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The effect of soil supplementation with different forms of nitrogen fertilizer on modification of generative yield in two different types of maize (*Zea mays* L.) hybrids

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Abstract. The paper presents results of field trials, the aim of which was to evaluate the effect of soil supplementation with different forms of nitrogen fertilizers and with magnesium in the modification of generative yield in two different types of maize cultivars. The study determined grain yield at a 15% moisture content, grain moisture content, grain yield components, i.e. the number of productive ears per unit area, thousand kernel weight, number of kernels per ear and the number of kernel rows per ear as well as the number of kernels per row. Moreover, correlation coefficients were calculated for correlations between analysed traits. It was shown that the type of nitrogen fertilizer and the dose of magnesium did not differentiate significantly grain water content during maize harvest and grain yield volume. Among analysed nitrogen fertilizers, slow-release fertilizers such as ammonium sulfate, urea and an ammonium nitrate and urea mixture with a 50% proportion of each fertilizer in the component dose proved to be the most advantageous variants in terms of grain yield for the stay-green cultivar. For each of the tested nitrogen fertilizers except for ammonium sulfate the application of 25 kg MgO ha^{-1} resulted in an increase of grain yield in relation to the treatment where this nutrient was not used. A combined ammonium sulfate fertilization with 25 kg MgO ha^{-1} reduced grain yield. For both maize cultivars tested in the experiment at each form of nitrogen fertilization and at the absence of fertilization statistically significant positive correlations were found between the number of kernels in the ear and the number of kernels in the row.

keywords: maize, stay-green, nitrogen fertilizer, grain yield, grain yield structure

INTRODUCTION

The primary aspect of sustainable farming is connected with balanced fertilization, which should comprise all nutrients required for appropriate plant growth (Grzebisz, 2002). Providing optimal levels of plant growth factors, including nutrient availability, ensures the full utilization of yielding potential. Maize is characterised by a considerable natural nutrient uptake capacity at continuous fertilization; however, without a simultaneous improvement of soil fertility or a simultaneous regulation of soil reaction high yields may not be produced. Thus doses of mineral fertilizers should correspond to nutrient requirements, taking into consideration absorbable amounts of nutrients (Zeidan et al., 2006).

Maize is characterized by a very slow initial growth rate and up to the four-leaf stage it absorbs only approximately 2–3% N, while in the period of ripening it is approximately 12–13% N. Most of the total amount of absorbed N (approximately 85%) is taken up by maize starting from the four-leaf stage up to the blister stage (Grzebisz, 2002; Grzebisz and Gaj, 2007). Thus it is recommended to apply slow-release nitrogen fertilizers in order to satisfy nitrogen requirement of maize connected with the dynamics of this nutrient uptake at the initial development stages. These conditions are met by the conventional nitrogen fertilizers such as e.g. urea. This fertilizer contains nitrogen in the amide form, which in soil is converted to the ammonium form available for plants, and next to the nitrate form. These processes occur slowly in the soil medium, thus it is a typical slow-release fertilizer. The action of urea is accelerated with growing soil temperature (increasing with the progressing plant vegetation). Thus the application of slow-release nitrogen fertilizers is meant to provide a lower concentration of mineral nitrogen in the soil than that resulting from the application of standard fertilizers. Decomposition of such fertilizers is a slow process and the gradually released nitrogen is quickly absorbed by plants, which prevents its losses caused by leaching.

In literature on the subject we may find publications concerning fertilization of maize using different forms of nitrogen fertilizers (Borowiecki and Koter, 1983a, 1983b;

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Hammad et al., 2011; Kruczek, 2005; Mordogan et al., 2004; Uziak et al., 1993). However, there are practically no reports in literature presenting a comparison of response of individual maize cultivar types to different forms of nitrogen fertilizers. From the scientific point of view it is a very important problem, since a stay-green hybrid is characterised by a negative nitrogen remobilisation (translocation) index, i.e. in the period of generative yield formation soil resources are the decisive sources of this nutrient (Szulc et al., 2012). Thus in the cultivation of such cultivars we need to apply only slow-release nitrogen fertilizers.

For this reason studies were undertaken to evaluate the response of two different maize cultivar types grown for grain to soil supplementation with different forms of nitrogen fertilizers and with magnesium.

MATERIAL AND METHODS

Field experiment

The field experiment was conducted at the Swadzim Experimental Station of the Department of Agronomy, the Poznań University of Life Sciences in the years of 2009–2011. It was run as the split-plot design with three experimental factors in four field replications. The first-order factor comprised forms of nitrogen fertilizers at six levels (Table 1), the second-order factor – two levels of magnesium: 0 kg MgO ha^{-1} and 25 kg MgO ha^{-1}, while the third-order factor – types of maize cultivars, i.e. ES Palazzo and ES Paroli SG (stay-green). In each year of the study prior to the establishment of the experiment identical mineral fertilization was applied over the entire experimental plot at 120 kg $N \cdot ha^{-1}$ (in accordance with the level of the first-order factor), 80 kg P_2O_5 ha^{-1} (35.2 kg P ha^{-1}) in the form of pelleted triple superphosphate 46% P_2O_5, 120 kg K_2O ha^{-1} (99.6 kg K ha^{-1}) in the form of a 60% potash salt. Magnesium was applied in the form of kieserite (25% MgO, 50% SO_3 – 20% S, sulfate sulfur). The field experiment was conducted on grey-brown podsolic soil, of light loamy sands, in shallow deposits over light loam belonging to the good rye complex. The soil contents of basic nutrients and soil pH in individual years of the study are given in Table 2.

Maize sowing rate in all the fertilizer combinations was the same and amounted to 7.93 pcs. m^{-2} (79,300 pcs. ha^{-1}).

Biometric measurements were taken on 10 ears from each plot. The harvested plot was 15.4 m^2. Maize was harvested using a maize combine harvester by Wintersteiger and grain yield was calculated in terms of a constant moisture content of 15%, according to the following formula:

$$P = 0.85 \cdot P_o(100 - Z_w)$$

where:
P – denotes the yield of grain at a 15% moisture content,
P_o – fresh matter yield of threshed grain [kg],
Z_w – water content in threshed grain [%].

After maize harvest an amount of 250 g grain was collected from each plot in order to determine grain water contents.

Thermal and humidity conditions

Thermal and humidity conditions for maize growth and development varied greatly during the growing period in individual years of the experiments. The effect of the thermal as well as humidity factors may be best illustrated in a comprehensive manner by the hydrothermal coefficient of water supply [S] according to Sielianinov (Molga, 1986) (Table 3).

$$S = \frac{10 \cdot \text{monthly precipitation total [mm]}}{\text{the number of days} \cdot \text{mean monthly diurnal air temperature [°C]}}$$

The optimal value of this coefficient is 1. Values below 1 indicate the drought period, while values above 1 – the period of relative humidity.

Statistical analysis

Firstly, the normality of distribution for grain yield, the number of ears, thousand kernel weight, the number of kernels, the number of rows per ear, the number of kernels per row as well as kernel moisture content were tested using the Shapiro-Wilk normality test (Shapiro and Wilk, 1965). The four-way analysis of variance (ANOVA) was carried out to determine the effect of years (Y), forms of nitrogen fertilizers (N), levels of magnesium (Mg), type of cultivars (C), and the Y×N, Y×Mg, Y×C, N×Mg, N×C,

Table 1. Characteristics of levels for the first-order factor.

No.	Form of nitrogen fertilizer	Chemical formula	Nitrogen content [%]	Contents of other components [%]	Release rate#
1	no fertilizer				
2	ammonium nitrate	NH_4NO_3	34	-	+
3	ammonium sulfate	$(NH_4)_2SO_4$	21	24 S	-
4	urea	$CO(NH_2)_2$	46	-	-
5	Canwil nitro-chalk	$NH_4NO_3 + CaCO_3 + MgCO_3$	27	4 MgO 7 CaO	+
6	ammonium nitrate (50% dose of N) + urea (50% dose of N)	$NH_4NO_3 + CO(NH_2)_2$	-	-	-/+

- slow-release fertilizer, + quick-action fertilizer

Table 2. Nutrient status of soil at Swadzim.

Specification	Years 2009	2010	2011
P [mg P kg^{-1} of soil]	31.7	36.1	16.7
K [mg K kg^{-1} of soil]	97.1	45.6	63.9
Mg [mg Mg kg^{-1} of soil]	69.0	34.0	62.0
pH [in 1 mol dm^{-3} KCl]	5.3	7.6	5.1

The assessment of the content of macroelements, pH was conducted according to research procedures/standards (the Regional Chemical and Agricultural Station in Poznań):
P_2O_5 – PB.64 ed. 6 of 17.10.2008; K_2O – PB.64 ed. 6 of 17.10.2008
Mg – PB.65 ed. 6 of 17.10.2008; pH – PB.63 ed. 6 of 17.10.2008

Table 3. Meteorological conditions during the research period.

Months	2009 T	2009 P	2009 S	2010 T	2010 P	2010 S	2011 T	2011 P	2011 S
April	12.9	19.2	0.49	9.30	26.8	0.96	12.4	9.80	0.26
May	14.0	110.0	2.53	12.2	111.0	2.92	15.5	22.5	0.46
June	16.0	114.0	2.37	18.4	43.4	0.78	19.9	66.5	1.11
July	20.3	75.4	1.19	22.6	97.5	1.39	18.5	219	3.81
August	20.1	26.2	0.42	19.2	144.0	2.41	19.5	50.5	0.83
September	15.8	48.6	1.02	13.0	69.9	1.79	15.9	28.5	0.59
October	7.6	59.2	2.51	7.0	9.1	0.42	9.8	27.7	0.91
April – – October	15.2	452.6	1.50	14.5	501.7	1.52	15.9	424.5	1.13

T – average monthly air temperature [°C]
P – monthly amount of precipitation [mm]
S – hydrothermal coefficient of water supply according to Sielianinov (Molga, 1986)

Mg×C, Y×N×Mg, Y×N×C, Y×Mg×C, N×Mg×C and Y×N×Mg×C interactions on the variability of the observed traits. Least significant differences (LSDs) were calculated for each trait. The relationships between the traits were estimated using correlation coefficients.

RESULTS AND DISCUSSION

Variability of analysed traits for the period of the three years of field experiments, caused by the form of nitrogen fertilizer and the type of maize hybrid, irrespective of magnesium doses, is presented in Tables 4 and 5. A greater variation in the analysed traits was found for cv. ES Palazzo than ES Paroli SG. This is manifested by the fact that the stay-green hybrid is characterised by more uniform values of the traits in relation to the traditional form. Values of individual traits are more stable and do not fluctuate under the influence of variable weather conditions. In turn, the response of ES Palazzo hybrid to changing weather conditions was more marked, as confirmed by greater coefficients of variation. In earlier investigations Szulc and Bocianowski (2011) obtained a similar dependence of the effect of the maize hybrid type in the modification of values for the analysed traits.

Although kernel moisture content in maize at harvest is not a yield-forming factor, it may still influence production costs as a result of outlays incurred for drying, thus determining the profitability of production (Szulc and Bocianowski, 2011). According to Sulewska (1997), forced drying of grain after harvest accounts for as much as 32.3% of the direct costs of growing in case of this crop. Grain water content during harvest of maize was modified by the variable weather conditions between the years of the study ($P < 0.001$). The highest water content in grain (29.6%) was recorded in 2010 (the highest precipitation total for the April–October period of 501.7 mm), while the lowest was observed in 2011 (24.0) (Table 6).

The lowest water content in grain in 2011 resulted from a deficit of precipitation in August (S = 0.83), September (S = 0.59) and October (S = 0.91) (Table 3). On average in the three years of the study only the maize hybrid type significantly modified water content in grain ($P < 0.001$). Significantly higher kernel water content during harvest was found for grain of the hybrid ES Paroli SG in comparison to cv. ES Palazzo. This difference was 1.3% (Table 6). The above mentioned dependence was observed in each of the three years of the study (1.7% in 2009, 0.6% in 2010, and 1.5% in 2011). The result recorded in this study confirms earlier literature sources (Szulc et al., 2008a). In this study it was also shown that the stay-green hybrid was characterised by a lower water content (by 2.8%) in kernels during threshing in comparison to the traditional cultivar.

The recorded results indicate that weather conditions varying between the years of the study had a significant effect on the volume of the obtained yield of kernels ($P < 0.001$). When averaged over a long-term period the lowest yield of grain was recorded in 2010 (93.9 dt ha^{-1}), while the highest – in 2009 (107 dt ha^{-1}) (Table 7). Overall in the synthetic approach for the three-year period the volume of grain yield was significantly modified by the type of nitrogen fertilizer ($P < 0.001$) and the type of maize hybrid ($P < 0.001$). In the case of magnesium levels the differences were not significant statistically ($P = 0.226$). The only observed trend towards an increased yielding (by 1.0 dt ha^{-1}) was found at a dose of 25 kg MgO ha^{-1} in comparison to the treatment with no magnesium applications. Earlier studies (Szulc et al., 2008b) indicated a significant increase in grain yield by 7.35 dt ha^{-1} as a result of a combined NPK fertilization with 25 kg MgO ha^{-1} in relation to the NPK application alone. When investigating the effect of nitrogen fertilizer in the modification of the generative yield it was found that maize yielded the lowest in the treatment with no nitrogen fertilization applied in comparison to the other applied forms of nitrogen fertilizers, for which grain yield remained statistically the same (Table 7). Also Kruczek (2005) in his four-year field

Table 4. Variation of investigated traits in maize cv. ES Palazzo.

Trait	Value of trait			Standard deviation	Coefficient of variation [%]
	minimal	maximal	mean		
No nitrogen fertilizer					
Number of ears [ears m^{-2}]	6.15	7.36	7.01	0.402	5.73
1000 kernel weight [g]	303	335	320	12.0	3.74
Number of kernels in ear [pcs]	528	591	565	20.1	3.55
Yield of kernels [dt ha^{-1}]	76.6	91.1	83.7	6.44	7.70
Grain moisture content [%]	25.3	27.5	26.4	0.62	2.33
Number of rows in ear [pcs]	14.9	15.6	15.2	0.26	1.72
Number of kernels in row [pcs]	34.0	38.2	37.1	1.39	3.74
Ammonium nitrate NH_4NO_3					
Number of ears [ears m^{-2}]	7.28	8.21	7.64	0.32	4.21
1000 kernel weight [g]	313	341	333	9.38	2.82
Number of kernels in ear [pcs]	581	616	595	11.2	1.88
Yield of kernels [dt ha^{-1}]	91.1	110	98.3	6.03	6.14
Grain moisture content [%]	25.7	26.9	26.1	0.41	1.56
Number of rows in ear [pcs]	14.9	15.7	15.2	0.26	1.73
Number of kernels in row [pcs]	38.1	39.6	39.1	0.55	1.42
Ammonium sulfate $(NH_4)_2SO_4$					
Number of ears [ears m^{-2}]	6.71	7.39	7.03	0.231	3.29
1000 kernel weight [g]	305	345	326	4.19	3.64
Number of kernels in ear [pcs]	566	606	588	15.4	2.62
Yield of kernels [dt ha^{-1}]	90.2	101	96.0	3.87	4.04
Grain moisture content [%]	25.7	26.6	26.1	0.38	1.44
Number of rows in ear [pcs]	15.0	16.0	15.4	0.30	1.95
Number of kernels in row [pcs]	36.6	39.9	38.3	1.23	3.21
Urea $CO(NH_2)_2$					
Number of ears [ears m^{-2}]	6.95	7.59	7.33	0.22	2.94
1000 kernel weight [g]	320	342	333	6.62	1.99
Number of kernels in ear [pcs]	566	636	595	26.3	4.41
Yield of kernels [dt ha^{-1}]	93.1	109	97.7	4.89	5.01
Grain moisture content [%]	25.4	27.0	26.3	0.50	1.91
Number of rows in ear [pcs]	14.9	16.3	15.4	0.47	3.08
Number of kernels in row [pcs]	37.1	39.9	38.7	0.81	2.09
Canwil nitro-chalk $NH_4NO_3 + CaCO_3 + MgCO_3$					
Number of ears [ears m^{-2}]	6.74	7.76	7.26	0.33	4.54
1000 kernel weight [g]	318	353	333	13.2	3.96
Number of kernels in ear [pcs]	554	619	600	22.5	3.74
Yield of kernels [dt ha^{-1}]	92.1	105	97.7	4.69	4.79
Grain moisture content [%]	25.3	27.3	26.0	0.60	2.29
Number of rows in ear [pcs]	15.2	15.9	15.6	0.23	1.48
Number of kernels in row [pcs]	36.0	39.5	38.6	1.20	2.85
Ammonium nitrate + urea $NH_4NO_3 + CO(NH_2)_2$					
Number of ears [ears m^{-2}]	6.74	8.25	7.31	0.47	6.45
1000 kernel weight [g]	327	344	334	6.74	2.02
Number of kernels in ear [pcs]	563	608	593	14.5	2.44
Yield of kernels [dt ha^{-1}]	93.3	103	98.9	3.22	3.25
Grain moisture content [%]	25.2	26.6	25.9	0.54	2.08
Number of rows in ear [pcs]	14.5	15.7	15.3	0.40	2.60
Number of kernels in row [pcs]	37.9	39.6	38.8	0.51	1.30

Table 5. Variation of investigated traits in maize cv. ES Paroli SG.

Trait	Value of trait			Standard deviation	Coefficient of variation [%]
	minimal	maximal	mean		
No nitrogen fertiliser					
Number of ears [ears m^{-2}]	7.02	7.67	7.40	0.19	2.63
1000 kernel weight [g]	310	363	349	16.53	4.74
Number of kernels in ear [pcs]	432	510	472	27.2	5.77
Yield of kernels [dt ha^{-1}]	83.1	99.4	92.4	6.31	6.83
Grain moisture content [%]	26.4	28.8	27.7	0.72	2.62
Number of rows in ear [pcs]	12.8	14.1	13.3	0.41	3.05
Number of kernels in row [pcs]	33.0	37.1	35.5	1.41	3.98
Ammonium nitrate NH_4NO_3					
Number of ears [ears m^{-2}]	7.41	8.16	7.65	0.25	3.22
1000 kernel weight [g]	359	383	373	7.41	1.98
Number of kernels in ear [pcs]	482	522	498	16.2	3.25
Yield of kernels [dt ha^{-1}]	104	113	107	3.14	2.93
Grain moisture content [%]	26.5	28.3	27.4	0.53	1.94
Number of rows in ear [pcs]	12.9	13.7	13.2	0.23	1.76
Number of kernels in row [pcs]	36.9	39.2	37.8	0.79	2.10
Ammonium sulfate $(NH_4)_2SO_4$					
Number of ears [ears m^{-2}]	7.39	8.27	7.79	0.28	3.63
1000 kernel weight [g]	348	382	364	12.20	3.35
Number of kernels in ear [pcs]	487	540	500	18.5	3.70
Yield of kernels [dt ha^{-1}]	106	118	112	4.26	3.80
Grain moisture content [%]	26.5	29.0	27.7	0.80	2.91
Number of rows in ear [pcs]	12.9	13.9	13.3	0.34	2.55
Number of kernels in row [pcs]	36.6	38.9	37.7	0.81	2.15
Urea $CO(NH_2)_2$					
Number of ears [ears m^{-2}]	7.39	8.93	7.84	0.49	6.25
1000 kernel weight [g]	340	382	372	8.10	2.18
Number of kernels in ear [pcs]	486	511	498	9.29	1.87
Yield of kernels [dt ha^{-1}]	105	115	111	3.90	3.50
Grain moisture content [%]	26.2	28.0	27.3	0.58	2.12
Number of rows in ear [pcs]	12.8	13.5	13.3	0.21	1.56
Number of kernels in row [pcs]	36.6	38.3	37.6	0.68	1.81
Canwil nitro-chalk $NH_4NO_3 + CaCO_3 + MgCO_3$					
Number of ears [ears m^{-2}]	7.11	9.04	7.66	0.63	8.20
1000 kernel weight [g]	364	384	373	5.93	1.59
Number of kernels in ear [pcs]	481	512	495	10.5	2.12
Yield of kernels [dt ha^{-1}]	97.9	113	107	4.38	4.10
Grain moisture content [%]	27.1	28.0	27.4	0.31	1.12
Number of rows in ear [pcs]	12.8	13.3	13.1	0.21	1.59
Number of kernels in row [pcs]	36.6	39.0	37.8	0.78	2.06
Ammonium nitrate + urea $NH_4NO_3 + CO(NH_2)_2$					
Number of ears [ears m^{-2}]	7.53	8.11	7.75	0.17	2.25
1000 kernel weight [g]	365	383	373	5.46	1.47
Number of kernels in ear [pcs]	469	522	496	15.6	3.15
Yield of kernels [dt ha^{-1}]	108	115	112	2.71	2.42
Grain moisture content [%]	26.6	28.2	27.3	0.54	1.98
Number of rows in ear [pcs]	12.9	13.7	13.2	0.21	1.59
Number of kernels in row [pcs]	36.3	38.3	37.5	0.74	1.96

Table 6. Grain moisture content [%] (± standard deviation).

	Factor	Years			Mean
		2009	2010	2011	
Form of nitrogen fertilizer	no fertilizer	27.2 ±1.25	29.8 ±1.44	24.1 ±1.02	27.0 ±2.64
	NH_4NO_3	26.9 ±1.14	29.5 ±1.13	23.8 ±1.08	26.8 ±2.59
	$(NH_4)_2SO_4$	27.0 ±1.43	29.7 ±1.47	24.0 ±0.86	26.9 ±2.67
	$CO(NH_2)_2$	26.6 ±1.13	29.8 ±1.37	24.0 ±0.91	26.8 ±2.66
	$NH_4NO_3 + CaCO_3 + MgCO_3$	26.5 ±1.30	29.6 ±1.39	24.1 ±1.06	26.7 ±2.58
	$NH_4NO_3 + CO(NH_2)_2$	26.8 ±0.95	29.3 ±1.48	23.9 ±1.02	26.6 ±2.50
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Dose of magnesium [kg MgO ha^{-1}]	0	26.8 ±1.20	29.7 ±1.28	23.9 ±0.98	26.8 ±2.65
	25	26.9 ±1.25	29.5 ±1.44	24.1 ±0.97	26.8 ±2.53
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Hybrid type	ES Palazzo	26.0 ±0.76	29.3 ±1.40	23.2 ±0.63	26.2 ±2.66
	ES Paroli SG	27.7 ±0.85	29.9 ±1.24	24.7 ±0.62	27.5 ±2.34
$LSD_{0.05}$		0.29	0.25	0.28	0.15
Mean		26.9 ±1.20	29.6 ±1.36	24.0 ±0.97	-

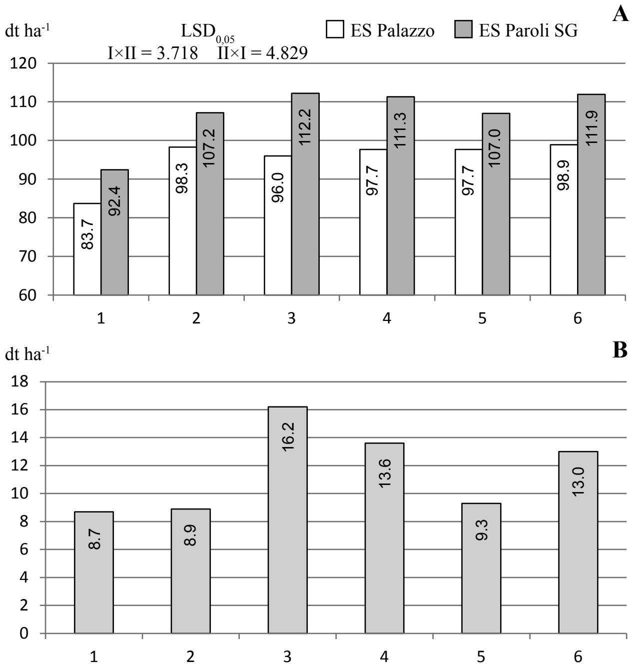
n-s.d. – non-significant difference at P = 0.05

Table 7. Yield of kernels [dt ha^{-1}] 15% H_2O (± standard deviation).

	Factor	Years			Mean
		2009	2010	2011	
Form of nitrogen fertilizer	no fertilizer	81.2 ±18.7	88.2 ±9.60	94.8 ±4.00	88.0 ±13.3
	NH_4NO_3	111 ±13.9	94.4 ±8.50	103.1 ±4.60	103 ±11.7
	$(NH_4)_2SO_4$	114 ±13.9	94.4 ±10.2	103.9 ±7.80	104 ±13.4
	$CO(NH_2)_2$	112 ±13.7	95.6 ±9.80	106.2 ±6.40	104 ±12.2
	$NH_4NO_3 + CaCO_3 + MgCO_3$	109 ±5.60	95.0 ±11.0	103.5 ±7.30	102 ±9.90
	$NH_4NO_3 + CO(NH_2)_2$	114 ±9.4	95.8 ±9.40	107 ±7.60	105 ±11.5
$LSD_{0.05}$		12.2	3.25	2.38	4.05
Dose of magnesium [kg MgO ha^{-1}]	0	105 ±16.8	93.6 ±10.5	103 ±8.10	100 ±13.3
	25	108 ±17.9	94.2 ±9.30	103 ±6.80	101 ±13.5
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Hybrid type	ES Palazzo	101 ±15.3	85.8 ±5.50	99.7 ±5.40	95.4 ±12.0
	ES Paroli SG	113 ±17.3	102 ±5.70	106 ±7.70	107 ±12.2
$LSD_{0.05}$		3.30	2.42	2.22	1.52
Mean		107 ±17.3	93.9 ±9.90	103 ±7.40	-

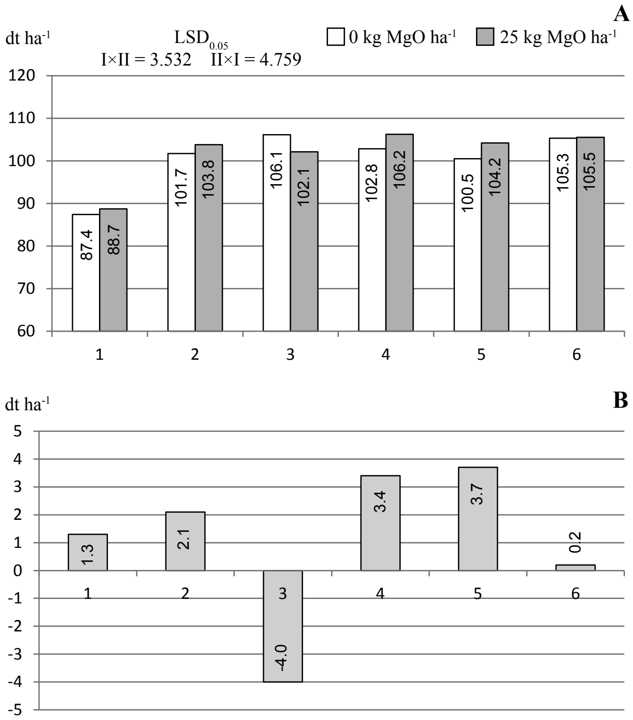
n-s.d. – non-significant difference at P = 0.05

trial showed no significant effect of the nitrogen fertilizer type (urea – 86.4 dt ha^{-1}, ammonium nitrate – 86.5 dt ha^{-1}, hydrofoska – 87.3 dt ha^{-1}) on grain yield. In the case of maize hybrid type it was found that cv. ES Paroli SG yielded significantly higher (by 11.6 dt ha^{-1}) than cv. ES Palazzo (Table 7). A similar effect of the form of nitrogen fertilizer and the type of maize hybrid in the modification of generative yield was recorded in each of the three years of the field experiment. The result recorded in this study is consistent with the earlier report by Szulc et al. (2008a). Those researchers showed that, irrespective of nitrogen and magnesium doses, the stay-green hybrid yielded higher by 0.80 t ha^{-1} in comparison to the traditional cultivar. In turn, in another study (Szulc and Bocianowski, 2011) the difference between the stay-green hybrid and the traditional cultivar in terms of the produced generative yield was 0.98 t ha^{-1}. Moreover, in this study an interaction was found for the form of nitrogen fertilizer and the type of maize hybrid on grain yield (Fig. 1). Higher yields for each of the tested nitrogen fertilizers were observed for the stay-green hybrid in comparison to the traditional hybrid. The difference between the tested cultivars ranged from 8.70 dt ha^{-1} to 16.2 dt ha^{-1}. In the case of slow-release fertilizers, such as ammonium sulfate, urea and a mixture of ammonium



1, 2, 3, ..., 6 – form of fertilizer (see Table 1)

Fig. 1. Interaction between the form of nitrogen fertilizer (I) and maize hybrid type (II) in modification of grain yield volume (A) and increment in grain yield (B) (2009–2011).



1, 2, 3, ..., 6 – form of fertilizer (see Table 1)

Fig. 2. Interaction of the form of nitrogen fertilizer (I) and magnesium dose (II) in modification of grain yield volume (A) and increment in grain yield (B) (2009–2011).

nitrate with urea, the advantage of the stay-green cultivar was significantly greater than in treatments with no nitrogen fertilizer applied, ammonium nitrate and a nitro-chalk Canwil. The result recorded in this study is a confirmation of earlier literature reports indicating that the behaviour of the stay-green plants should imply the slow-release fertilization system. This is determined by the negative remobilisation coefficient (nitrogen translocation) at the kernel filling stage (Szulc et al., 2012). In that stage the primary source of nitrogen accumulation is supplied by soil resources rather than nitrogen accumulated in plants before the flowering stage in the vegetative biomass. It clearly results from the above considerations that the release of nitrogen from slow-release fertilizers occurs according to the dynamics of demand for nitrogen by this type of cultivars. Thus in the autumn after harvest of the stay-green maize hybrid plants there is less mineral nitrogen in soil (N_{min}) in comparison to the traditional cultivar (Szulc, 2010; Szulc, 2012). Moreover, obtaining the highest increase in grain yield grown on ammonium sulfate may also be informative whether the stay-green cultivar is a sulfur-loving cultivar.

Grain yield of maize in this study was also determined by the interaction of the form of nitrogen fertilizer with the dose of magnesium (Fig. 2). When grown on any of the analysed nitrogen fertilizers, except for ammonium sulfate, the application of 25 kg MgO ha^{-1} caused an increase in grain yield in relation to the treatment on which this nutrient was not applied. This difference ranged from 0.2 dt ha^{-1} to 3.7 dt ha^{-1}. When applying urea and the Canwil nitro-chalk with 25 kg MgO ha^{-1} a significant increase of grain yield was recorded in comparison to the other nitrogen fertilizers. In turn, when using ammonium sulfate with 25 kg MgO ha^{-1} grain yield was found to decrease significantly (Fig. 2). The reduction of grain yield as a consequence of a combined application of ammonium sulfate with magnesium needs to be explained by the mutual antagonism of NH_4^+ with Mg^{2+}. The presence of ammonia nitrogen in soil causes a considerable reduction of magnesium uptake. Absorption of nitrogen by plants in the form of ammonium cations leads to strong acidification of the rhizosphere, which in turn results in a limitation of cation uptake at the simultaneous high accumulation of chloride, sulfate and phosphate anions. As a consequence, plants suffer from a strong deficit of alkaline cations (Mg^{2+}, K^+), particularly calcium ions (Ca^{2+}), which in turns leads to the production of organic cations in order to maintain constant pH values in the cytoplasm. As a result the production of organic acids is reduced, which consequently decreases the growth rate of plants (Grzebisz, 2008; Marschner, 1986).

The number of productive ears per unit area was modified by variable weather conditions in the period of the study ($P < 0.001$). The highest value of the analysed trait, amounting to 8.27 ears per 1 m^2 was found in 2009, while the lowest (7.05 ears per 1 m^2) in 2011 (Table 8). In the synthetic approach the form of nitrogen fertilizer ($P = 0.010$)

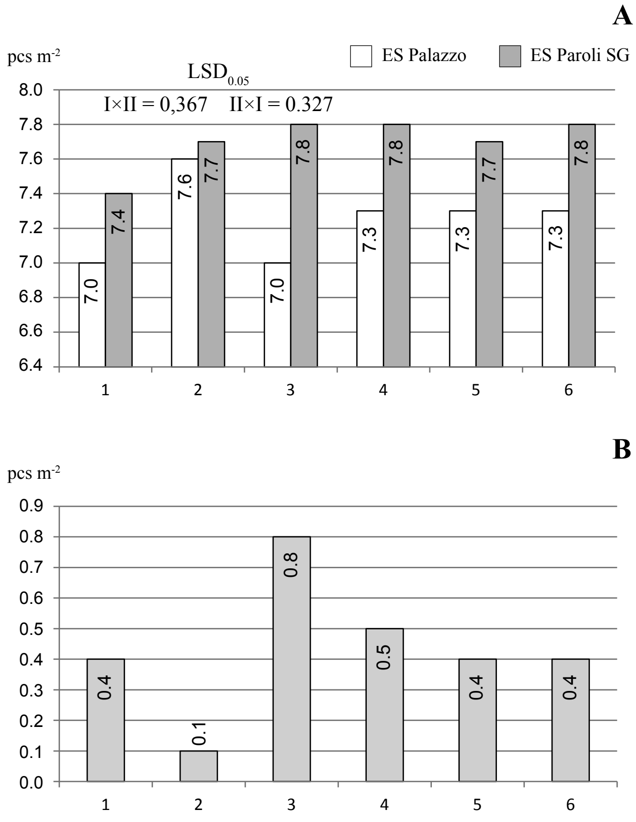
Table 8. Number of productive ears [ears m^{-2}] (± standard deviation).

Factor		Years 2009	2010	2011	Mean
Form of nitrogen fertilizer	no fertilizer	7.67±0.48	6.97±0.68	6.97±0.42	7.20±0.62
	NH_4NO_3	8.44±0.74	7.17±0.26	7.32±0.45	7.64±0.77
	$(NH_4)_2SO_4$	8.23±0.78	7.02±0.41	6.99±0.50	7.41±0.82
	$CO(NH_2)_2$	8.57±1.15	7.14±0.24	7.03±0.35	7.58±0.99
	$NH_4NO_3 + CaCO_3 + MgCO_3$	8.28±1.33	7.11±0.38	6.98±0.24	7.46±0.99
	$NH_4NO_3 + CO(NH_2)_2$	8.41±1.09	7.14±0.31	7.03±0.33	7.53±0.92
$LSD_{0.05}$		0.55	0.12	n-s.d.	0.20
Dose of magnesium [kg MgO ha^{-1}]	0	8.27±0.87	7.08±0.47	7.07±0.41	7.47±0.83
	25	8.27±1.10	7.11±0.33	7.04±0.40	7.47±0.90
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Hybrid type	ES Palazzo	7.98±0.82	6.85±0.39	6.96±0.43	7.26±0.77
	ES Paroli SG	8.55±1.06	7.34±0.23	7.15 ±0.34	7.68±0.90
$LSD_{0.05}$		0.41	0.15	0.15	0.15
Mean		8.27±0.99	7.09±0.40	7.05±0.40	-

n-s.d. – non-significant difference at P = 0.05

and the type of maize hybrid (P < 0.001) significantly determined the number of ears (Table 8). Significantly the lowest number of ears was recorded in the treatment with no application of nitrogen fertilizer in relation to the other nitrogen fertilizers (Table 8), for which the value of the discussed parameter was statistically the same. The above dependence for the effect of nitrogen fertilizer form on the number of productive ears was observed in the years 2009 and 2010. In turn, when investigating the role of the type of maize hybrid in the modification of the number of productive ears it was shown that cv. ES Paroli SG had a significantly higher value of the analysed trait, the difference being 0.42 ears per 1 m^2, in comparison to cv. ES Palazzo (Table 8). Also in individual years of the study a similar effect was shown for maize cultivars in the modification of the number of productive ears. This difference amounted to 0.57 ears per 1 m^2, 0.49 ears per 1 m^2 and 0.19 ears per 1 m^2, respectively (Table 8). In this study an interaction was also shown between the form of nitrogen fertilizer and the type of maize hybrid (P = 0.042) in terms of the effect on the number of formed productive ears (Fig. 3). For each of the nitrogen fertilizers a higher number of ears was produced by the stay-green hybrid in comparison to the traditional cultivar. On the control treatment with no nitrogen application, with ammonium sulfate, urea, the Canwil nitro-chalk and a mixture of urea with ammonium nitrate the stay-green hybrid formed significantly greater numbers of productive ears in comparison to the variant with ammonium nitrate (Fig. 3).

The thousand kernel weight was modified by the variable weather conditions in the period of the study (P < 0.001). Values of the discussed trait were significantly determined



1, 2, 3, ..., 6 – form of fertilizer (see Table 1)

Fig. 3. Interaction between the form of nitrogen fertilizer and maize hybrid type in modification of the number of productive maize ears (A) and (B) increment in the number of ears (2009–2011).

Table 9. Thousand kernel weight [g] (± standard deviation).

Factor		Years 2009	2010	2011	Mean
Form of nitrogen fertilizer	no fertilizer	324 ±30	329 ±29	347 ±18	335 ±28
	NH_4NO_3	353 ±26	335 ±31	371 ±22	353 ±30
	$(NH_4)_2SO_4$	341 ±31	339 ±29	355 ±24	345 ±28
	$CO(NH_2)_2$	355 ±19	339 ±35	364 ±19	353 ±27
	$NH_4NO_3 + CaCO_3 + MgCO_3$	352 ±30	342 ±27	365 ±19	353 ±27
	$NH_4NO_3 + CO(NH_2)_2$	362 ±12	338 ±34	359 ±25	353 ±27
$LSD_{0.05}$		21.1	n-s.d.	13.4	8.37
Dose of magnesium [kg MgO ha^{-1}]	0	350 ±23	338 ±31	360 ±22	350 ±27
	25	347 ±32	336 ±30	360 ±23	348 ±30
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Hybrid type	ES Palazzo	333 ±26	311 ±14	346 ±18	330 ±24
	ES Paroli SG	363 ±21	364 ±16	375 ±15	367 ±18
$LSD_{0.05}$		5.60	5.36	5.71	3.14
Mean		348 ±28	337 ±31	360 ±22	-

n-s.d. – non-significant difference at P = 0.05

Table 10. Number of kernels in ear [pcs] (± standard deviation).

Factor		Years 2009	2010	2011	Mean
Form of nitrogen fertilizer	no fertilizer	455 ±68	562 ±69	538 ±60	519 ±79
	NH_4NO_3	542 ±50	551 ±70	547 ±49	547 ±56
	$(NH_4)_2SO_4$	524 ±52	556 ±69	551 ±52	544 ±59
	$CO(NH_2)_2$	524 ±60	565 ±69	551 ±56	547 ±63
	$NH_4NO_3 + CaCO_3 + MgCO_3$	518 ±63	569 ±71	557 ±60	548 ±67
	$NH_4NO_3 + CO(NH_2)_2$	527 ±52	561 ±76	546 ±45	545 ±59
$LSD_{0.05}$		43.9	n-s.d.	n-s.d.	15.65
Dose of magnesium [kg MgO ha^{-1}]	0	520 ±57	559 ±70	548 ±53	542 ±62
	25	510 ±69	562 ±68	549 ±53	540 ±67
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Hybrid type	ES Palazzo	550 ±58	625 ±26	593 ±28	590 ±50
	ES Paroli SG	480 ±46	496 ±21	503 ±26	493 ±34
$LSD_{0.05}$		16.08	10.92	9.59	7.06
Mean		515 ±63	561 ±69	548 ±53	-

n-s.d. – non-significant difference at P = 0.05

also by the form of nitrogen fertilizer ($P < 0.001$) and the type of maize hybrid ($P < 0.001$). As a result of the application of different nitrogen fertilizers the thousand kernel weight did not show significant differences in the fertilized objects, while these values differed significantly in relation to the treatment with no application of nitrogen fertilizer (Table 9). Also in the years 2009 and 2011 the form of nitrogen fertilizer significantly modified the value of the analysed trait. In turn, when investigating the role of the type of maize hybrid it was found that cv. ES Paroli SG had a significantly higher thousand kernel weight (by 37.5 g) in comparison to cv. ES Palazzo. Also in individual years of the study a similar relationship was shown for the compared cultivars in terms of the fluctuations in produced thousand kernel weights. This difference amounted to 30 g, 53 g and 29 g, respectively (Table 9). The result recorded in this study confirms earlier literature data (Szulc et al., 2008a; Szulc and Bocianowski, 2011). In those studies also the stay-green hybrid formed heavier kernels in comparison to the traditional cultivar. Stay-green cultivars in the autumn period, thanks to the still active green vegetative organs, conduct assimilation processes longer, frequently until full kernel maturity. Cirilo and Andrade (1996) reported that effective formation of grain is dependent on temperature and availability of assimilates. Generally the higher the nitrogen content in leaves, the longer the pho-

Table 11. Number of rows in ear [pcs] (± standard deviation).

	Factor	Years			Mean
		2009	2010	2011	
Form of nitrogen fertilizer	no fertilizer	14.2 ±0.79	14.4 ±1.37	14.3 ±1.24	14.3 ±1.14
	NH_4NO_3	14.3 ±1.04	14.1 ±1.37	14.2 ±1.04	14.2 ±1.14
	$(NH_4)_2SO_4$	14.4 ±1.00	14.2 ±1.31	14.3 ±1.27	14.3 ±1.18
	$CO(NH_2)_2$	14.2 ±1.06	14.5 ±1.41	14.3 ±1.29	14.3 ±1.24
	$NH_4NO_3 + CaCO_3 + MgCO_3$	14.2 ±1.11	14.4 ±1.47	14.3 ±1.44	14.3 ±1.32
	$NH_4NO_3 + CO(NH_2)_2$	14.2 ±0.90	14.5 ±1.48	14.1 ±1.18	14.3 ±1.19
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Dose of magnesium [kg MgO ha^{-1}]	0	14.3 ±0.91	14.3 ±1.40	14.2 ±1.26	14.3 ±1.20
	25	14.2 ±1.03	14.4 ±1.36	14.2 ±1.19	14.3 ±1.20
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Hybrid type	ES Palazzo	15.0 ±0.63	15.6 ±0.52	15.4 ±0.57	15.3 ±0.62
	ES Paroli SG	13.5 ±0.51	13.1 ±0.44	13.1 ±0.41	13.2 ±0.49
$LSD_{0.05}$		0.23	0.23	0.18	0.12
Mean		14.3 ±0.97	14.3 ±1.37	14.2 ±1.22	-

n-s.d. – non-significant difference at P = 0.05

tosynthetic activity of leaves. Nitrogen deficit leads to the destruction of chlorophyll and thus reduces the period of CO_2 assimilation (Rajcan and Tollenaar, 1999a). For this reason we may expect an additional increase in yield and better grain filling (Kowalik and Michalski, 2006), which was shown within this study. In turn, Jones et al. (1996) reported that the duration and rate of grain growth to a considerable degree are determined by the difference in the genotypes of analysed cultivars. Rajcan and Tollenaar (1999b) described leaf senescence in stay-green cultivars as the ratio of the assimilate supply to the demand for this assimilate in the period of grain filling.

The number of kernels in the ear was modified by variable weather conditions between individual years of the study ($P < 0.001$). Their highest number was recorded in 2010 (561 kernels), while the lowest in 2011 (548 kernels) (Table 10). When investigating the effect of nitrogen fertilizer on the number of kernels per ear it was found that in the treatment with no application of nitrogen fertilizer this number was significantly ($P < 0.001$) the lowest in comparison to the other forms of nitrogen fertilizers, for which the number of kernels in the ear was statistically the same. In the case of the type of maize hybrid it was found that cv. ES Paroli SG formed significantly ($P < 0.001$) lower numbers of kernels in the ear in relation to cv. ES Palazzo (Table 10). A similar effect of the form of nitrogen fertilizer was shown only for the year 2009, while that of the type of maize hybrid was found for each of the three years of the study.

The average number of rows per ear for the three years of the study was significantly determined only by the cultivar factor ($P < 0.001$). Significantly greater values of the analysed trait were found for cv. ES Palazzo in comparison to cv. ES Paroli SG (Table 11). A similar effect of the type of maize hybrid on the number of rows in the ear was shown for each of the three years of analyses. As it was reported by Grzebisz (2008), in the phase from the 6th to 12th leaves plants form a potential yield structure, as they set ears and the number of rows in the ear is determined, being a genetically determined trait, which was aslo shown in this study. In this period maize as a result of the action of environmental and cultivation factors reduces the number of rows in the ear.

The number of kernels in the row was modified by variable thermal and humidity conditions found in the period of the study ($P < 0.001$). The lowest value of this trait was observed in 2009 (36.1 kernels), while it was highest in 2010 (39.0 kernels) (Table 12). On average for the years of the study the number of kernels per row was significantly determined by the form of nitrogen fertilizer ($P < 0.001$) and the type of maize hybrid ($P < 0.001$). As a result of the application of different nitrogen fertilizers significantly the lowest number of kernels in the row was found for the treatment with no application of nitrogen fertilizer in comparison to fertilized objects (Table 12), for which the value of the analysed trait was statistically the same. Also in the years 2009 and 2011 the form of nitrogen fertilizer had a significant effect on the number of kernels in the row. In turn, when investigating the role of the type of maize hybrid in the modification of the number of kernels in the row it was found that cv. ES Paroli SG had a significantly lower value of the trait (by 1.10 kernels) in comparison to cv. ES Palazzo. A similar effect of the type of maize hybrid on the number of kernels in the row was shown for the years 2009 and 2010.

In the development of annual plants such as maize we may distinguish several stages, of which each plays a specific role in their life cycle. Despite such a high diversity in

Table 12. Number of kernels in row [pcs] (± standard deviation).

Factor		Years 2009	2010	2011	Mean
Form of nitrogen fertilizer	no fertilizer	32.2 ±4.37	39.0 ±1.42	37.6 ±1.34	36.3 ±4.02
	NH_4NO_3	37.7 ±1.25	39.1 ±1.46	38.6 ±1.28	38.5 ±1.43
	$(NH_4)_2SO_4$	36.4 ±2.85	39.0 ±1.50	38.7 ±0.91	38.0 ±2.23
	$CO(NH_2)_2$	37.0 ±2.14	38.8 ±1.28	38.6 ±0.15	38.1 ±1.76
	$NH_4NO_3 + CaCO_3 + MgCO_3$	36.4 ±2.81	39.4 ±1.27	38.8 ±0.98	38.2 ±2.25
	$NH_4NO_3 + CO(NH_2)_2$	37.0 ±1.91	38.7 ±1.70	38.7 ±0.90	38.1 ±1.73
$LSD_{0.05}$		2.97	n-s.d.	0.72	0.99
Dose of magnesium [kg MgO ha^{-1}]	0	36.2 ±2.45	39.1 ±1.48	38.5 ±1.08	37.9 ±2.13
	25	36.0 ±2.87	39.0 ±1.38	38.5 ±1.25	37.8 ±2.80
$LSD_{0.05}$		n-s.d.	n-s.d.	n-s.d.	n-s.d.
Hybrid type	ES Palazzo	36.6 ±3.23	40.0 ±0.95	38.7 ±0.87	38.4 ±2.44
	ES Paroli SG	35.6 ±3.19	38.0 ±1.06	38.3 ±1.38	37.3 ±2.40
$LSD_{0.05}$		0.82	0.43	n-s.d.	0.34
Mean		36.1 ±3.22	39.0 ±1.42	38.5 ±1.16	-

n-s.d. – non-significant difference at P = 0.05

the development stages the yield of grain in maize results from the formation of individual elements of its structure, i.e. the number of ears, the number of kernels in the ear and 1000 kernel weight (Sylvester-Bradley et al., 2002). The number of kernels in the ear is a quotient of the number of rows in the ear and the number of kernels in the row. The effect of individual yielding components on grain yield in maize is given in Tables 13-18. For both maize cultivars analysed in this experiment at each form of nitrogen fertilization and at the absence of such fertilization statistically significant positive correlations were observed between the number of kernels and the number of kernels in the row (Tables 13-18). Moreover, for the hybrid ES Palazzo the number of kernels and the number of rows in the ear were significantly positively correlated at all types of nitrogen fertilization and at its absence. For all the discussed types of nitrogen fertilization no correlation was observed between the yield of grain and the number of rows in the ear

Table 13. Correlation coefficients between observed traits at no nitrogen fertilization for cv. ES Palazzo (below diagonal) and ES Paroli SG (above diagonal).

No fertilizer	Yield of kernels	Number of ears	Thousand kernel weight	Number of kernels	Number of rows in ear	Number of kernels in row
Yield of kernels	1	-0.217^{ns}	0.544^{**}	0.548^{**}	-0.373^{ns}	0.702^{***}
Number of ears	0.001^{ns}	1	-0.152^{ns}	-0.210^{ns}	0.379^{ns}	-0.370^{ns}
Thousand kernel weight	0.632^{***}	0.219^{ns}	1	0.338^{ns}	-0.394^{ns}	0.513^{*}
Number of kernels	0.446^{*}	-0.394^{ns}	0.313^{ns}	1	0.194^{ns}	0.899^{***}
Number of rows in ear	0.147^{ns}	-0.435^{*}	-0.072^{ns}	0.699^{***}	1	-0.254^{ns}
Number of kernels in row	0.500^{*}	-0.322^{ns}	0.411^{*}	0.965^{***}	0.488^{*}	1

* P<0.05, ** P<0.01, *** P<0.001, ns – non-significant

Table 14. Correlation coefficients between observed traits at ammonium nitrate fertilization for cv. ES Palazzo (below diagonal) and ES Paroli SG (above diagonal).

Ammonium nitrate NH_4NO_3	Yield of kernels	Number of ears	Thousand kernel weight	Number of kernels	Number of rows in ear	Number of kernels in row
Yield of kernels	1	0.607^{**}	0.062^{ns}	-0.067^{ns}	0.424^{*}	-0.548^{**}
Number of ears	0.646^{***}	1	-0.165^{ns}	0.082^{ns}	0.482^{*}	-0.414^{*}
Thousand kernel weight	0.466^{*}	0.146^{ns}	1	0.296^{ns}	0.103^{ns}	0.283^{ns}
Number of kernels	-0.412^{*}	0.014^{ns}	-0.222^{ns}	1	0.688^{***}	0.608^{**}
Number of rows in ear	-0.079^{ns}	0.210^{ns}	-0.202^{ns}	0.772^{***}	1	-0.158^{ns}
Number of kernels in row	-0.553^{**}	-0.194^{ns}	-0.127^{ns}	0.734^{***}	0.135^{ns}	1

* P<0.05, ** P<0.01, *** P<0.001, ns – non-significant

Table 15. Correlation coefficients between observed traits at ammonium sulfate fertilization for cv. ES Palazzo (below diagonal) and ES Paroli SG (above diagonal).

Ammonium sulfate $(NH_4)_2SO_4$	Yield of kernels	Number of ears	Thousand kernel weight	Number of kernels	Number of rows in ear	Number of kernels in row
Yield of kernels	1	0.729^{***}	-0.110^{ns}	0.049^{ns}	0.468^{*}	-0.280^{ns}
Number of ears	0.565^{**}	1	-0.268^{ns}	-0.104^{ns}	0.377^{ns}	-0.406^{*}
Thousand kernel weight	0.490^{*}	0.065^{ns}	1	0.653^{***}	0.074^{ns}	0.748^{***}
Number of kernels	-0.498^{*}	-0.446^{*}	0.188^{ns}	1	0.581^{**}	0.795^{***}
Number of rows in ear	-0.298^{ns}	-0.212^{ns}	-0.198^{ns}	0.484^{*}	1	-0.032^{ns}
Number of kernels in row	-0.428^{*}	-0.418^{*}	0.306^{ns}	0.899^{***}	0.052^{ns}	1

* P<0.05, ** P<0.01, *** P<0.001, ns – non-significant

Table 16. Correlation coefficients between observed traits at urea fertilization for cv. ES Palazzo (below diagonal) and ES Paroli SG (above diagonal).

Urea $CO(NH_2)_2$	Yield of kernels	Number of ears	Thousand kernel weight	Number of kernels	Number of rows in ear	Number of kernels in row
Yield of kernels	1	0.632^{***}	0.339^{ns}	0.017^{ns}	0.093^{ns}	-0.041^{ns}
Number of ears	0.196^{ns}	1	-0.026^{ns}	-0.155^{ns}	-0.009^{ns}	-0.153^{ns}
Thousand kernel weight	0.630^{**}	0.168^{ns}	1	0.152^{ns}	-0.357^{ns}	0.389^{ns}
Number of kernels	-0.216^{ns}	-0.359^{ns}	-0.307^{ns}	1	0.342^{ns}	0.792^{***}
Number of rows in ear	-0.182^{ns}	-0.328^{ns}	-0.262^{ns}	0.929^{***}	1	-0.302^{ns}
Number of kernels in row	-0.197^{ns}	-0.328^{ns}	-0.271^{ns}	0.887^{***}	0.654^{***}	1

* P<0.05, ** P<0.01, *** P<0.001, ns – non-significant

Table 17. Correlation coefficients between observed traits at nitro-chalk fertilization for cv. ES Palazzo (below diagonal) and ES Paroli SG (above diagonal).

Canwil nitro-chalk $NH_4NO_3 + CaCO_3 + MgCO_3$	Yield of kernels	Number of ears	Thousand kernel weight	Number of kernels	Number of rows in ear	Number of kernels in row
Yield of kernels	1	0.058^{ns}	0.362^{ns}	0.004^{ns}	0.068^{ns}	-0.048^{ns}
Number of ears	0.461^{*}	1	-0.366^{ns}	-0.418^{*}	0.287^{ns}	-0.674^{***}
Thousand kernel weight	0.242^{ns}	0.287^{ns}	1	-0.027^{ns}	-0.406^{*}	0.251^{ns}
Number of kernels	-0.469^{*}	-0.199^{ns}	0.330^{ns}	1	0.496^{*}	0.780^{***}
Number of rows in ear	-0.148^{ns}	-0.306^{ns}	0.200^{ns}	0.804^{***}	1	-0.155^{ns}
Number of kernels in row	-0.550^{**}	-0.111^{ns}	0.357^{ns}	0.959^{***}	0.603^{**}	1

* P<0.05, ** P<0.01, *** P<0.001, ns – non-significant

Table 18. Correlation coefficients between observed traits at ammonium nitrate and urea fertilization for cv. ES Palazzo (below diagonal) and ES Paroli SG (above diagonal).

Ammonium nitrate + urea $NH_4NO_3 + CO(NH_2)_2$	Yield of kernels	Number of ears	Thousand kernel weight	Number of kernels	Number of rows in ear	Number of kernels in row
Yield of kernels	1	0.543^{**}	0.141^{ns}	0.042^{ns}	0.497^{*}	-0.228^{ns}
Number of ears	0.329^{ns}	1	-0.062^{ns}	-0.336^{ns}	0.488^{*}	-0.651^{***}
Thousand kernel weight	0.606^{**}	0.393^{ns}	1	0.125^{ns}	-0.146^{ns}	0.222^{ns}
Number of kernels	-0.498^{*}	-0.367^{ns}	-0.559^{**}	1	0.491^{*}	0.877^{***}
Number of rows in ear	-0.364^{ns}	-0.334^{ns}	-0.494^{*}	0.866^{***}	1	0.013^{*}
Number of kernels in row	-0.435^{*}	-0.226^{ns}	-0.350^{ns}	0.656^{***}	0.191^{ns}	1

* P<0.05, ** P<0.01, *** P<0.001, ns – non-significant

for cv. ES Palazzo and between the thousand kernel weight and the number of ears for ES Paroli SG (Tables 13-18).

SUMMARY AND CONCLUSIONS

1. No significant effect was observed for the form of nitrogen fertilizer and the dose of magnesium on grain moisture content.

2. The hybrid ES Paroli SG was characterised by a significantly greater grain yield potential and significantly higher water content in grain in comparison to cv. ES Palazzo.

3. Among the three yielding components cv. ES Paroli SG was characterised by a significantly greater number of productive ears per unit area, thousand kernel weight and a lower number of kernels in the ear in comparison to cv. ES Palazzo.

4. For slow-release fertilizers such as ammonium sulfate, urea and a mixture of ammonium nitrate and urea with a 50% proportion of each of these fertilizers in the fertilizer dose an advantage of the stay-green cultivar over the traditional cultivar in terms of the produced grain yield was significantly greater than in the treatments with no application of nitrogen fertilizer, ammonium nitrate and the Canwil nitro-chalk.

5. For each of the analysed nitrogen fertilizers, except for ammonium sulfate, the application of 25 kg $MgO \cdot ha^{-1}$ resulted in an increase in grain yield in relation to the treatment, on which this component was not used. When applying urea and the Canwil nitro-chalk with 25 kg $MgO \cdot ha^{-1}$ a significant positive increase was obtained in grain yield in comparison to the other nitrogen fertilizers. In turn, at the application of ammonium sulfate with 25 kg MgO ha^{-1} grain yield was significantly reduced.

6. The number of kernels in the ear and the number of kernels in the row were correlated irrespective of the form of nitrogen fertilization for both maize hybrids.

REFERENCES

Borowiecki J., Koter Z., 1983a. A comparison of ammonium nitrate and urea as the sources of nitrogen for maize. Pam. Puł., 81: 77-90. [in Polish]

Borowiecki J., Koter Z., 1983b. Emergence and growth of maize seedlings as related to the time of preplant nitrogen application in different forms and rates. Pam. Puł., 81: 91-103. [in Polish]

Cirilo A.G., Andrade F.H., 1996. Sowing date and kernel weight in maize. Crop Sci., 36: 325-331.

Grzebisz W., 2002. Proecological and economically effective technologies of fertilization of maize for grain. Mat. szkol., DWODR zs. w Świdnicy. [in Polish]

Grzebisz W., 2008. Fertilisation of crops. I. The basics of fertilisation. PWRiL. [in Polish]

Grzebisz W., Gaj R., 2007. Integrated system of maize fertilization. Integrated maize production. IOR Poznań. [in Polish]

Hammad H.M., Ahmad A., Wajid A., Akhter J., 2011. Maize response to time and rate of nitrogen application. Pak. J. Bot., 43(4): 1935-1942.

Jones R.J., Schreiber B.M.N., Roessler J.A., 1996. Kernel sink capacity in maize: Genotypic and maternal regulation. Crop Sci., 36: 301-306.

Kowalik I., Michalski T., 2006. Influence of selected elements of cultivation technology on the qualitative parameters of maize silage (stay green type variety). Pam. Puł., 142: 201-213. [in Polish]

Kruczek A., 2005. The effect of nitrogen rate, nitrogen fertilizer application method and multi-component fertilizer on the yield of maize. Pam. Puł., 140: 129-138. [in Polish]

Marschner H., 1986. Mineral nutrition of higher plants. First ed., Academic Press, London.

Molga M., 1986. Agrometeorology. PWRiL Warszawa. [in Polish]

Mordogan N., Yagmur B., Hakerlerler H., 2004. Effect of N forms on maize yield and leaf components. Bodenkultur, 55(3): 121-127.

Rajcan I., Tollenaar M., 1999a. Source : sink ratio and leaf senescence in maize. I. Dry matter accumulation and partitioning during grain filling. Field Crops Res., 60: 245-253.

Rajcan I., Tollenaar M., 1999b. Source : sink ratio and leaf senescence in maize. II. Nitrogen metabolism during grain filling. Field Crops Res., 60: 255-265.

Shapiro S.S., Wilk M.B., 1965. An analysis of variance test for normality (complete samples). Biometrika, 52: 591-611.

Sulewska H., 1997. Environmental and economical conditions of maize cultivation and its yields utilization in Poland. Zesz. Probl. Post. Nauk Rol., 450: 15-29. [in Polish]

Sylvester-Bradley R., Lunn G., Foulkes J., Shearman V., Spink J., Ingram J., 2002. Management strategies for high yields of cereals and oilseed rape. HGCA Conference: Agronomic Intelligence: the basis for profitable production, 8.1.-8.18.

Szulc P., 2010. Effect of differentiated levels of nitrogen fertilization and the method of magnesium application on the utilization of nitrogen by two different maize cultivars for grain. Polish J. Environ. Stud., 19(2): 407-412.

Szulc P., 2012. Differences in the accumulation and redistribution of dry matter and N_{min} content in the cultivation of two different maize (*Zea mays* L.) cultivars for grain. Polish J. Environ. Stud., 21(4): 1039-1046.

Szulc, P., Bocianowski, J., 2011. Variability and correlation of components of grain yield structure of two different types of maize cultivars (*Zea mays* L.). Fres. Environ. Bull., 20(10a): 2684-2692.

Szulc P., Bocianowski J., Rybus-Zając M., 2012. Accumulation of N, P, K and Mg nutrient elements and nutrient remobilization indices in the biomass of two contrasting maize (*Zea mays* L.) hybrids. Fres. Environ. Bull., 21(8): 2062-2070.

Szulc P., Skrzypczak W., Waligóra H., 2008a. Improvement of the effectiveness of maize (*Zea mays* L.) fertilization with nitrogen by the application of magnesium. Part I. Grain yield and its structure. Acta Sci. Polon., 7(4): 125-135.

Szulc P., Waligóra H., Skrzypczak W., 2008b. Better effectiveness of maize fertilization with nitrogen through additional application of magnesium and sulphur. Nauka Przyr. Technol., 2, 3 # 19.

Uziak Z., Borowski E., Blamowski Z., 1993. The attempt to explain the various reactions of rape and corn plants on the nitrogen use in the ammonium or nitrate forms. Acta Agrobot., 46(1): 39-49. [In Polish]

Zeidan M.S., Amany A., Bahr El-Kramany M.F., 2006. Effect of N-fertilizer and plant density on yield and quality of maize in sandy soil. Res. J. Agric. Biol. Sci., 2(4): 156-161.