: 100 kg $N{\cdot}ha^{-1}$ (fertilizer in accordance with the 1st degree factor), 80 kg $P_2O_5{\cdot}ha^{-1}$ (35.2 kg $P{\cdot}ha^{-1}$) as triple-granulated 46% superphosphate P_2O_5, and 120 kg $K_2O{\cdot}ha^{-1}$ (99.6 kg $K{\cdot}ha^{-1}$) as 60% potassium salt.

The experiment was conducted on luvisol, with the granulometric composition of shallow, light clay sand on light clay, belonging to the good rye soil class (IUSS Working Group WRB 2006). The content of humus in the arable layer (0-25 cm) in the years of research ranged from 1.41% to 1.46%. Content of mineral nitrogen in the soil was as follows: in the year 2009, 0-30 cm soil profile depth - 1.23 mg/100g $^{-1}$ soil dry weight; 31-60 cm soil profile depth -0.90 mg/100 g^{-1} soil dry weight; in the year 2011, 0-30 cm soil profile depth 1.47 mg/100g $^{-1}$ soil dry weight; 31-60 cm soil profile depth - 1.28 mg/100 g^{-1} soil dry weight. The contents of macroelements as well as soil pH determined in individual years of the study are presented in Figure 1. The number of productive ears/m^2 was determined, as well as other biometrical parameters, i.e. number of kernels in a cob and thousand grain weight, which were determined in 10 ears from each plot, collected before harvesting. Corn was harvested with a Wintersteiger field harvester, and the grain yield was recalculated to constant moisture of 15%. After the harvest, 250 g of grain was collected from each plot to determine the water content.

Weather data were obtained from a weather station located at the site of the Institute for Education and Experiment in Swadzim, at a distance of 200 m from the experimental field (Tab. 1). The highest mean daily air temperature during the growing period (IV-X) was recorded in 2011 (15.9^{o}C). In turn, the coldest vegetation season occurred in 2010 (14.5^{o}C). However, the air temperatures during the experiment years were generally beneficial for corn growth and development. Meaningful differences between the years were observed in the amount, or more specifically, the distribution of precipitation (Tab. 1) during the growing period. The highest amount of precipitation in the growing season was recorded in 2010 (500.7 mm), which was higher for 76.5 mm than the precipitation in growing season of 2011. It must be noted that, despite the lower amount of precipitation in the last year of the study, as much as 218.7 mm of rain fell in July, which contributed to slight, short-term inundations of the plants. It proves that precipitation during corn flowering is of greatest importance for grain yield formation, and that sum of precipitation is not as important as its favorable distribution in the whole growth and development season of the plant.

The obtained results were subjected to single-factor variance analysis for orthogonal factor experiments, and subsequently synthesis for multi-year experiments was performed. Significance of differences was assessed at $\alpha = 0.05$ with Tukey test. Statistical processing of the acquired data was performed using the STATPAK program.

Table 1. Air temperature and precipitation during growing period (2009-2011) in Swadzim

Years	APR	MAY	JUN	JUL	AUG	SEP	OCT	Mean – Sum
				Temperature in °C				
2009	12.9	14.0	16.0	20.3	20.1	15.8	7.6	15.2
2010	9.3	12.2	18.4	22.6	19.2	13.0	7.0	14.5
2011	12.4	15.5	19.9	18.5	19.5	15.9	9.8	15.9
1956-2008	8.1	13.4	16.7	18.5	17.9	13.6	8.8	13.8
Years				Rainfall in mm				
2009	19.2	109.9	113.8	75.4	26.2	48.6	59.2	452.3
2010	26.8	110.5	43.4	97.5	143.5	69.9	9.1	500.7
2011	9.8	22.5	66.5	218.7	50.5	28.5	27.7	424.2
1956-2008	32.6	52.3	57.0	72.2	56.9	43.2	38.4	352.6

RESULTS AND DISCUSSION

Corn grain moisture under the weather conditions of this study varied among years depending on the amount of rainfall and average daily air temperatures. The highest grain moisture content occurred during the harvest of 2010 (28.17%), and the lowest in 2011 (23.72%). Regardless of the year, only the hybrid has had a significant effect on the grain moisture content after harvest (Tab. 2). A markedly higher value of this trait was observed in the ES Paroli SG hybrid, as compared to the ES Palazzo variety. The difference between the studied variety types was 1.61% (Tab. 2). Szulc and Bocianowski (2012b) also noticed this kind of varietal difference in their research. They demonstrated that the "stay-green" variety was characterized by a higher moisture content in the grain, as compared to the traditional variety. This can be explained by the fact that in "stay-green" varieties, grain ripens while the stem remains green (Bekavac et al. 2002). Furthermore, "stay-green" hybrids are characterized by longer and more intensive nitrogen intake during grain filling, as compared to classic varieties, what delays their ripening (Szulc et al. 2012). The weather conditions modified the dry grain yield scale to the greatest extent (Tab. 3). Irrespective of examined factors of the experiment, the highest grain yield was achieved in 2009 (105.90 dt·ha^{-1}), and the lowest in 2010 (90.02 dt·ha^{-1}).

The worst conditions for corn yields were recorded in 2010, while the most beneficial – in 2009. The difference in mean grain yield between these years was 15.88 dt·ha^{-1} (Tab. 3). On average across years, nitrogen fertilization method and corn hybrid significantly affected grain yield as well (Tab. 3). The lowest grain yield was recorded for spread application of nitrogen, as compared to both row fertilization and row combined with top dressing during the 5-6 leaves stage (Tab. 3). There was no significant differences in corn yield between nitrogen fertilizers applied in rows, and the variant with the combination of row and top dressing during the 5-6 leaves stage. Kruczek (2005) concluded that starter application of nitrogen fertilizers or a multi-component fertilizer give better effects than their spread application, regardless of the meteorological conditions, level of nitrogen dosage, or fertilizer type. In general, considering the effects of the corn hybrid type on the grain yield, the "stay-green" variety (ES Paroli) achieved a markedly higher grain yield than the ES Palazzo hybrid. The difference between these two genotypes was 8.5 $dt \cdot ha^{-1}$ (Tab. 3).

Table 2. Influence of type of nitrogen fertilizer, method of fertilization and cultivar on corn grain moisture content [%]

Experimental factors		Years			Mean
		2009	2010	2011	
Type of nitrogen fertilizer (A)	ammonium saltpetre	25.67	28.09	23.69	25.82
	Canwil nitro-chalk	25.81	28.25	23.75	25.94
LSD $_{0.05}$		ns	ns	ns	ns
Method of fertilization (B)	broadcast	25.62	28.21	23.83	25.89
	in rows	25.81	28.29	23.68	25.93
	in rows + top -dressing	25.7	28.01	23.66	25.82
LSD $_{0.05}$		ns	ns	ns	ns
Cultivar (C)	ES Palazzo	25.31	28.38	22.60	25.43
	ES Paroli "stay -green"	26.17	27.96	24.85	26.33
LSD $_{0.05}$		0.315	0.247	0.223	0.243
Control [0 kg $N \cdot ha^{-1}$]	ES Palazzo	25.45	28.30	22.05	25.26
	ES Paroli "stay -green"	27.02	28.5	25.10	26.87
Mean		25.74	28.17	23.72	25.88

n.s. – non-significant differences

Table 3. Influence of type of nitrogen fertilizer, method of fertilization and cultivar on corn grain yield [$dt \cdot ha^{-1}$] (2009-2011)

Experimental factors		Years			Mean
		2009	2010	2011	
Type of nitrogen fertilizer (A)	ammonium saltpetre	107.30	89.60	104.48	100.46
	Canwil nitro-chalk	104.51	90.45	104.41	99.79
LSD $_{0.05}$		ns	ns	ns	ns
Method of fertilization (B)	broadcast	102.76	88.30	101.85	97.63
	in rows	107.46	91.91	105.20	101.52
	in rows + top -dressing	107.49	89.87	106.28	101.21
LSD $_{0.05}$		ns	ns	3.064	2.091
Cultivar (C)	ES Palazzo	100.68	86.34	100.83	95.95
	ES Paroli "stay -green"	111.12	93.71	108.05	104.30
LSD $_{0.05}$		3.547	1.295	1.441	2.549
Control [0 kg $N \cdot ha^{-1}$]	ES Palazzo	76.82	75.23	84.03	78.69
	ES Paroli "stay -green"	78.93	77.90	89.55	82.12
Mean		105.90	90.02	104.44	100.12

n.s. – non-significant differences

It must be noted that in each year of the experiment, the "stay-green" variety had a significantly higher grain yield, as compared to the traditional hybrid (by 10.44 dt·ha^{-1}; 7.37 dt·ha^{-1}; 7.22 dt·ha^{-1}, respectively). According to Szulc and Bocianowski (2012a), the "stay-green" variety's nitrogen management is more effective than that of the traditional hybrid. This is decisive for the higher yield potential, a capability to form generative and vegetative plant parts, as compared to traditional varieties, which was demonstrated in this study.

The grain yield in our research was also influenced by the interaction between the nitrogen fertilizer application method and the corn hybrid type (Fig. 2A). With all of the tested nitrogen application methods, the SG ES Paroli hybrid achieved significantly higher yield than the ES Palazzo hybrid. These differences ranged from 5.97 dt·ha^{-1} in spread application, to 11.55 dt·ha^{-1} in row fertilization combined with top dressing during the 5-6 leaves stage (Fig. 2B). Significantly higher yield was obtained with row fertilization combined with top dressing in comparison with other applied methods of fertilization (Fig. 2B). The result obtained in our research is a confirmation of the previous reports stating that in the case of "stay-green" variety, the main source of nitrogen during the grain filling stage are soil resources rather than nitrogen accumulated in the plant in the vegetative biomass before the flowering phase (Szulc et al., 2012). The above statement clearly indicates that nitrogen from the nitrogen dose applied in the split dose system is released according to the dynamics of such varieties' demand for nitrogen.

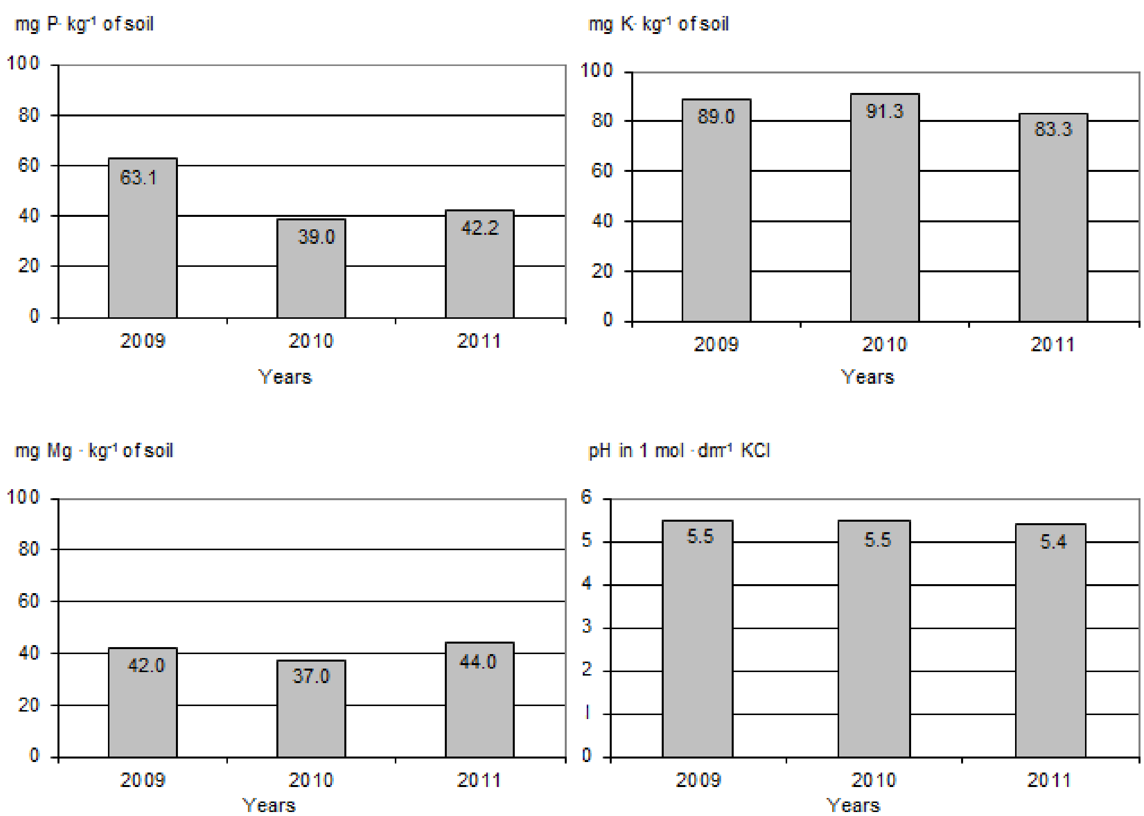

Figure 1. Soil content of nutrients and soil pH in corn growing period (2009-2011)

Table 4. Influence of type of nitrogen fertilizer, method of fertilization and cultivar on corn yield parameters (2009 - 2011)

Experimental factors		Number of productive ears/m²	Number of kernels in cob	Thousand kernel weight (g)
Type of nitrogen fertilizer (A)	ammonium saltpetre	7.60	532.1	358.8
	Canwil nitro-chalk	7.64	525.9	341.1
LSD 0.05		ns	ns	ns
Method of fertilization (B)	broadcast	7.55	525.7	343.3
	in rows	7.68	537.1	362.8
	in rows + top -dressing	7.62	527.2	343.7
LSD 0.05		ns	ns	ns
Cultivar (C)	ES Palazzo	7.38	572.8	330.8
	ES Paroli "stay -green"	7.85	487.2	369.1
LSD 0.05		0.278	27.439	7.957
Control [0 kg N·ha⁻¹]	ES Palazzo	7.36	518.5	310.2
	ES Paroli "stay -green"	7.47	440.8	345.1
Mean		7.62	530.0	349.9

n.s. – non-significant differences

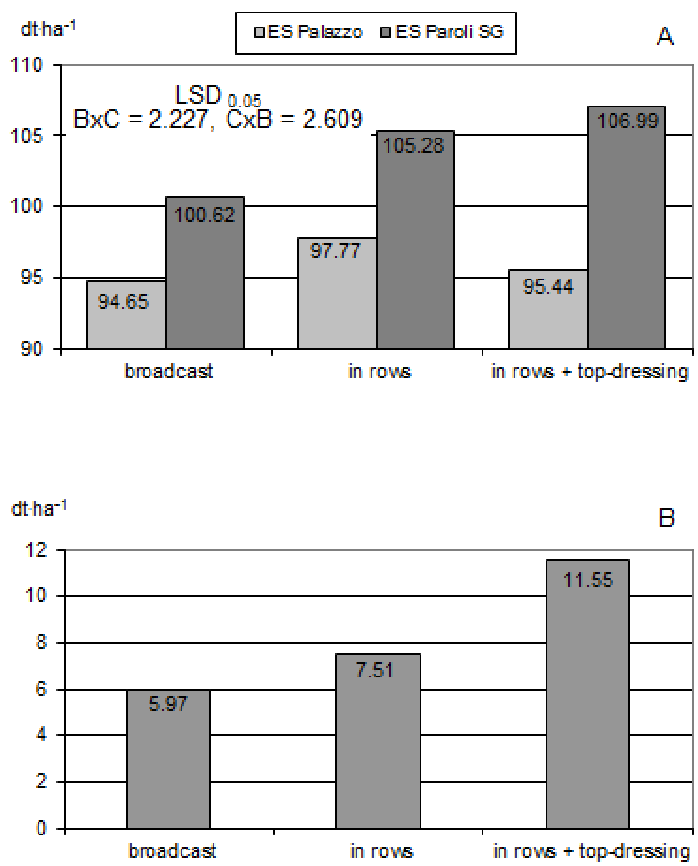

Figure 2. Yield of corn grain as affected by interaction of fertilization method and type of corn hybrid (A), and grain yield increase (B)

In terms of grain yield components, the direction of changes under the effects of the studied factors was similar for each year, and the statistically confirmed interaction was solely the result of differences in the scale of the factor's impact during individual years of the experiment. Thus, in order to present this relation more clearly, the influences of the nitrogen fertilizer type, fertilizer application methods and the corn hybrid type on the yield parameters were presented as an average of all years of the study (Tab. 3). Grain yield structure analyses showed that the number of developed cobs per unit of area, 1000 grains weight and the number of grains per cob changed significantly only under hybrid type influence (Tab. 4). The effect of this factor was year-dependent. A markedly higher number of cobs per unit of area, and weight of 1000 grains were recorded for the SG ES Paroli hybrid, in comparison to the ES Palazzo variety (Tab. 3). When the number of grains per cob was concerned, a significantly higher number was noted for ES Palazzo than for ES Paroli SG (Tab. 4). Rajcan and Tollenaar (1999) reported that the grain filling period depends on factors responsible for the persistence of the green colour of leaves and on the mobilization rate of nitrogen and assimilates from the vegetative parts of corn plant. At the end of the vegetation period, owing to the vegetative green parts that still remain active, the "stay-green" variety continues the assimilation, often until the grain is completely ripe, so a higher weight of 1000 grains is to be expected, as compared to the classical variety.

The number of grains per cob in our research was significantly affected by the interaction of the nitrogen fertilizer type and the corn hybrid type (Fig. 3). Regardless of the nitrogen fertilizer type, the ES Palazzo hybrid produced a higher number of grains per cob than did SG ES Paroli. On the other hand, the use of Canwil nitro-chalk with the SG ES Paroli variety reduced grain number per cob in comparison with the application of ammonium saltpetre (Fig. 3).

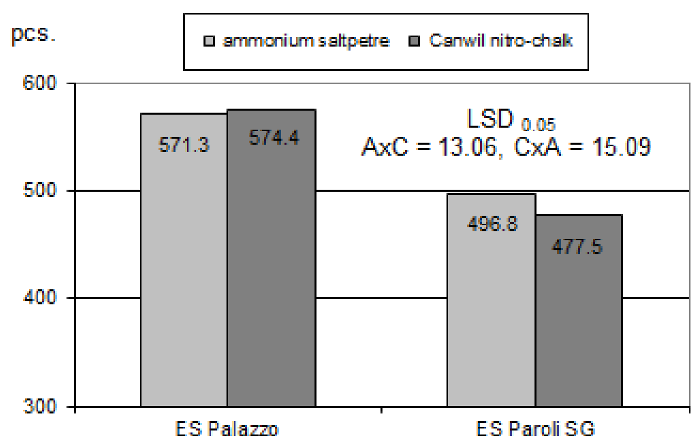

Figure 3. Number of grains per ear as affected by interaction of type of nitrogen fertilizer and type of corn hybrid

CONCLUSIONS

1. Starter fertilization beneficially affected the grain yield, as compared to spread fertilization, both when using a full dose of 100 kg $N \cdot ha^{-1}$ and when applying only 50 kg $N \cdot ha^{-1}$ supplemented with top dressing.
2. The "stay-green" variety provided greater grain yield in comparison to the traditional variety in all test years and regardless of the year.
3. The "stay-green" variety reacted to the splitting of the nitrogen dose with greater grain yield increase than the traditional variety. The splitting of the nitrogen dose into pre-sowing,

row-applied, and the top dressing parts resulted with a grain yield increase in the "stay-green" variety.

4. The "stay-green" hybrid produced a greater number of cobs per unit of area, larger grains (1000 grain weight), as well as a lower number of grains per cob, as compared to the traditional hybrid.

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