Original Research

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

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Abstract

A field experiment was carried out in the Department of Agronomy of Poznań University of Life Sciences on the fields of the Research and Education Unit in Swadzim in 2009-10. Two different genotypes of maize cultivated for grain that exhibited different aging rates were compared: ES Palazzo and ES Paroli "stay-green"-type cultivar. The dynamics of dry matter accumulation were assessed 10 times every 14 days. We found that together with the progress of vegetation, the "stay-green" hybrid accumulated a significantly greater amount of dry matter in comparison with the traditional cultivar. During the generative development, the differences in production of dry matter of a single plant between the examined cultivar types were even significantly greater. The absolute growth rate (AGR) of dry matter of a single plant, leaf blades, and grain was higher for the "stay-green" hybrid when compared to the other examined cultivar. In order to assess the amount of soil mineral nitrogen remaining after plant harvesting in the autumn, the N_{min} method was used in the present research. The soil mineral nitrogen content ($N\text{-}NH_4$+$N\text{-}NO_3$) after harvesting of ES Palazzo cultivar was significantly higher in comparison with the ES Paroli "stay-green" cultivar. A higher content of both mineral nitrogen forms after plant harvesting was observed in the 0-30 cm soil layer than in the 31-60 cm soil layer, irrespective of the type of maize hybrid. The content of nitrate nitrogen $N\text{-}NO_3$ in the total amount of N_{min} in the 0-30 cm soil layer amounted to 79.6%, while at a depth of 31-60 cm it amounted to 81.2%. The examined cultivars affected the content of potassium and magnesium in soil after harvesting. However, no significant influence of maize hybrid type on the content of phosphorus and soil pH was found. A significantly lower amount of magnesium and potassium in soil after harvesting the "stay-green" cultivar when compared to the traditional cultivar proves that the main source of accumulation of these macroelements in the stage of generative growth are soil resources. This results from demand for these elements in the stage of maximum increase in biomass of generative yield. Such behavior of "stay-green"-type plants should imply a fertilization system with slow-acting fertilizers. Lack of magnesium and potassium in soil in the period of maturation of "stay-green"-type maize may be a classical example of the law of the minimum.

Keywords: "stay-green," maize, dynamics of dry matter accumulation, absolute growth rate (AGR), N_{min}

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Introduction

Knowledge of cultivars and making right cultivar choice for cultivation is one of the most important abilities of a modern producer. Older hybrids are constantly replaced with new ones with higher yield potential and greater resistance to diseases, pests, and environmental stress. Hence one should be up-to-date with the subject because maize cultivation progress is considerable and only a few cultivars are profitable for a longer period of time. For several years the selection of maize cultivars has included "stay-green" type hybrids, in whom full greenness of the whole plant is retained during grain ripening [1-3]. "Stay-green" cultivars delay senescence and can maintain photosynthetic abilities during the grain filling period by constant delivery of assimilates to the generative yield [3]. This characteristic is favourable from an agricultural point of view because maintaining the greenness of the cornfield (plant photosynthetic apparatus) for a long period of time is one of the most effective ways to increase plant yield.

During plant vegetative growth, the flow of nitrogen from older to younger organs occurs at different speeds, and the main source of nitrogen is always soil [4]. In the maturation period, nitrogen taken up from soil accounts for only a small portion of nitrogen accumulated in generative organs (grain). Most nitrogen comes from remobilization of this element that was previously accumulated in vegetative organs. Therefore, the more nitrogen is accumulated in plant vegetative organs (leaves, stems), the greater should be grain yield. Ta and Welland [5] state that greater utilization of nitrogen by "stay-green" type cultivars in comparison with traditional hybrids results from the ability to take up nitrogen from soil for a longer period of time and from the repeat remobilization of nitrogen from vegetative tissues to grain. As a result, less-produced $N\text{-}NO_3$ remains in soil after plant harvesting in the autumn, available to wash out deep into the soil profile. Thus, cultivation of "stay-green" type hybrids for grain is well-founded from both the ecological and economic points of view [6, 7]. Additionally, as stated by Szulc et al. [8, 9] "stay-green" hybrids may also be used in ecological agriculture.

The aim of the field research was to assess the accumulation and redistribution of dry matter during the whole plant vegetation period by two different maize genotypes exhibiting different aging rates. Moreover, the content of mineral nitrogen in soil ($N\text{-}NO_3$ and $N\text{-}NH_4$) was assessed after plant harvesting at depths of 0-30 cm and 31-60 cm, which aimed at determining the influence of the examined cultivars on nitrogen eutrophication of the environment.

Material and Assessment Methods

Field Experiment

The field experiment was carried out in the Department of Agronomy of the Poznań University of Life Sciences on the fields of the Research and Education Unit in Swadzim, 2009-10. Two maize hybrids that differed morphologically were compared with each other: ES Palazzo (FAO 230-240) and ES Paroli (FAO 250), "stay-green" type. Each year the field experiment was established on 19 April. The field size was 15.4 m^2.

Cultivation measures, fertilization, and other agrotechnological elements were implemented according to the recommendations on maize cultivation for grain. The same NPK fertilization was used every year of research on the whole experimental field in the amount of: 100 kg $N \cdot ha^{-1}$ in the form of urea, 80 kg P_2O_5 ha^{-1} (35.2 kg $P \cdot ha^{-1}$) in the form of Polifoska 6, and 120 kg K_2O ha^{-1} (99.6 kg $K \cdot ha^{-1}$) in the form of 60% potassium salt.

Maize harvesting for grain was performed with the use of a Wintersteiger plot combine.

Plant Material

In order to determine the accumulation and redistribution of dry matter, plant samples (8 plants) were collected ten times every year (number of days from the sowing date: – 32, 46, 60, 74, 88, 102, 116, 130, 144, 158). Each time of the observation the samples were divided according to their developmental stages into sub-samples: whole plants, stems, leaves, husks, ears, core, grain, and also dry matter of a single plant.

Absolute growth rate of dry matter of a single plant, leaf blades, and grain (AGR) were calculated according to the following formula [4]:

$$AGR = (W_2\text{-}W_1) / (T_2\text{-}T_1)$$

...where:

AGR – absolute growth rate ($g \cdot plant^{-1} \cdot d^{-1}$)

W_1 – initial plant weight (of leaves or grain)

W_2 – plant weight (of leaves or grain) in a given harvesting time

$T_2\text{-}T_1$ – time between the assessment of dry matter W_1 and W_2 (days)

Collection of Soil Samples

The assessment of the content of macroelements, pH, and the amount of soil mineral nitrogen (the 0-30 cm, 31-60 cm soil layers) 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

$N\text{-}NH_4$ – PB.50 ed. 6 of 17.10.2008

$N\text{-}NO_3$ – PB.50 ed. 6 of 17.10.2008

The assessment of soil phosphorus, potassium, magnesium, pH, and mineral nitrogen ($N\text{-}NO_3$ and $N\text{-}NH_4$) was conducted after maize harvesting.

Table 1. Meteorological conditions during the research period.

Months	Years					
	2009			2010		
	T	P	S	T	P	S
IV	12.9	19.2	0.49	9.3	26.8	0.96
V	14.0	109.9	2.53	12.2	110.5	2.92
VI	16.0	113.8	2.37	18.4	43.4	0.78
VII	20.3	75.4	1.19	22.6	97.5	1.39
VIII	20.1	26.2	0.42	19.2	143.5	2.41
IX	15.8	48.6	1.02	13.0	69.9	1.79
X	7.6	59.2	2.51	7.0	9.1	0.42
Vegetation period	15.2	452.3	1.50	14.5	500.7	1.52

T – average monthly air temperature (ºC)
P – monthly amount of precipitation (mm)
S – hydrothermal coefficient of water supply according to Sielianinov [10]

$$\text{Amount of } N_{min} \text{ kg}\cdot\text{ha}^{-1} = $$
$$= \text{content of } N_{min} \text{ in mg}\cdot 100 \text{ g}^{-1} \text{ of dry matter} \cdot 45$$

...where: 45 – coefficient for light soil.

Thermal and Humidity Conditions

The thermal and humidity conditions during maize vegetation are presented in Table 1. The amount of precipitation of the time period from April to September amounted to 452.3 mm in 2009 and 500.7 mm in 2008. The calculated hydrothermal coefficients according to Sielianinov – Molga [10] (Table 1) revealed that during the field experiment, periodic water deficiencies in soil occurred in 2009 in April and August (the coefficient amounted to 0.96 and 0.78, respectively), and in 2010 in April and June (respectively 0.49 and 0.42). Average daily air temperature measured at 2 m during the vegetation period in 2009 amounted to 15.2ºC, and 14.5ºC in 2010.

Results and Discussion

The conducted analysis of variance did not confirm the significant influence of maize hybrid type on dry matter of a single plant in the 2-3 and 5-6 leaf stages (respectively 32 and 46 days from the sowing date) – Table 2. On those dates only a tendency for greater dry matter accumulation by “stay-green”-type hybrid in comparison with the traditional cultivar was noted. Significantly higher dry matter of a single plant of “stay-green”-type hybrid in the 5-6 leaf stage by 0.13 g in comparison with the traditional cultivar was previously observed by Szulc et al. [11].

Maize hybrid type significantly modified the amount of dry matter of a single plant from the 60th day after the sowing date until the end of plant vegetation (158 days from sowing). On average for the years of research, significantly higher dry matter of a single plant was noted for ES Paroli “stay-green” type hybrid in comparison with ES Palazzo traditional cultivar (Table 2). The difference amounted to, respectively: 60 days from the sowing date (0.35 g), 74 days from the sowing date (3.12 g), 88 days from the sowing date (6.34 g), 102 days from the sowing date (5.76 g), 116 days from the sowing date (15.17 g), 130 days from the sowing date (29.82 g), 144 days from the sowing date (40.32 g), and 158 days from the sowing date (68.29 g). The result obtained in the previous research indicates that together with the progress of plant vegetation, the rate of dry matter accumulation by “stay-green” maize hybrid increases when compared to the traditional cultivar (Fig. 1).

The intensity of photosynthesis, despite considerable variations due to changeable environmental conditions, is genetically determined and is a species and cultivar characteristic [12]. A positive correlation between the intensity of photosynthesis and yield is observed only in some cases. Very often hybrids that are characterized by high intensity of photosynthesis yield lower than the cultivars whose efficiency of this process is reduced. The reason for this phe-

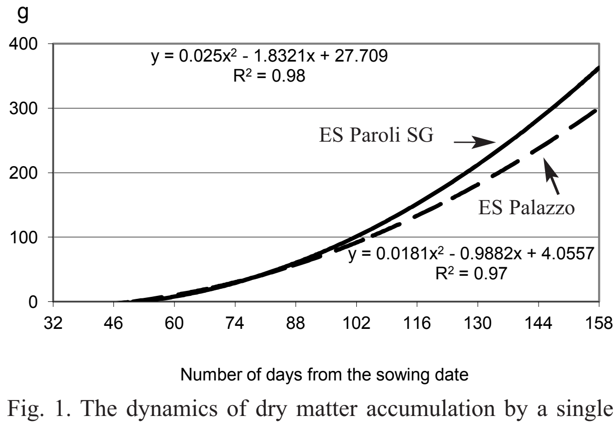

Fig. 1. The dynamics of dry matter accumulation by a single maize plant during the vegetation period (2009-10).

Table 2. The dynamics of dry matter accumulation (g) during the maize vegetation period.

Cultivar type	Number of days after the sowing date – vegetative development														
	32 – the 2-3 leaf stage			46 – the 5-6 leaf stage			60			74			88		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
ES Palazzo	0.05	0.05	0.05	0.23	0.21	0.22	1.12	1.69	1.41	7.39	14.15	10.77	51.26	73.66	62.46
ES Paroli SG	0.06	0.05	0.06	0.25	0.26	0.26	1.51	2.00	1.76	10.33	17.46	13.89	58.10	79.50	68.80
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.281	0.194	0.276	2.441	2.342	2.148	4.921	3.878	4.237

Cultivar type	Number of days after the sowing date – generative development														
	102			116			130			144			158		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
ES Palazzo	87.00	98.48	92.74	120.57	127.24	123.90	193.61	214.40	204.00	248.41	270.01	259.21	263.50	285.96	274.73
ES Paroli SG	90.59	106.42	98.50	127.24	150.90	139.07	213.64	254.00	233.82	274.61	324.46	299.53	328.84	357.21	343.02
$LSD_{0.05}$	2.476	4.131	3.728	4.371	10.441	8.874	9.443	11.487	14.390	13.280	15.643	17.449	19.119	24.328	21.090

n.s. – non-significant

nomenon is that not only the intensity of photosynthesis but also the assimilation area of a plant and the length of time when a plant is able to perform effective photosynthesis plays a substantial role in biomass production. Thomas and Smart [13] described the characteristic of constant greenness of "stay-green" as phenotypes that exhibit delayed senescence and have higher content of water and chlorophyll in leaves during the maturation period. Therefore, they have higher yielding potential in comparison with traditional cultivars, provided that fundamental requirements of right agrotechnology are met. In the present study, dry matter of leaf blades of a single plant of the "stay-green" type hybrid from the 88th to the 158th day after the sowing date was higher when compared to the value of the traditional cultivar (Fig. 2). For both examined hybrids the relationships were described by a linear equation. The daily increase in dry matter of leaf blades of a single plant of the traditional cultivar amounted to 0.17 g, and of the "stay-green" type hybrid – 0.24 g (Fig. 2). The obtained result corresponds to earlier reports [2] because the authors described "stay-green" type hybrids as plants that have a greater amount of leaves and greater leaf surface area in comparison with traditional cultivars. Also, Szulc [14] stated that the "stay-green" type hybrid produced significantly greater assimilation area of a single plant by 231.1 cm^2 and of an ear leaf by 39.7 cm^2, when compared to the traditional cultivar.

The analysis of plant growth is the basic tool of the general assessment of factors responsible for accumulation of dry matter during the plant vegetation period. Regular measurements enable us to determine plant weight or the area of assimilation organs – e.g. leaf blades. The accumulation of plant dry matter described in this way provides information on the actual state of biomass production by a plant (cultivar types) in the conditions dependent on natural and agrotechnological factors [4]. For this purpose, the absolute growth rate (AGR) of dry matter of a single plant, leaf blades, and grain was determined in the present research (Figs. 3, 4, and 5). The AGR of dry matter of a single plant and of leaf blades of the examined cultivars was described with formula 2º, and in the case of ES Paroli "stay-green"-type hybrid the relationships were higher in comparison with ES Palazzo traditional cultivar (Figs. 3 and 4).

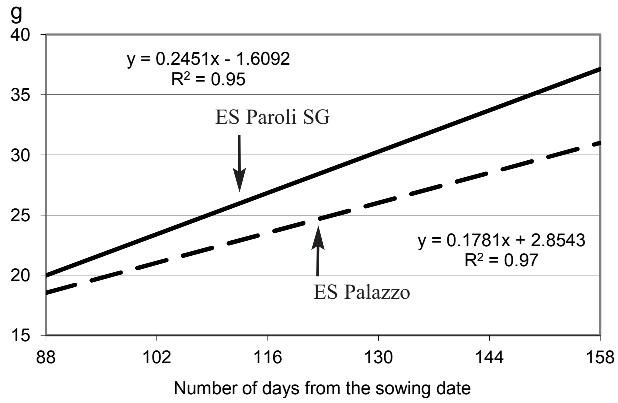

Fig. 2. The dynamics of accumulation of dry matter of leaves by a single maize plant during generative development (2009-10).

The absolute growth rate (AGR) of dry matter of grain from a single plant on the 144th day after the sowing date and at the end of the vegetation period (158 days after the sowing date) was significantly higher in the "stay-green" hybrid when compared to the traditional cultivar (Fig. 5). The present research revealed a greater increase in the dry matter of the grain of both examined cultivars on the 144th than on the 158th day after the sowing date, and a greater difference – by more than 300% (1.19 $g \cdot plant^{-1} \cdot d^{-1}$) – between the examined cultivar types was observed at the end of the vegetation period (Fig. 5). Results obtained in the present research are not a coincidence but rather a regularity and confirms the usefulness of the choice of a "stay-green" hybrid for cultivation for grain, which was previously demonstrated by Szulc et al. [7].

According to Grzebiesz [4], most carbon accumulated in grain comes from running photosynthesis of photosynthetically active organs. The grain demand for assimilates is so high that generative and vegetative organs or particular generative structures compete with each other (Fig. 6). In the first case, the development of vegetative organs is inhibited, whereas in the second one the amount of accumulated carbon depends on the age of an acceptor. The older the acceptor, the greater the odds on its accumulation of a respectively high amount of carbon, which obviously has its repercussions for the amount of produced generative yield.

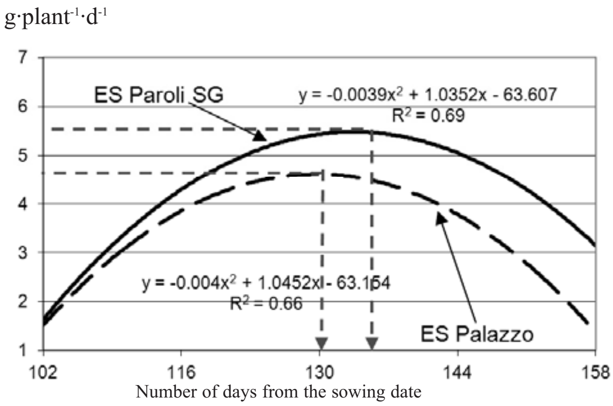

Fig. 3. The absolute growth rate (AGR) of dry matter of a single maize plant during generative development (2009-10).

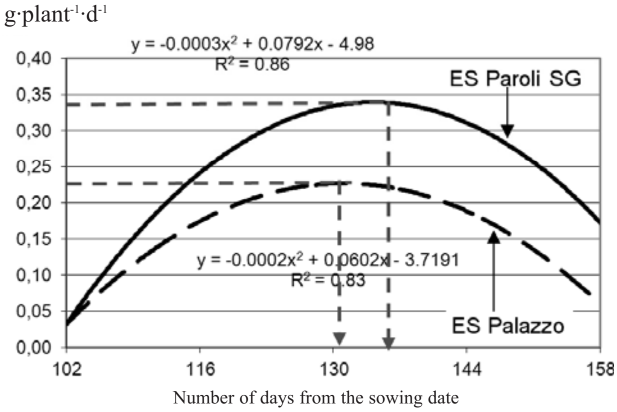

Fig. 4. The absolute growth rate (AGR) of dry matter of leaf blades of a single maize plant during generative development (2009-10).

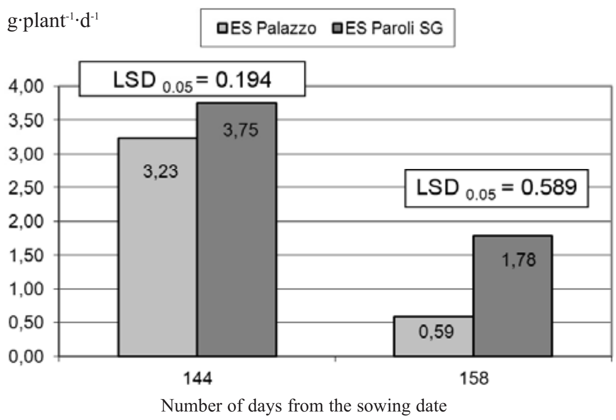

Fig. 5. The absolute growth rate (AGR) of dry matter of grain of a single plant (2009-10).

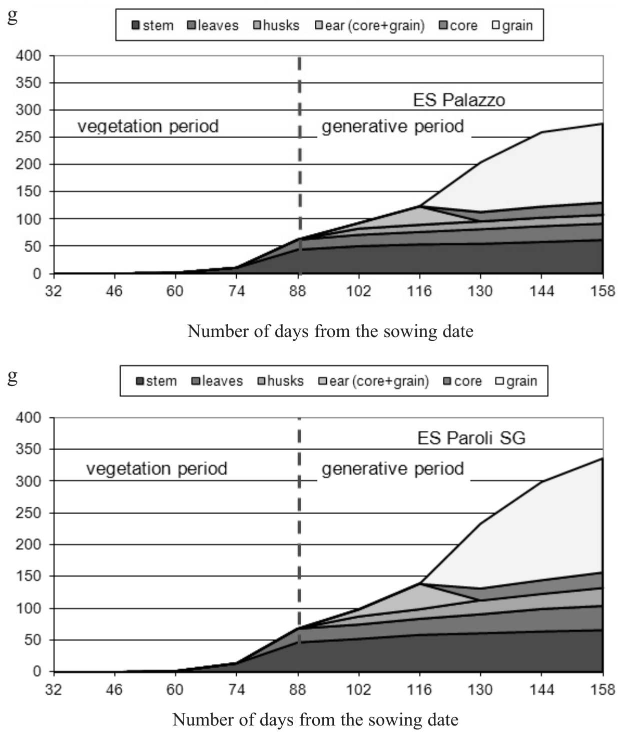

Fig. 6. The model of accumulation and redistribution of dry matter between organs of a single plant of two maize cultivar types during the vegetative period (2009-10).

Mineral nitrogen (N_{min}) remaining in soil after plant harvesting poses a potential threat to the environment. Nitrate nitrogen may be washed out and reduced to nitrogen oxides. Ammonium nitrogen is significantly less mobile and if it is not nitrified, the loss of this form of nitrogen is little probable. The perfect situation is when soil contains no nitrate nitrogen after plant harvesting; obviously, such a situation never occurs, and a definite content of $N\text{-}NO_3$ is an indicator of soil state in good soil culture [15]. The adverse effect of nitrogen on the natural environment is observed after exceeding its optimal doses, when considerable accumulation of mineral nitrogen forms in soil takes place, so nitrogen eutrophication of a habitat can be

Table 3. The content of mineral nitrogen (N_{min}) in soil after maize harvesting.

Cultivar type	Sampling depth (cm)	Element	Years			
			2009	2010	Mean	Mean
			mg·100 g^{-1} d.m.			N_{min} kg·ha^{-1}
ES Palazzo	0-30	$N-NH_4$	0.38	0.24	0.31	13.9
ES Paroli "stay-green"			0.16	0.32	0.24	10.8
$LSD_{0.05}$			0.151	n.s.	-	1.948
ES Palazzo	31-60		0.27	0.26	0.26	11.7
ES Paroli "stay-green"			0.12	0.18	0.15	6.7
$LSD_{0.05}$			0.099	0.078	-	3.519
ES Palazzo	0-30	$N-NO_3$	1.40	0.92	1.16	52.2
ES Paroli "stay-green"			1.10	0.89	0.99	44.5
$LSD_{0.05}$			0.124	n.s.	-	2.713
ES Palazzo	31-60		0.92	1.12	1.02	45.9
ES Paroli "stay-green"			0.85	0.65	0.75	33.7
$LSD_{0.05}$			n.s.	0.238	-	4.819
ES Palazzo	0-30	NH_4NO_3	1.78	1.16	1.47	66.1
ES Paroli "stay-green"			1.26	1.21	1.23	55.3
$LSD_{0.05}$			0.231	n.s.	-	3.471
ES Palazzo	31-60		1.19	1.38	1.28	57.6
ES Paroli "stay-green"			0.97	0.83	0.90	40.5
$LSD_{0.05}$			n.s.	0.219	-	4.101
ES Palazzo	0-60	NH_4NO_3	2.97	2.54	2.75	123.7
ES Paroli "stay-green"			2.23	2.04	2.13	95.8
$LSD_{0.05}$			0.314	0.211	-	6.579

n.s. – non-significant

observed [16]. What is more, an excessive amount of nitrogen in soil is undesirable since the element can migrate into groundwater, and groundwater is connected with both open water and drinking water. Thus the assessment of the content of soil mineral nitrogen after plant harvesting is used in the examination of ecological effects of nitrogen use. In the present research the assessment of the amount of mineral nitrogen in soil after maize harvesting was performed with the commonly used N_{min} method [17].

The statistical analysis of the obtained results showed a significance of years in establishing the content of soil mineral nitrogen ($N-NH_4$ and $N-NO_3$) after harvesting the two different types of maize cultivars (Table 3). However, the proven significance of the influence of this factor on the value of the examined characteristic in the analyses of interactions (years × factor) indicates a strongly directed influence of cultivar types on the content of N_{min} in soil after plant harvesting, and enables us to generalize the conclusions for the whole soil and climate region. On average for the years of research, a significantly lower amount of mineral nitrogen in soil after plant harvesting was found for the ES Paroli "stay-green" cultivar in comparison with ES Palazzo traditional cultivar. The difference was respectively 10.8 kg N_{min}·ha^{-1} (0-30 cm) and 17.1 kg N_{min}·ha^{-1} (31-60 cm) – Table 3. The results obtained in the present research correspond to the earlier results by Szulc [6], who investigated the response of two different maize cultivar types to a various level of applied nitrogen and magnesium, and showed a smaller amount of mineral nitrogen after plant harvesting in the 0-60 cm soil layer by 28.1 kg N_{min}·ha^{-1} in favor of the "stay-green"-type hybrid, regardless of the amount of the applied elements. In addition, the author stated that for the purpose of protection of the natural environment against an excessive amount of N_{min} in soil after maize harvesting, only "stay-green"-type hybrids are the best to be cultivated for grain and the used nitrogen fertilization should be combined with magnesium. What is more, Müller and Görlitz [17] note the hazard of an excessive amount of mineral nitrogen in soil after harvesting and state that the average content of this form of nitrogen in loamy sand in the 0-60 cm soil layer in the autumn is 107 kg $N_{min}·ha^{-1}$. In the present research, the content of soil mineral nitrogen in the 0-60 cm soil layer amounted to 123.7 kg $N_{min}·ha^{-1}$ for ES Palazzo hybrid, while for the ES Paroli "stay-green" hybrid it was lower by 27.9 kg $N_{min}·ha^{-1}$ and amounted to 95.8 kg $N_{min}·ha^{-1}$ (Table 3).

In the present research a higher content of both forms of mineral nitrogen was found in the 0-30 cm soil layer in comparison with the 31-60 cm soil layer, irrespective of the type of maize hybrid (Fig. 7), which is in accordance with observations of other researchers [18]. The content of nitrate and ammonium form of nitrogen in the soil profile was also determined (Fig. 8). Irrespective of maize hybrid type, the content of nitrate form was higher in the 0-30 cm soil layer ($N-NO_3$ 79.6%, $N-NH_4$ 20.4%) and in the 31-60 cm soil layer ($N-NO_3$ 81.2%, $N-NH_4$ 18.8%). Trawczyński [19] demonstrated that after the plant vegetation period the content of nitrate form in the the 0-30 cm and 31-60 cm soil layers was higher than in the plant vegetation period and accounted for over 70% of the total amount of mineral nitrogen, which was also proved in the present study.

In the case of the content of phosphorus, potassium, magnesium, and soil pH after plant harvesting, the conducted statistical analysis showed an interaction between

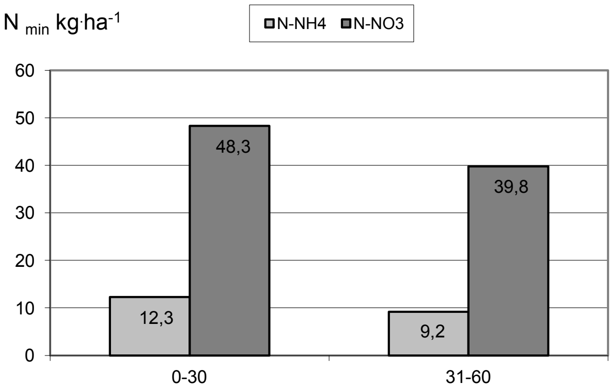

Fig. 7. The content of nitrate and ammonium nitrogen form in soil after plant harvesting irrespective of maize hybrid type (2009-10).

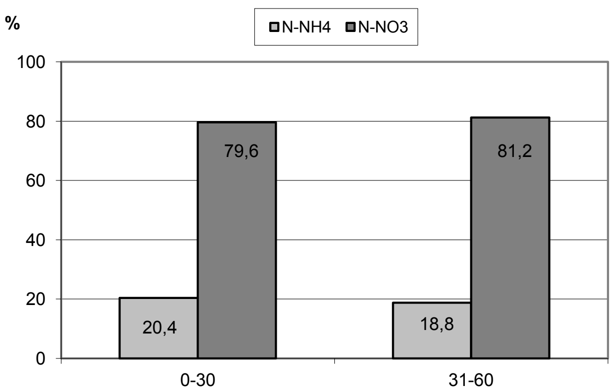

Fig. 8. The percentage content of $N-NH_4$ and $N-NO_3$ in the total amount of mineral nitrogen after plant harvesting (2009-10).

Table 4. The content of macroelements in soil and soil pH after maize harvesting (2009-10).

Cultivar type	P*	K*	Mg*	pH
	mg·kg^{-1} of soil			1 m KCl
ES Palazzo	32.6	69.7	58.2	5.7
ES Paroli "stay-green"	32.1	64.7	52.8	5.4
$LSD_{0.05}$	n.s.	2.29	3.34	n.s.

n.s. – non-significant

*The assessment of the content of macroelements: P and K – low content, Mg – medium content

years and maize hybrid type. However, the direction of the changes was similar in all the years of research and the statistically confirmed interaction resulted only from differences in the strength of effect of the factor in the particular years of the experiment. Hence, in order to clearly present the relationships and make generalizations in the study, the influence of maize cultivar type on those characteristics was presented using mean values for the years of research (Table 4). Maize hybrid type did not affect significantly the content of phosphorus and soil pH after plant harvesting, while in the case of potassium and magnesium content the examined cultivars significantly influenced the content of these macroelements in soil. A significantly lower amount of potasium and magnesium was noted in soil after harvesting of the ES Paroli "stay-green" cultivar in comparison with the other examined cultivar. The difference amounted to 5 mg K·kg^{-1} of soil and 5.4 mg Mg·kg^{-1} of soil, respectively (Table 4).

The main reason for a significantly lower amount of magnesium in soil after harvesting "stay-green" cultivar in comparison with the other examined cultivar is the negative remobilization (transfer) rate of this macroelement [21]. It demonstrates that in the stage of generative growth (grain-filling period), the "stay-green" cultivar did not use the resources accumulated in vegetative yield but took only that of soil resources. On the other hand, Szulc et al. [20] obtained a positive remobilization rate for potassium, which proves that potassium accumulated in vegetative biomass, not soil fertility, plays a decisive role in the stage of generative growth. Hence the line of thinking explaining the lower amount of potassium in soil after harvesting "stay-green" plants in comparison with the traditional cultivar is completely different and slightly longer. For maize, potassium accumulation in the initial stage of growth is relatively small. However, it determines nitrogen intake, which in turn determines a range of processes that influence the size of generative yield. A stage critical for potassium intake is the stage of linear plant growth, when intensive dry matter increase is observed, determined by both nutrition with nitrogen and water supply [4]. A plant, in order to accumulate the optimum amount of potassium, first has to develop a deep root system able to exploit deeper layers of the soil profile. Maize in the stage of technological maturity accumulates the smallest amount of this macroelement in grain and the greatest in vegetative biomass. Thus, due to heavier foliage and higher biomass production, demand for "stay-green" cultivars for potassium and other macroelements is considerably higher than that of their traditional equivalents [21]. It explains also the lower amount of this element in soil after harvesting "stay-green" maize when compared to the traditional cultivars.

Low soil pH after harvesting both examined maize cultivars can be explained by washing out Ca^{2+}, Mg^{2+}, and K^{+} alkaline ions by climate itself, which results in soil acidification [22]. A high amount of precipitation was observed during the maize vegetation period in the years of the field experiments (Table 1), which largely determined the acidity of soil after plant harvesting.

Conclusions

During maize vegetation, the "stay-green" hybrid had a greater increase in dry matter of a single plant in comparison with the traditional cultivar. Greater differences in the increase in dry matter of a single plant were noted together with the progress of vegetation of the examined cultivars. The absolute growth rate (AGR) of dry matter of a single plant, dry matter of leaf blades, and dry matter of grain was higher for the "stay-green" cultivar when compared to the traditional cultivar. The content of soil mineral nitrogen after harvesting the ES Palazzo cultivar was significantly higher in comparison with the ES Paroli "stay-green" cultivar. The difference amounted to 10.8 kg $N_{min}\cdot ha^{-1}$ in the 0-30 cm soil layer and to 17.1 kg $N_{min}\cdot ha^{-1}$ in the 31-60 cm soil layer. A higher content of both forms of soil mineral nitrogen after plant harvesting was demonstrated in the 0-30 cm soil layer than in the 31-60 cm soil layer, regardless of maize hybrid type. The content of nitrate nitrogen $N-NO_3$ in the total amount of N_{min} in the 0-30 cm soil layer amounted to 79.6%, and to 81.2% in the 31-60 cm soil layer. A significantly lower amount of potassium and magnesium was noted in soil after harvesting the "stay-green" hybrid in comparison with the other examined hybrid. Therefore, taking into consideration ecological issues (lower environmental eutrophication) as well as potential abilities to produce generative yield (AGR), the best choice for the purpose of cultivation for grain would be "stay-green"-type hybrids.

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