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Dynamics of dry matter accumulation in the initial growth period of maize (*Zea mays* L.)

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Abstract. The study presents the results of 3-year field tests, the aim of which was to assess the dynamics of initial growth of maize (*Zea mays* L.) of „stay-green" and classical cultivars characterized by different genetic profile depending on the method of application of nitrogen fertilizer and nitrogen-magnesium fertilizer. The development of annual grain crops, such as maize is divided into a number of development stages, each of which performs a specific role in the life cycle. In the juvenile stage, i.e. from the 6th to the 12th leaf, the maize builds its potential yield structure, because at that time ears are formed and the number of rows in an ear is determined. Understanding the dynamics of initial growth, which is dependent on the selection of cultivars and fertilization, is therefore a very valuable achievement of the study because the yield of maize is closely correlated with the dynamics of the initial growth and nutritional status in the juvenile phase. It was found that band fertilisation, in comparison with broadcast fertilisation and in-row application supplemented with topdressing at the BBCH 15/16 phase, had positive impact on the initial rate of maize growth. The ES Paroli "stay-green" cultivar, in comparison with the traditional ES Palazzo, exhibited faster rate of dry matter increase at the initial stages (BBCH 16/17) of the development. The most significant differences showing the advantages of the "stay-green" cultivars in comparison with the traditional cultivar, as far as the characteristics under examination are concerned, were found with regard to broadcast-applied nitrogen fertiliser. The differences between "stay-green" and conventional cultivars in features tested in dry matter weight and in dry matter content per plant were smaller for banded vs. broadcast fertiliser application and were the smallest with banded application supplemented with topdressing at the BBCH 15/16 stage.

Keywords: *Zea mays* L., stay-green, initial growth

INTRODUCTION

The research by many authors (Dibb et al., 1989; Mozafar et al., 1993; Kruczek and Szulc, 2006; Szulc 2013) indicate that the changing soil temperature has great impact on many mechanisms involved in nutrient uptake by crops. A drop in soil temperature lowers the rate of mineralisation of the organic matter, penetrability of the cytoplasmic membrane and weakens root activity. As indicated by Sowiński and Maleszewski (1989), at low soil temperature, the root pressure, responsible for providing the stem with mineral salts, is less dynamic. Diminished nitrogen uptake by maize takes place at temp. below 5°C, and it results in plants turning yellow and their rate of growth decreasing (Kruczek, Sulewska, 2005). Fertilising is one of the most important elements of maize agro-technology and limits this adverse effect. According to Baran et al. (2011), it has the strongest impact on yields and chemical composition of the crops. Moreover, it is the necessary condition of obtaining high quality crops. Young maize has a poorly developed root system which can provide the plant with nutrients only at high concentration of the ingredient in the soil solution (Kruczek, Szulc, 2006). Mollier and Pellerin (1999) as well as Yanai et al. (1996) state that fast growth of the root system is possible at appropriate concentration of nitrogen and phosphorus in the soil solution; such concentration may be reached by band application in which the fertiliser is placed in immediate vicinity of the roots (Tlustos et al., 1997; Uhart, Andrade, 1995). Additionally, in order to overcome these obstacles, one should resort to a range of other agrotechnical measures, such as: selection of appropriate fertilizer and selection of a hybrid for cultivation (Szulc, 2013). It is related to the fact that maize hybrids (their types) exhibit different sensitivity to thermal conditions and varied dynamics of initial development of the root system required for nutrient uptake. According to scientific reports, malnutrition of maize until the 6-leaf stage reduces maize grain yield even by 12%. Maize grain yield is also positively correlated to aboveground dry matter of a single plant and dry matter yield in the juvenile stage (Szulc, Bocianowski, 2012). Hence the understanding of crop management factors that promote greater vigour of initial growth (dry matter accumulation)

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is a crucial issue not only from the scientific but also from the utilitarian point of view. Comprehensive knowledge of the problem explains yield potential of presently cultivated cultivars.

Accordingly, a field study was undertaken to determine how the method of application of nitrogen and nitrogen-magnesium fertilizers affects the dynamics of the initial growth. The initial growth was expressed by the accumulation of dry matter by maize at its initial growth period depending on the type of hybrid.

MATERIALS AND METHODS

Field experiment

Field experiments were conducted at the Department of Agronomy at Poznań University of Life Sciences on the fields of the Research Institute in Swadzim (52°26′20″ N, 16°44′58″ E) in the years 2009–2011. They were conducted under the „split-split-plot" design with four replications. The following factors were examined: A) type of nitrogen fertiliser: ammonium nitrate (NH_4NO_3) and Canwil calcium ammonium nitrate (NH_4NO_3+$CaCO_3$+$MgCO_3$), B) fertiliser application method: broadcast (entire fertilizer dose before maize sowing, in-row (entire nitrogen dose band-applied when sowing), in-row supplemented with topdressing [50 kg N·ha^{-1} in-row at seed sowing + 50 kg N·ha^{-1} of topdressing at the 5–6 leaf stage (BBCH 15/16)] and C) hybrid maize types: traditional ES Palazzo and „stay-green" ES Paroli. Each year before establishing the experimental crop, the following fertilisation was applied for the entire experimental plot: 100 kg N·ha^{-1}, 80 kg P_2O_5·ha^{-1} (35.2 kg P·ha^{-1}) in the form of granular triple superphosphate 46% P_2O_5, 120 kg K_2O·ha^{-1} (99.6 kg K ·ha^{-1}) in the form of potassium salt 60%. The size of the plot was 15.4 m-^{2}.

Table 1. Soil conditions at Swadzim.

Specification	Years		
	2009	2010	2011
P [mg P·kg^{-1} of soil]	63.1	39.0	42.2
K [mg K·kg^{-1} of soil]	89.0	91.3	83.3
Mg [mg Mg·kg^{-1} of soil]	42.0	37.0	44.0
pH [in 1 mol·dm^{-1} KCl]	5.5	5.5	5.4

Soil pH and soil content of basic macro nutrients in the study years are included in Table 1. Assessment of soil fertility and pH was performed by the regional soil testing laboratory (OSCHR, Poznań, Poland) using standard protocols employed at that facility: 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.

Sampling methods

At the 6–7 leaf stage (BBCH 16/17) sample plants (10 pcs.) were taken from two central rows of each experimental plot and then the roots were separated from the aboveground part. After drying, the dry matter content as well as dry weight of an individual plant were defined. The dry matter content per unit area was determined based on the dry weight of individual plants and the number of plants per unit area.

Absolute rate of dry matter accumulation (AGR) was calculated using the following formula (Szulc, 2012):

$$AGR = (W_2-W_1) / (T_2-T_1),$$

where: AGR – absolute growth rate (g plant^{-1} d^{-1}, kg ha^{-1} d^{-1}), W_1 – initial dry mass accumulation, W_2 – accumulation of dry mass at a given time, T_2-T_1 – time (in days) that passed between W_1 and W_2 accumulation assays.

Thermal and humidity conditions

Weather conditions during the periods between maize sowing and reaching the 6–7 leaf stage (BBCH 16/17) are included in Table 2.

Statistical analysis

The four-way analysis of variance (ANOVA) was carried out to determine the effects of years, type of nitrogen fertiliser, manner of fertiliser application, hybrid type, as well as all interactions on variability of observed traits. Mean values, and standard deviations were calculated. When critical differences were noted, multiple comparisons were carried out using least significant differences (LSDs) for each trait; based on this, homogeneous groups (not significantly different from each other) were determined for the analyzed traits. The relationships between observed traits were estimated using Pearson's correlation coefficients (Kozak et al., 2010) and presented in the scatterplot matrix. Data analysis was performed using the statistical package GenStat 17.

Table 2. Weather conditions in the time period from sowing to the 6–7 leaf stage (BBCH 16/17).

Specification	Years		
	2009	2010	2011
Date of sowing	14 IV	21 IV	21 IV
Date of reaching the 6–7 leaf stage	3 VI	11 VI	27 V
Number of days from sowing to the 6–7 leaf stage	50	52	36
Amount of precipitation in the time period sowing – 6–7 leaf stage [mm]	130.7	143.8	23.8
Mean air temperature in the time period sowing – 6–7 leaf stage [°C]	14.6	13.8	14.9
Mean soil temperature at a depth of 10 cm in the time period sowing – 6–7 leaf stage [°C]	12.1	10.8	12.8

RESULTS AND DISCUSSION

ANOVA results indicate significant ($p<0.001$) influence of weather conditions on all traits under observation. Manner of fertiliser application and maize hybrid type significantly differentiated statistically all traits under observation. Similarly statistically important impact on all the traits was exerted by the following interactions: manner of fertiliser application × maize hybrid type, year × maize hybrid type and year × manner of fertiliser application (the last interaction except for the dry matter content). The remaining interactions and type of the nitrogen fertiliser did not differentiate any of the traits under observation ($p>0.05$). Dry weight of the aboveground part of an individual plant and total crop dry weight from the unit area at the 6–7 leaf stage depended on weather conditions ($F=200.79$, $p<0.001$ and 162.11, $p<0.001$, respectively) during the growing seasons (Tables 3 and 4). During this period (sowing – BBCH 16/17), the years were characterised by very diverse total rainfall and changing average daily air and soil temperatures. The growing season of 2010 proved to be the most rainy and also the coldest period (sowing – BBCH 16/17). On the other hand, the year of the lowest amount of precipitation, while at the same time of the highest average daily air and soil temperature coinciding with BBCH 16/17 maize growth stage, was the last year of the study (Table 2).

These variable thermal and humidity conditions during the maize growing seasons turned out to be very favourable as they enabled comprehensive assessment of the experiment factors (type of nitrogen fertiliser, manner of application, hybrid type) with respect to the dynamics of dry mass accumulation during the initial period of maize growth. The highest values of the traits under discussion were noted in 2009 (1.69 g; 122.83 kg ha^{-1} respectively). On the

Table 3. Dry matter of a single plant (and standard deviations) in the 6–7 leaf stage [g].

Experimental factors		Years			Mean
		2009	2010	2011	
Type of nitrogen fertilizer	ammonium nitrate	1.67 (0.29)	0.98 (0.15)	1.46 (0.24)	1.37 (0.37)
	Canwil nitro-chalk	1.70 (0.27)	1.01 (0.14)	1.44 (0.21)	1.38 (0.36)
$LSD_{0.05}$		n.s.	n.s.	n.s.	n.s.
Method of fertilization	broadcasting	1.66 (0.32)	0.97 (0.11)	1.32 (0.19)	1.32 (0.36)
	in rows	1.71 (0.27)	1.13 (0.10)	1.63 (0.15)	1.49 (0.32)
	in rows + top-dressing	1.69 (0.26)	0.89 (0.11)	1.40 (0.18)	1.33 (0.38)
$LSD_{0.05}$		n.s.	0.048	0.134	0.061
Cultivar	ES Palazzo	1.48 (0.18)	0.99 (0.13)	1.44 (0.27)	1.30 (0.30)
	ES Paroli “stay-green”	1.90 (0.19)	1.01 (0.16)	1.46 (0.17)	1.46 (0.41)
$LSD_{0.05}$		0.080	n.s.	n.s.	0.044
Control [0 kg N ha^{-1}]	ES Palazzo	0.98	0.63	1.08	0.89
	ES Paroli “stay-green”	1.20	0.81	1.21	1.07
Mean		1.69	1.00	1.45	1.38

n.s. – non-significant differences

Table 4. Dry matter yield (and standard deviations) [kg ha^{-1}].

Experimental factors		Years			Mean
		2009	2010	2011	
Type of nitrogen fertilizer	ammonium nitrate	121.98 (23.3)	75.25 (11.4)	111.07 (18.9)	102.77 (27.2)
	Canwil nitro-chalk	123.68 (23.3)	77.20 (11.8)	111.46 (16.8)	104.11 (26.6)
$LSD_{0.05}$		n.s.	n.s.	n.s.	n.s.
Method of fertilization	broadcasting	121.14 (26.7)	74.15 (9.84)	100.33 (15.0)	98.54 (26.6)
	in rows	124.31 (22.2)	86.61 (8.25)	125.20 (14.4)	112.04 (23.99)
	in rows + top-dressing	123.04 (21.5)	67.91 (7.44)	108.26 (14.1)	99.74 (27.98)
$LSD_{0.05}$		n.s.	3.638	10.717	4.752
Cultivar	ES Palazzo	104.46 (13.4)	73.73 (9.81)	108.53 (20.5)	95.57 (21.7)
	ES Paroli “stay-green”	141.20 (14.3)	78.71 (12.7)	114.01 (14.1)	111.31 (29.1)
$LSD_{0.05}$		5.504	4.426	7.391	3.252
Control [0 kg N ha^{-1}]	ES Palazzo	84.75	49.42	83.50	72.55
	ES Paroli “stay-green”	110.30	59.85	94.29	88.15
Mean		122.83	76.22	111.26	103.44

n.s. – non-significant differences

other hand, the values were the lowest in 2010 (1.00 g; 76.22 kg·ha^{-1} respectively); in the period between sowing and the 6–7 leaf stage, the highest total rainfall with the lowest air and soil temperatures were noted. It was a very humid and, at the same time, cold year. The result obtained in our study finds its confirmation in research by Kruczek and Sulewska (2005) and Kruczek and Szulc (2006). According to the above authors, lower maize yields result from unfavourable thermal and humidity conditions in the initial period of maize growth and development.

The overall result for the period of three experimental years is that the weight of an individual plant and crop dry weight from the unit area depended on the manner of fertiliser application and maize hybrid type (Tables 3 and 4). The significantly highest values of the traits under discussion were obtained for in-row application at the time of sowing in comparison with the broadcast fertiliser distribution and for in-row application supplemented with top-dressing at the 5–6 leaf stage. The above correlation was noted in years 2010 and 2011, namely in the growing seasons characterised by unfavourable thermal and humidity conditions during the period between sowing and 6–7 leaf stage. On the other hand, in 2009, characterised by favourable weather conditions, the manner of fertiliser application did not have significant impact on the dry weight of an individual plant or the dry weight of the crop per area unit at the 6–7 leaf stage (Tables 3 and 4).

Independently of the weather pattern in individual years, the ES Paroli "stay-green", when compared with the classic ES Palazzo hybrid, showed more vigorous initial growth in terms of dry matter accumulation at the 6–7 leaf stage ($F=22.52$, $p<0.001$). The differences between the cultivars amounted to: 0.16 g and 15.74 kg·ha^{-1} (Tables 3 and 4). Also other studies by the author (Szulc, Bocianowski, 2012; Szulc, 2012; Szulc, 2013; Bocianowski et al., 2016) showed that the "stay-green" cultivar demonstrated higher vigour of initial growth expressed as dry matter accumulation than did the classic cultivar. Those results came from the same research station at which the present study was carried out.

This interdependence was demonstrated only in 2009 for the dry weight of an individual plant (the difference of 28.4%), while in rainy and cold as well as dry and hot years no significant impact of the maize hybrid type was noted for this trait. On the other hand, this interdependence was confirmed in all years for the dry weight of the crop but the actual values were different. The accumulation of dry matter at the 6–7 leaf stage was as follows: 2009 (35.2%), 2010 (6.7%), 2011 (5.0%) (Table 4).

Dry mass of an individual plant and the dry matter yield from the unit area at the 6–7 leaf stage depended on interrelation between the manner of fertiliser application and maize hybrid type ($F=6.07$, $p=0.01$ and $F=8.04$, $p=0.003$) (Figs. 1 and 2). Those interactions took place independently of the year and their strength was the same over the years. For each manner of fertiliser application, the SG cultivar ES Paroli was characterised by greater dry weight of an individual plant and by greater dry matter yield. The above interdependence consisted in greater difference in growth for broadcast vis-à-vis in-row application and for broadcast vis-à-vis the combined in-row plus topdressied application (Figs. 1 and 2). Thus, we can state that the better the nutritional conditions for the classic cultivar, the smaller the difference between the cultivar types. In turn, as the nutrition of the plants deteriorates, the superiority of „stay-green" cultivars over the classic cultivar becomes greater. It is also confirmed by the value of these characteristics in the control treatment (Tables 3 and 4).

Variable conditions in the experimental years caused differences ($F=22.56$, $p<0.001$) in the dry matter content in the plants (Table 5). Independently of the factors tested in the experiment, the highest content of dry weight in plants was noted in 2011 (14.34%), while the plants had the lowest content of dry matter in 2009 (13.50%). The overall result shows the content of dry matter in plants to depend on the manner of fertiliser application ($F=8.15$, $p=0.006$) and maize hybrid type ($F=25.26$, $p<0.001$) (Table 5). The

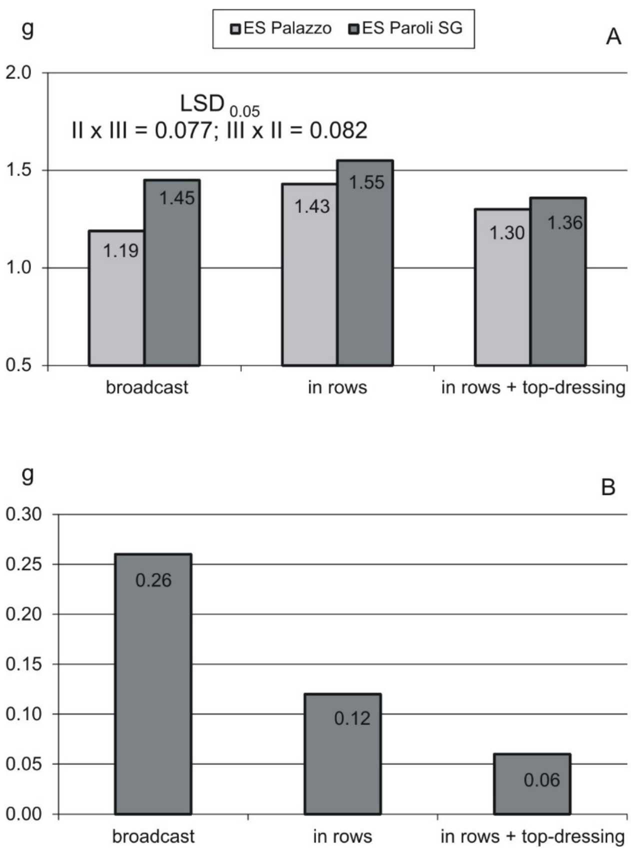

Figure 1. Combined effect of fertilizer application method (II) and maize hybrid type (III) on dry matter of a single plant in the BBCH 16/17 stage (A), (B) increase of dry matter of a single plant (2009–2011).

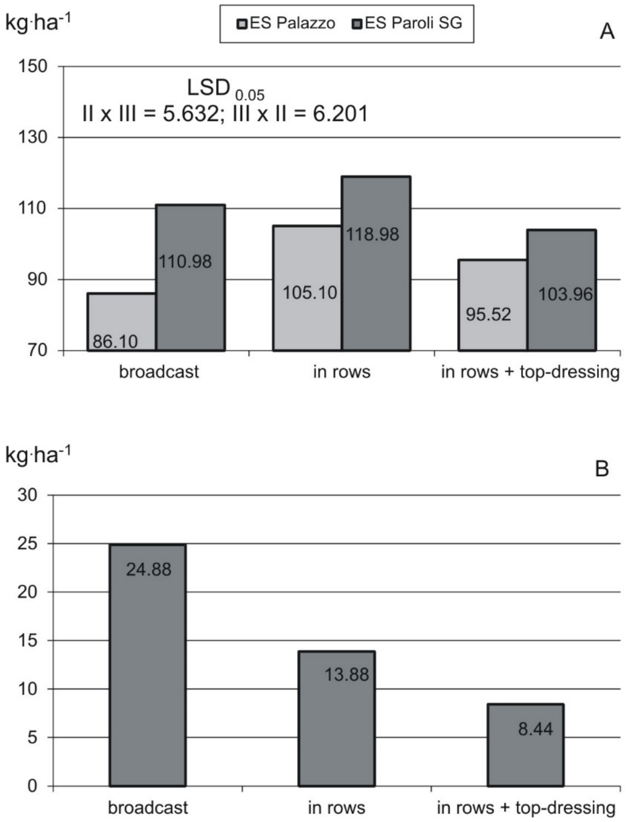

Figure 2. Combined effect of fertilizer application method (II) and maize hybrid type (III) on dry matter yield in the BBCH 16/17 stage (A), (B) increase of dry matter yield (2009–2011).

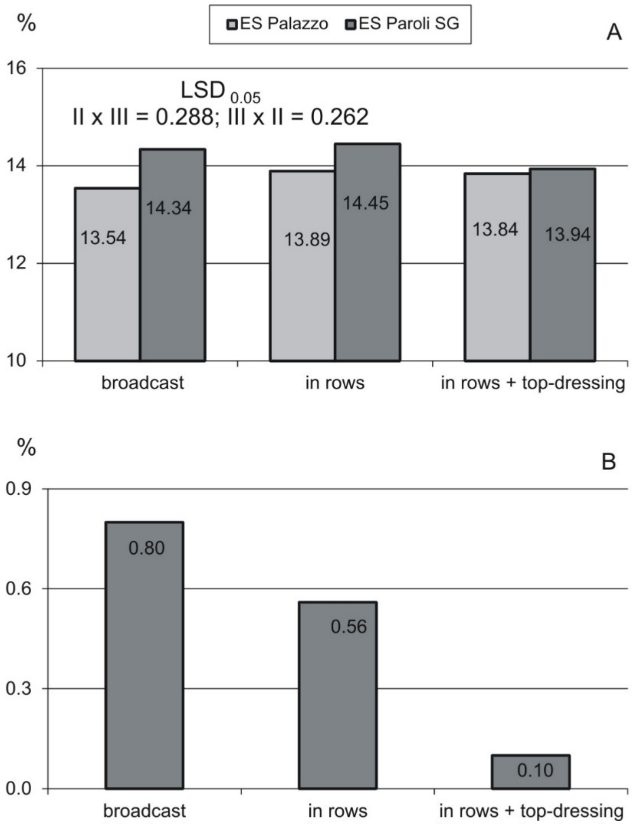

Figure 3. Combined effect of fertilizer application method (II) and maize hybrid type (III) on dry matter content in the BBCH 16/17 stage (A), (B) increase of dry matter content (2009–2011).

Table 5. Dry matter content (and standard deviations) [%].

Experimental factors		Years 2009	2010	2011	Mean
Type of nitrogen fertilizer	ammonium nitrate	13.47 (0.84)	14.25 (1.15)	14.27 (0.47)	14.00 (0.93)
	Canwil nitro-chalk	13.52 (0.82)	14.08 (0.74)	14.41 (0.50)	14.01 (0.78)
$LSD_{0.05}$		n.s.	n.s.	n.s.	n.s.
Method of fertilization	broadcasting	13.17 (0.75)	14.30 (1.12)	14.35 (0.60)	13.94 (1.00)
	in rows	13.80 (0.86)	14.32 (0.93)	14.39 (0.37)	14.17 (0.79)
	in rows + top-dressing	13.52 (0.78)	13.87 (0.80)	14.27 (0.49)	13.89 (0.75)
$LSD_{0.05}$		0.324	0.329	n.s.	0.164
Cultivar	ES Palazzo	12.84 (0.51)	14.07 (0.88)	14.35 (0.55)	13.76 (0.93)
	ES Paroli “stay-green”	14.15 (0.48)	14.26 (1.04)	14.33 (0.43)	14.24 (0.70)
$LSD_{0.05}$		0.283	n.s.	n.s.	0.166
Control [0 kg N·ha^{-1}]	ES Palazzo	12.33	14.09	14.08	13.50
	ES Paroli “stay-green”	13.69	14.95	14.27	14.30
Mean		13.50	14.16	14.34	14.00

n.s. – non-significant differences

highest dry matter content was in plants after in-row fertiliser application when compared with either broadcast or the combined in-row topdressed application at the 5–6 leaf stage. In turn, averaged over the experiment years, the ES Paroli „stay-green” cultivar contained more dry matter in comparison with the classic ES Palazzo cultivar (Table 5). The difference between the cultivars was 0.48 pp. The above interdependence was noted only in 2009.

Table 6. Absolute growth rate (AGR) of dry matter of a single plant (and standard deviations) and dry matter yield in the BBCH 16–17 stage.

Experimental factors		Years 2009		2010		2011		Mean	
		g plant^{-1} d^{-1}	kg ha^{-1} d^{-1}	g plant^{-1} d^{-1}	kg ha^{-1} d^{-1}	g plant^{-1} d^{-1}	kg ha^{-1} d^{-1}	g plant^{-1} d^{-1}	kg ha^{-1} d^{-1}
Type of nitrogen fertilizer	ammonium nitrate	0.033 (0.006)	2.43 (0.47)	0.019 (0.003)	1.44 (0.22)	0.040 (0.007)	3.08 (0.52)	0.031 (0.011)	2.32 (0.80)
	Canwil nitro-chalk	0.034 (0.005)	2.47 (0.047)	0.019 (0.003)	1.48 (0.23)	0.040 (0.006)	3.09 (0.47)	0.031 (0.010)	2.35 (0.78)
$LSD_{0.05}$		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Method of fertilization	broadcast-ing	0.033 (0.006)	2.42 (0.53)	0.018 (0.002)	1.42 (0.19)	0.036 (0.005)	2.78 (0.42)	0.029 (0.009)	2.21 (0.70)
	in rows	0.034 (0.005)	2.48 (0.44)	0.021 (0.002)	1.66 (0.16)	0.045 (0.005)	3.47 (0.40)	0.033 (0.010)	2.54 (0.83)
	in rows + top-dress-ing	0.033 (0.005)	2.46 (0.43)	0.017 (0.002)	1.60 (0.14)	0.039 (0.005)	3.00 (0.39)	0.030 (0.010)	2.25 (0.79)
$LSD_{0.05}$		n.s.	n.s.	0.0009	0.070	0.0037	0.297	0.0015	0.114
Cultivar	ES Palazzo	0.029 (0.004)	2.08 (0.27)	0.019 (0.002)	1.41 (0.19)	0.040 (0.008)	3.01 (0.57)	0.029 (0.010)	2.17 (0.76)
	ES Paroli “stay -green”	0.038 (0.004)	2.82 (0.29)	0.019 (0.003)	1.51 (0.24)	0.041 (0.005)	3.16 (0.39)	0.032 (0.010)	2,50 (0.78)
$LSD_{0.05}$		0.0016	0.110	n.s.	n.s.	n.s.	n.s.	0.0011	0.078
Control [0 kg N·ha^{-1}]	ES Palazzo	0.019	1.69	0.012	0.95	0.030	2.31	0.020	1.65
	ES Paroli “stay -green”	0.024	2.21	0.015	1.15	0.034	2.61	0.024	1.99
Mean		0.033	2.45	0.019	1.46	0.040	3.09	0.031	2.33

n.s. – non-significant differences

The plant dry matter depended also on the interaction between the manner of fertiliser application and hybrid type ($F=4.54$, $p=0.025$) (Fig. 3). The interaction took place independently of the year and its strength in those years was the same. For each manner of fertiliser application, the ES Paroli SG cultivar was characterised by greater dry matter content. The above interdependence consisted in greater difference in growth for spread fertiliser application when compared with in-row application and the in-row application supplemented with topdressing.

In our experiment, the absolute growth rate (AGR) of dry matter was determined for the period between sowing and the 6–7 leaf stage. This index was used to determine the rate of maize initial growth expressed as accumulation of dry matter. Thus accumulation of the plant dry matter is informative of the actual state of biomass production by a specific plant genotype (cultivar) under both natural and agro-technological conditions (Szulc, Bocianowski, 2012). The absolute rate of dry matter accumulation (AGR) depended on the course of thermal and humidity conditions in the years when the experiment was conducted (AGR of an individual plant: $F=341.5$, $p<0.001$; AGR from a unit area: $F=328.39$, $p<0.001$). The highest daily growth of dry matter in a unit area and in individual plant, independently of the observed experiment factors, was found/recorded in 2011 (0.040 g plant^{-1} d^{-1}; 3.09 kg ha^{-1} d^{-1}, respectively), while the lowest was in 2010 (0.019 g plant^{-1} d^{-1}; 1.46 kg ha^{-1} d^{-1}, respectively) (Table 6). The average maize AGR for the experiment years expressed as accumulation of dry matter over the period from sowing to 6–7 leaf stage was conditioned by the manner of fertiliser application (AGR of an individual plant: $F=24.04$, $p<0.001$; AGR from a unit area: $F=23.97$, $p<0.001$) and cultivar (AGR of an individual plant: $F=27.05$, $p<0.001$; AGR from a unit area: $F=63.26$, $p<0.001$) (Table 6). Maize after in-row fertilisation had higher AGR in comparison with plants after broadcast fertiliser application or in-row application supplemented with topdressing. The above interdependence was noted in 2010 (cold and wet) and 2011 (dry and warm). The favourable influence of temperature on the dry matter of an individual plant, dry matter yield, differences between manner of fertiliser application on the dry weight of an individual plant and the dry weight crop, N, P and K uptake during the period between sowing and 6–7 leaf stage was much stronger when the fertiliser was band applied rather than broadcast (Szulc, Kruczek, 2008). Moreover, in the above authors' opinion, localised fertiliser application (at the start) may be the way to limit negative impact of low water content in soil in the initial period of maize growth. ES Paroli SG had signifi-

Table 7. Absolute growth rate (AGR) of dry matter of a single plant (and standard deviations) and dry matter yield in the BBCH 16–17 stage depending on method of fertilizer application and hybrid type (2009–2011).

Specification	Dry matter of a single plant g plant^{-1} d^{-1}			Dry matter yield kg·ha^{-1}·d^{-1}		
	broadcasting	in rows	in rows + top-dressing	broadcasting	in rows	in rows + top-dressing
ES Palazzo	0.026 (0.008)	0.032 (0.012)	0.029 (0.010)	1.94 (0.59)	2.40 (0.88)	2.16 (0.73)
ES Paroli SG	0.032 (0.010)	0.034 (0.010)	0.031 (0.011)	2.48 (0.72)	2.67 (0.76)	2.34 (0.86)
$LSD_{0.05}$	II × III = 0.0019; III × II = 0.0020			II × III = 0.136; III × II = 0.149		
Difference	+ 0.006	+ 0.002	+ 0.002	+ 0.54	+ 0.27	+ 0.18

II – fertilizer application method, III – maize hybrid type

Table 8. Correlation coefficients between the observed traits.

Trait	Dry matter of a single plant	AGR a	Dry matter yield	AGR b	Dry matter content
Dry matter of a single plant	1				
AGR a	0.845***	1			
Dry matter yield	0.988***	0.872***	1		
AGR b	0.809***	0.993***	0.853***	1	
Dry matter content	0.026	0.1628	0.0961	0.209*	1

* p<0.05, *** p<0.001
AGR a – absolute growth rate of a single plant, AGR b – absolute growth rate of dry matter yield

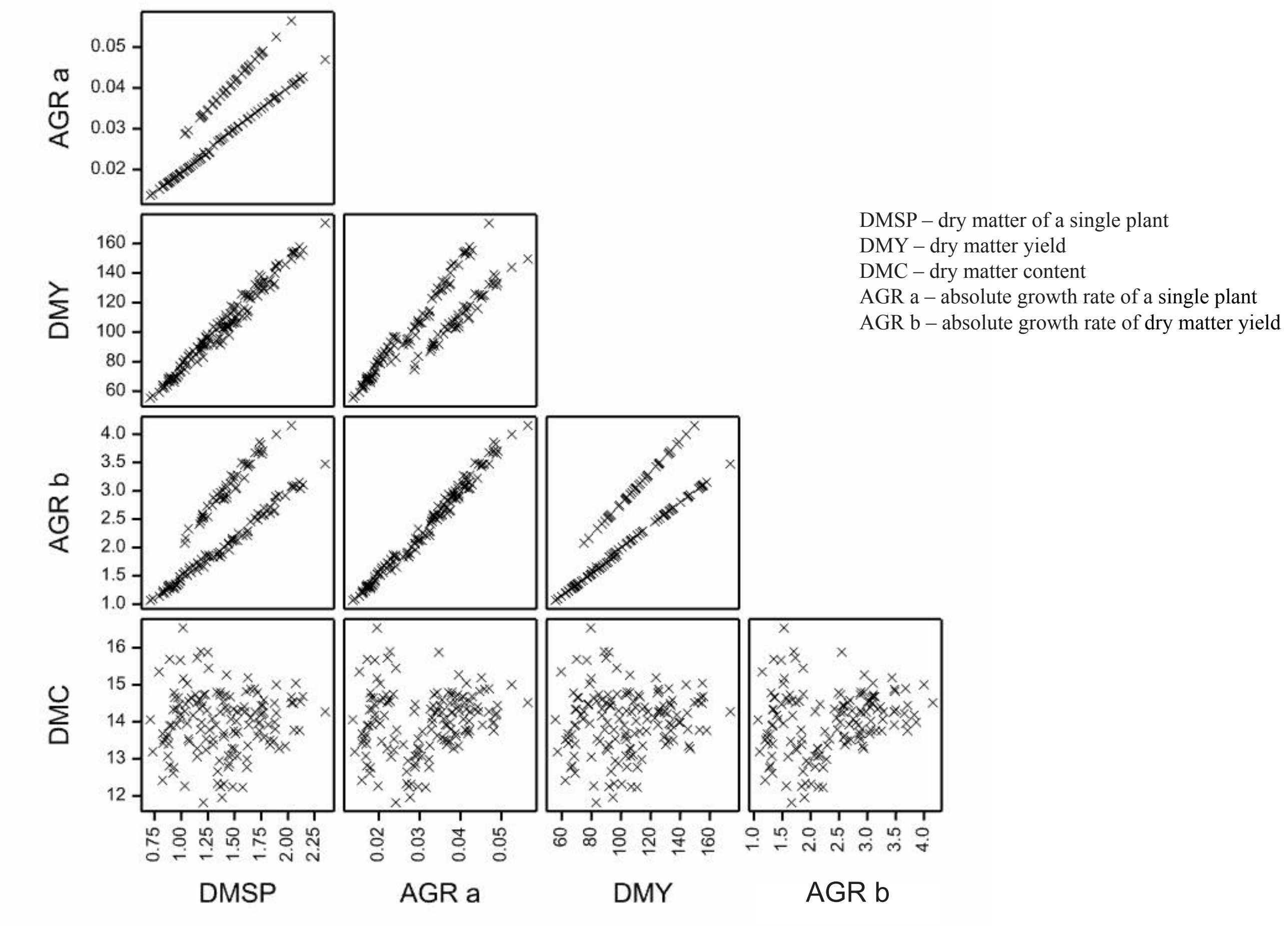

Figure 4. Scatterplot matrix for five traits of maize.

cantly higher growth of dry matter in individual plants and gave higher absolute growth rate on the yield from a unit area than did ES Palazzo. The differences between the cultivars amounted to: 0.003 g $plant^{-1}$ d^{-1}; 0.33 kg ha^{-1} d^{-1}, respectively (Table 6). The impact of maize cultivar on the AGR was noted only in 2009, which was the most favourable for maize growth. The AGR of dry matter of an individual plant and the yield of dry matter at the 6–7 leaf phase depended on correlation between the manner of fertiliser application and maize cultivar (Table 7). The impact of factors tested in this experiment was the same over the study years. For each tested manner of fertiliser application, ES Paroli SG was characterised by higher absolute initial AGR when compared with the classic ES Palazzo. The above interdependence consisted in greater difference in growth rate for broadcast fertiliser application when compared with in-row application and with the in-row application supplemented with topdressing.

The dry weight of a single plant was substantially correlated with: dry matter yield (r=0.988), absolute dry weight increase rate of an individual plant (r=0.845) and absolute dry matter growth rate (r=0.809). Moreover, the AGR of an individual plant was correlated with: AGR of dry matter (r=0.993) and dry matter yield (r=0.872). AGR of the dry matter yield was correlated with dry matter yield (r=0.853), dry matter content (r=0.209) and dry matter of a single plant (r=0.809) (Table 8, Fig. 4).

CONCLUSIONS

1. Band fertiliser application, in comparison with spread and in-row supplemented with topdressing, had positive influence on the vigour of maize initial growth which was expressed by greater dry weight of an individual plant at the 6–7 leaf phase, greater dry matter yield from a unit area at the 6–7 leaf phase, higher absolute dry weight growth of an individual plant and higher absolute dry matter increase rate.
2. The "stay-green" cultivar, when compared with the traditional hybrid, was characterised by faster accumulation of dry weight in the initial growth period expressed by greater dry weight of an individual plant and dry matter yield from 1 ha, dry matter content and absolute dry matter growth rate of an individual plant and dry matter yield at the BBCH 16–17 phase.
3. The greatest differences between the two cultivars in dry weight of a single plant in the yield of dry matter and the dry matter content in the 6–7 leaf stage, in favor of a „stay-green" cultivar compared to conventional cultivars, were found in the maize fertilizing in the traditional method (broadcasting). These differences were decreased by the band fertilization, and by the band fertilization supplemented by capitation fertilization were the smallest and insignificant in the case of dry matter per an individual plant and dry matter content of crops.
4. Significantly positive statistic correlation of the dry weight with dry matter yield, absolute dry weight growth rate of an individual plant and absolute growth rate of dry matter yield indicate strong connection between these factors and further experiments may be limited to observation of only one of them.

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