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SUSCEPTIBILITY OF MAIZE HYBRIDS (*Zea mays* L.) TO FRIT FLY (*Oscinella frit* L.) UNDER CONDITIONS OF DIVERSIFIED NITROGEN CONTENT IN THE SOIL AND DIFFERENT TYPES OF NITROGEN FERTILIZERS

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Abstract. Right selection of hybrid for cultivation is an especially important issue because maize belongs to a group of plants undergoing considerable breeding development. It is manifested not only in a higher number of new hybrids but also in changes in selection of various breeding types. The field experiments were carried out at the Department of Agronomy of the University of Life Sciences in Poznań, on the fields of the Agricultural-Experimental Station Swadzim in the years 2009-2011. The occurrence of frit fly (*Oscinella frit* L.) on various maize hybrids (ES Palazzo and ES Paroli – type stay-green) was evaluated, depending on the nitrogen content in the soil, and on the form of a nitrogen fertilizer. It was indicated that the course of weather conditions in the period from sowing until the 5-6 leaf stage (BBCH 15/16) significantly affected the extent of damage caused by frit fly. In the years with a cool spring, percentage of damaged plants was higher. Damage caused by frit fly larvae was directly proportional to the size of the applied dose of a nitrogen fertilizer. The type of a nitrogen fertilizer was not the factor determining the extent of damage caused by this agrophage. Cultivation of stay-green hybrids should be considered as an element of an integrated maize protection against frit fly.

Key words: frit fly, *Oscinella frit*, N dose, stay-green, nitrogen fertilizer

INTRODUCTION

Maize (*Zea mays* L.) belongs to thermophilous plants [Kim *et al.* 2007] and, for proper growth and quick development, it requires more heat in the growing season than other cereal plants [Sowiński 2000]. Among other effects, temperature affects the dynamics of accumulation of dry weight and the rate of initial growth [Szulc 2013]. Low temperature of soil and air during the period of sowing and during the initial growth stages is one of the main yield limiting factors in maize [Fageria and Baligar 2005, Subedi and Ma 2005]. In Poland, where sowing of maize is carried out late in

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April or at the beginning of May, thermal conditions are often unfavorable. Therefore, creating favorable nutrition conditions may allow for increased maize growth rate in the initial stages, which should positively affect the yield [Kruczek and Szulc 2006], and enhance maize resistance to some agrophages, especially frit fly (*Oscinella frit* L.) [Szulc *et al.* 2011]. According to Bereś and Pruszyński [2008], especially in cool springs, young maize plants are mainly threatened by the frit fly larvae. According to the integrated concept of maize protection against agrophages, growers should first use all non-chemical methods (e.g. mineral fertilization with NPK, selection of more resistant hybrids etc.) to reduce their number. Thus, integrated plant protection stands for careful consideration of all available methods of plant protection, and then undertaking proper means aimed at: inhibition of development of the population of harmful organisms, maintaining the use of plant protection products and other forms of intervention at an economically and ecologically reasonable level, and decreasing or minimizing threats for human health and environment [Matyjaszczyk *et al.* 2010]. The adoption of integrated plant protection methods is compulsory from the 1st of January 2014 onwards [Matyjaszczyk *et al.* 2010].

Maize hybrids are characterized by diverse sensitivity to thermal conditions in the initial growth period [Kruczek and Szulc 2006], which may determine the various rate of dry matter accumulation. In comparison with the traditional hybrid, the stay-green type hybrid exhibits significantly greater vigour of initial growth, expressed as dynamics of dry matter accumulation and its daily increase [Szulc and Bocianowski 2012a, Szulc 2013]. Due to this favourable genotypically-conditioned trait, stay-green type hybrids should be less susceptible to infestation with larvae of *Oscinella frit*.

The experiment hypothesis assumed that nitrogen content in soil and type of nitrogen fertilizer may significantly affect the extent of damage caused by frit fly in maize plants, which are characterized by a different genetic profile. Additionally, in the pot experiment, the dynamics of the development of root system in the studied hybrid types was regarded as one of the determining elements for initial growth rate and plant vigour.

The aim of the study was the evaluation of the occurrence of frit fly (*Oscinella frit* L.) on maize plants which are characterized by a different genetic profile depending on nitrogen content in the soil and on the form of a nitrogen fertilizer.

MATERIAL AND METHODS

Field experiment

The field experiment was carried out at the Department of Agronomy of the Poznań University of Life Sciences, on the fields of the Agricultural-Experimental Station Swadzim (52°26’ N; 16°44’ E) in the years 2009-2011. In 2009 maize was sown on 14 April, while in the years 2010 and 2011 – on 21 April. In the first field experiment, the experimental factors were the dose of urea with four levels (0, 50, 100, 150 $kg \cdot ha^{-1}$ N) and maize hybrid, with two levels [ES Palazzo and ES Paroli – stay green (SG)].

In the second experiment, the experimental factors were the form of nitrogen fertilizer, with six levels (Table 1) and maize hybrid, with two levels (ES Palazzo and ES Paroli SG). In order to compare the traditional hybrid with the stay-green type (SG), the following conditions must be observed. The hybrids should derive from the same seed production company, should be of a similar maturity class (FAO number) and should serve the same purpose of use. The hybrids selected for the author's research came from Euralis Semences, a world-wide seed production company. The same mineral fertilization was applied on the entire experimental field each year of the study at a dose of 120 kg·ha^{-1} N, prior to establishing the experiment. Both experiments were carried out in a split-plot design with four replicates. Nitrogen fertilization treatments (doses or types) were randomized to main plots, while hybrids were randomized to subplots. In all years of research, NPK fertilizers were incorporated into the soil before sowing maize. Cultivation measures and other agricultural practices were realized according to recommendations referring to maize cultivation in grain technology [Szulc and Bocianowski 2012b].

Table 1. Characteristics of the primary factor levels (experiment II) [Szulc and Bocianowski 2012b]
Tabela 1. Charakterystyka poziomów czynnika I-go rzędu (doświadczenie II) [Szulc i Bocianowski 2012b]

No Nr	Trade name of the nitrogen fertilizer Nazwa handlowa nawozu azotowego	Chemical formula Wzór chemiczny	Nitrogen content Zawartość azotu %	Content of other components Zawartość innych składników %	Rate of action Szybkość działania*
1	Without fertilizer Bez nawozu				
2	Ammonium saltpeter Saletra amonowa	NH_4NO_3	34	–	+
3	Ammonium sulphate Siarczan amonu	$(NH_4)_2SO_4$	21	24 S	–
4	Urea Mocznik	$CO(NH_2)_2$	46	–	–
5	Nitrochalk Saletrzak Canwil	$NH_4NO_3+CaCO_3+MgCO_3$	27	4 MgO 7 CaO	+
6	Ammonium saltpeter (50% N dose) + urea (50% N dose) Saletra amonowa (50% dawki N) + mocznik (50% dawki N)	$NH_4NO_3 + CO(NH_2)_2$	–	–	–/+

* – slow-acting fertilizer – nawóz wolno działający, + fast-acting fertilizer – nawóz szybko działający

Soil content in nutrients, the course of thermal and moisture conditions

The examined soil, according to the FAO classification, was an Albic Luvisol, originating from loam sand lying on sandy loam. According to the Polish agronomic evaluation, this soil represents good rye complex. Humus content of the arable layer (0-25 cm) in the years of the research ranged from 1.41% to 1.46%. Soil richness in basic macroelements as well as soil pH in particular years of research is shown in Table 2. Thermal and moisture conditions in the period from sowing until maize reaching the 5-6 leaf stage BBCH 15/16 is presented in Fig. 1.

Table 2. Soil conditions in Swadzim
Tabela 2. Warunki glebowe w Swadzimiu

Specification Wyszczególnienie	Year – Rok					
	2009		2010		2011	
	I*	II*	I*	II*	I*	II*
P, mg P·kg^{-1} of soil – gleby	36.1	31.7	37.8	36.1	61.2	16.7
K, mg K·kg^{-1} of soil – gleby	121.2	97.1	97.1	45.6	54.8	63.9
Mg, mg Mg·kg^{-1} of soil – gleby	44.0	69.0	40.0	34.0	81.0	62.0
pH in 1 mole·dm^{-3} KCl	5.2	5.3	5.5	7.6	5.1	5.1

* I experiment – I doświadczenie, II experiment – II doświadczenie

Damage determination, statistical evaluation of the results

Damage in maize plants caused by frit fly was determined at the stage BBCH 15/16. Only the number of plants with symptoms of feeding was noted, and the result was expressed as percentage. As a first step in the analysis, we carried out normality and homoscedasticity tests in order to determine whether the data met the conditions needed for a formal analysis of variance test. To do this we applied the Shapiro-Wilks normality test [Shapiro and Wilk 1965] of normality and the Fligner-Killeen test of homoscedasticity to the groups with sufficient data [Conover *et al.* 1981]. Three-way (years, hybrid type, fertilizer type or nitrogen dose) analysis of variance (ANOVA) was carried out in order to verify hypotheses of a lack of influence of years, hybrid type, fertilizer type or nitrogen dose as well as all the two- and three-ways interactions on the proportion of frit fly occurrence. Mean values were calculated, as well as standard deviations and coefficients of variation (cv) [Kozak *et al.* 2013]. The least significant differences (LSDs) at P = 0.05 were estimated, and used for multiple comparison testing. Linear correlation coefficients were estimated between climate parameters: total rainfall in the period of sowing, mean air temperature in the period of sowing, mean soil temperature at a depth of 10 cm, and the occurrence of frit fly. All calculations in terms of statistical analysis were carried out with the use of a statistical package GenStat 15 [Goedhard and Thissen 2012].

Methodology in pot experiment

Additionally, pot experiment was carried out in two series in 2011 at the Department of Agronomy of the University of Life Sciences in Poznań. Nitrogen was used in a form of ammonium saltpeter NH_4NO_3 – 34%N, phosphorus in a form of granular triple superphosphate 46% P_2O_5, potassium in a form of potassium salt (KCl) 60% K_2O. The following doses of particular mineral fertilizers were used per pot: N – 0.9 g fertilizer per pot (120 kg·ha^{-1} N), P_2O_5 – 0.5 g fertilizer per pot (35.2 kg P·ha^{-1}), K_2O – 0.5 g fertilizer per pot (99.6 kg K·ha^{-1}). Two seeds were placed in each pot of a volume of 8000 cm^3. After emergence, thinning was carried out, after which in each pot one plant was left. Measurements of roots were carried out at the following stages: BBCH 12/13 and BBCH 14/15. Soil of the following chemical composition was used in the experiment: (79 mg P·kg^{-1} soil, 98.8 mg K·kg^{-1} soil, 68 mg Mg·kg^{-1} soil, pH 5.02). Fresh weight of the root system of a single maize plant was determined after carefully taking the roots, along with the soil clod, out from the pot. Next, after carefully washing off the soil from roots, they were weighed. In order to determine length of the root system, wet roots were placed on a flat glass dish with a little amount of water. Graph paper was placed under the dish. The roots were straightened so that they would not overlap, and thanks to placing a glass sheet on them, they stayed in the same position. Next, with an accuracy to 1 millimeter, length of selected roots or their fragments was measured.

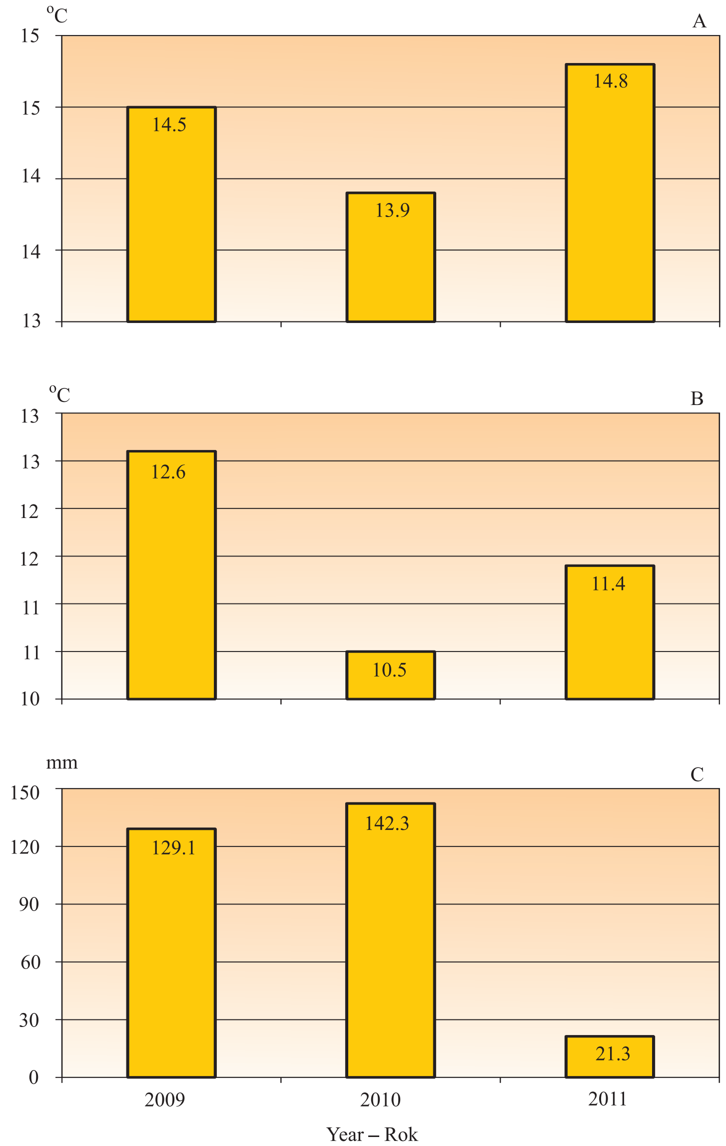


Fig. 1. Thermal and moisture conditions in growing seasons of maize in the period from sowing to maize reaching the stage BBCH 15/16 (A – mean air temperature, B – mean soil temperature at a depth of 10 cm, C – rainfall total)

Rys. 1. Warunki termiczne i wilgotnościowe w sezonach wegetacyjnych kukurydzy w okresie od siewu do uzyskania przez kukurydzę fazy BBCH 15/16 (A – średnia temperatura powietrza, B – średnia temperatura gleby na głębokości 10 cm, C – suma opadów atmosferycznych)

RESULTS

Experiment I

Results show a significant effect of weather conditions ($F_{2,48} = 893.44$, $P < 0.001$) on the extent of damage caused by the frit fly larvae (Table 3). On average, the highest percentage of plants damaged by this pest was observed in 2010 (4.71%), while the lowest in 2009 (2.20%). Coefficients of variation of the observed trait were 37.77%, 14.35% and 26.09%, in 2009, 2010 and 2011. In a synthetic approach – average across three years, the extent of damage caused by this agrophage was determined by the dose of a nitrogen fertilizer as well as by the type of maize hybrid (Table 4). Significantly the lowest number of plants with symptoms of feeding of this fly were observed for the dose of 0 $kg \cdot ha^{-1}$ N (2.75%, cv = 48.33%), while the extent of damage within the range of nitrogen doses between 50 and 150 $kg \cdot ha^{-1}$ N was not statistically different ($P > 0.05$). In the case of maize hybrid it was found that ES Paroli SG hybrid was damaged by frit fly to a lesser degree, compared with ES Palazzo hybrid (Table 4). Difference between the studied hybrid types in the extent of damage was 0.35%. The relationship between N dose and frit fly damage could be appropriately described with a second order polynomial equation. For ES Palazzo hybrid, higher values of the observed trait were noted than for ES Paroli SG hybrid (Fig. 2A).

Table 3. Mean squares from analysis of variance in considered experiments
Tabela 3. Średnie kwadraty z analizy wariancji rozważanych doświadczeń

Experiment I – Doświadczenie I			Experiment II – Doświadczenie II		
source of variation źródło zmienności	number of degrees of freedom liczba stopni swobody	mean square średni kwadrat	source of variation źródło zmienności	number of degrees of freedom liczba stopni swobody	mean square średni kwadrat
Replications Powtórzenia	3	1.29931	Replications Powtórzenia	3	0.495451
N	3	3.25307	Fertilizer (F) Nawóz (F)	5	2.123981
Residual 1 Błąd 1	9	1.25911	Residual 1 Błąd 1	15	3.345507
Hybrid (H) Odmiana (O)	1	3.02258	Hybrid (H) Odmiana (O)	1	0.365999
N × H N × O	3	0.24185	F × H F × O	5	5.682023
Residual 2 Błąd 2	12	1.66696	Residual 2 Błąd 2	18	2.671477
Year Rok	2	52.7378**	Year Rok	2	74.470775**
Year × N Rok × N	6	0.22979*	Year × F Rok × F	10	0.008786
Year × H Rok × O	2	0.3116*	Year × H Rok × O	2	0.054664**
Year × N × H Rok × N × O	6	0.08216	Year × F × H Rok × N × O	10	0.008626
Residual 3 Błąd 3	48	0.05903	Residual 3 Błąd 3	72	0.004744

* P < 0.01; ** P < 0.001

Table 4. Percentage of plants damaged by *Oscinella frit* depending on dose of nitrogen fertilizer and maize hybrid, %
Tabela 4. Udział roślin uszkodzonych przez ploniarkę zbożówkę w zależności od dawki nawozu azotowego i odmiany kukurydzy, %

Experimental factors Czynniki doświadczenia		Year – Rok						Mean Średnia	
		2009		2010		2011			
		%	SD	%	SD	%	SD	%	SD
N dose Dawka N kg·ha^{-1}	0	1.65 b	0.86	4.18 b	0.76	2.42 b	0.80	2.75 b	1.33
	50	2.09 ab	0.66	4.99 a	0.65	3.01 ab	0.61	3.36 ab	1.38
	100	2.48 a	0.90	4.65 ab	0.62	3.24 a	0.90	3.46 ab	1.21
	150	2.58 a	0.69	4.99 a	0.36	3.14 a	0.58	3.57 a	1.18
$LSD_{0.05}$ – $NIR_{0,05}$		0.59		0.55		0.67		0.73	
Hybryd Odmiana	ES Palazzo	2.47 a	0.84	4.77 a	0.66	3.14 a	0.79	3.46 a	1.23
	ES Paroli SG	1.93 b	0.76	4.63 a	0.71	2.76 b	0.72	3.11 b	1.35
$LSD_{0.05}$ – $NIR_{0,05}$		0.33		ns – ni		0.27		0.24	
Mean – Średnia		2.20 B	0.83	4.71 A	0.68	2.95 B	0.77	3.28	1.30

ns – ni – non-significant difference – różnice nieistotne
SD – standard deviation – odchylenie standardowe

Experiment II

Obtained results indicated a significant importance of weather conditions ($F_{2,72}$ = 15698.15, P < 0.001) on the extent of damage caused by *O. frit* (Table 3). Significantly the highest percentage of plants with symptoms of feeding by this pest was observed in 2010 (4.52%), while the lowest in the first year of the experiment (2.10%). Coefficients of variation of the observed trait were 49.48%, 21.45% and 34.71%, in 2009, 2010 and 2011. In a synthetic approach, no significant effect of the type of nitrogen fertilizer was proved (P = 0.676) on the extent of damage caused by this pest (Table 5).

Table 5. Percentage of plants damaged by *Oscinella frit* depending on type of nitrogen fertilizer and maize hybrid, %
Tabela 5. Udział roślin uszkodzonych przez ploniarkę zbożówkę w zależności od typu nawozu azotowego i odmiany kukurydzy, %

Experimental factors Czynniki doświadczenia		Year – Rok						Mean Średnia	
		2009		2010		2011			
		%	SD	%	SD	%	SD	%	SD
Type of nitrogen fertilizer Rodzaj nawozu azotowego	no fertilizer	1.74	0.82	4.16	0.76	2.51	0.78	2.80	1.28
	NH_4NO_3	2.13	1.31	4.55	1.15	2.80	1.22	3.16	1.57
	$(NH_4)_2SO_4$	2.01	0.64	4.51	0.66	2.74	0.63	3.08	1.24
	$CO(NH_2)_2$	2.02	0.67	4.45	0.61	2.70	0.59	3.06	1.21
	$NH_4NO_3 + CaCO_3 + MgCO_3$	2.69	1.66	5.06	1.55	3.34	1.55	3.70	1.83
	$NH_4NO_3 + CO(NH_2)_2$	1.99	0.82	4.39	0.83	2.74	0.81	3.04	1.29
$LSD_{0.05}$ – $NIR_{0,05}$		ns – ni		ns – ni		ns – ni		ns – ni	
Hybryd Odmiana	ES Palazzo	2.13	0.85	4.61	0.78	2.86	0.79	3.19	1.32
	ES Paroli SG	2.06	1.22	4.43	1.14	2.78	1.15	3.09	1.53
$LSD_{0.05}$ – $NIR_{0,05}$		ns – ni		ns – ni		ns – ni		ns – ni	
Mean – Średnia		2.10 B	1.04	4.52 A	0.97	2.81 A	0.98	3.14	1.42

ns – non-significant difference – różnice nieistotne
SD – standard deviation – odchylenie standardowe

The type of maize hybrid did not significantly modify the value of the studied trait. However, a slightly smaller damage caused by the fly larvae may be observed for ES Paroli SG hybrid. The extent of feeding of frit fly also not depended on the interaction of the type of nitrogen fertilizer and the type of maize hybrid (Fig. 2B). This difference was from 0.1% (urea) to 1.0% (for the mixture of ammonium saltpeter with urea with 50% proportion of each fertilizer per nitrogen dose). However, with ammonium saltpeter, ES Paroli SG hybrid was significantly more susceptible to feeding by this pest, compared with traditional hybrid ES Palazzo (Fig. 2B).

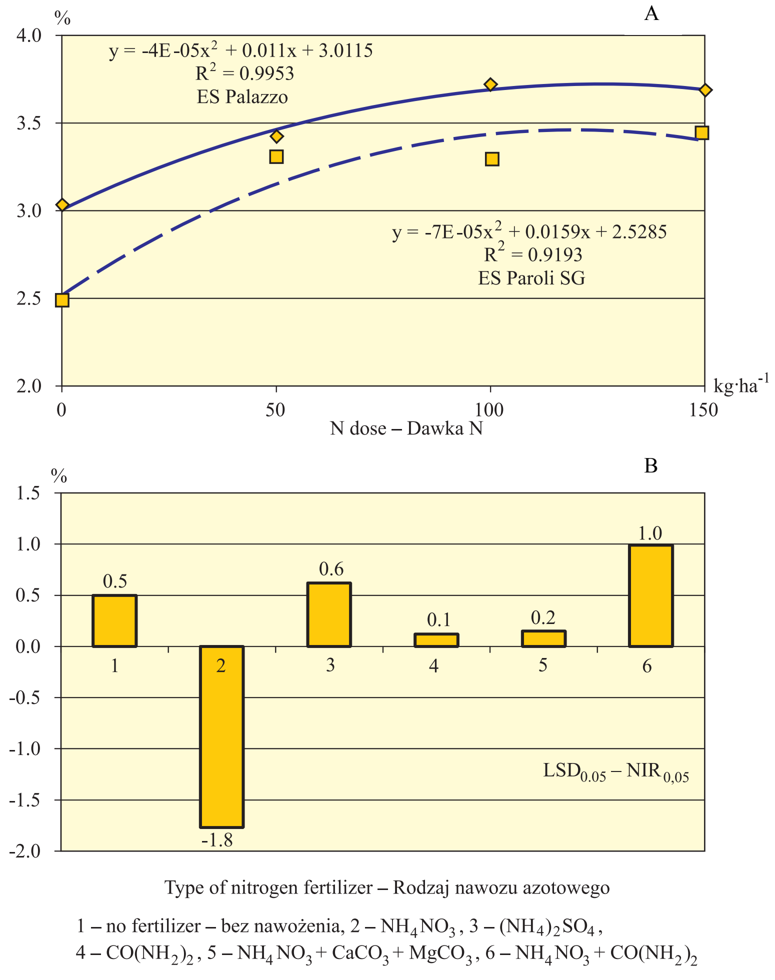


Fig. 2. Interaction of experimental factors on the extent of damage in maize caused by the frit fly larvae (A – interaction of a nitrogen dose with a type of maize hybrid, B – interaction of a type of nitrogen fertilizer with a type of maize hybrid expressed as a difference between the studied hybrid types)

Rys. 2. Współdziałanie czynników doświadczenia na wielkość uszkodzeń kukurydzy powodowanych przez larwy ploniarki zbożówki (A – współdziałanie dawki azotu z typem mieszańca kukurydzy, B – współdziałanie rodzaju nawozu azotowego z typem mieszańca kukurydzy wyrażone jako różnica pomiędzy badanymi typami odmian)

Pot experiment (root system)

The studied types of maize hybrids significantly differed with the length of the root system as well as with its fresh weight in both analyzed development stages (Table 6). Significantly longer and heavier root system was developed in ES Paroli SG hybrid, compared with ES Palazzo hybrid.

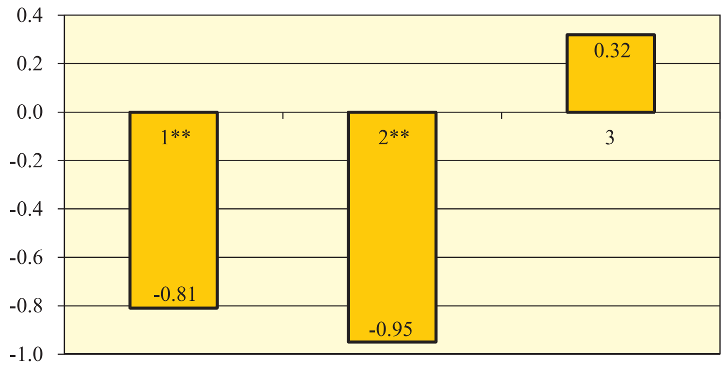
Table 6. Description of the root system of maize hybrids in two developmental stages
Tabela 6. Charakterystyka systemu korzeniowego odmian kukurydzy w dwóch fazach rozwojowych

Type of maize hybrid Typ mieszańca kukurydzy	2-3 leaf stage – faza 2-3 liści (BBCH 12/13)		4-5 leaf stage – faza 4-5 liści (BBCH 14/15)	
	root length długość korzeni cm	fresh weight of roots świeża masa korzeni g	root length długość korzeni cm	fresh weight of roots świeża masa korzeni g
ES Palazzo	94.1 ±12.7	0.277 ±0.09	216.2 ±25.4	0.436 ±0.12
ES Paroli SG	103.3 ±15.5	0.410 ±0.07	260.7 ±19.8	0.941 ±0.22
$LSD_{0.05}$ – $NIR_{0,05}$	4.32	0.0991	12.17	0.2889
Mean – Średnia	98.7 ±14.9	0.343 ±0.08	238.4 ±41.1	0.688 ±0.37

DISCUSSION

The years of field experiments were characterized by a highly differentiated course of thermal and moisture conditions in the period from sowing to maize reaching the stage BBCH 15/16 (Fig. 1). The coolest year and at the same time with the highest rainfall total was 2010, while the warmest and driest was the last research year, 2011. According to Bereś [2011], the occurrence of frit fly depends strictly on weather conditions in early spring. Also Szulc *et al.* [2011] state that humid and cool spring in initial developmental stages in maize increases damage in plants by frit fly. The effect of humid and cool spring on the extent of damage caused by this agrophage is confirmed also by linear correlation coefficients between the studied climate parameters and the fly's occurrence (Fig. 3). It was found that the extent of feeding of the frit fly larvae is significantly negatively correlated with the mean temperature of air and soil at a depth of 10 cm in the period from sowing to the stage BBCH 15/16. However, in the authors' own research no significant effect of the total rainfall was indicated in the studied time period on the extent of damage in maize by *O. frit* (Fig. 3).

In the authors' own research it was indicated that nitrogen dose significantly determines the extent of damage caused by frit fly. Significantly the lowest plant damage was observed for the dose of 0 $kg \cdot ha^{-1}$ N, while increase in nitrogen dose increased pest pressure in maize. According to Grzebisz *et al.* [2007], nitrogen with an unsuitable nutrition control, creates optimum conditions for increase in the parasite pressure. Nitrogen compounds, e.g. amino acids and amides, are directly incorporated by parasites into metabolic structures, which in consequence increases the rate of their proliferation. Undergrowth of mechanical tissue in plants nourished exclusively with this macroelement results not only from a quick growth but also from an insufficient nutrition with elements essential for lignin synthesis.



** significant at 0.01 level – istotne przy poziomie 0,01

Fig. 3. Correlation coefficients between the studied climate parameters and occurrence of frit fly
Rys. 3. Współczynniki korelacji pomiędzy badanymi parametrami klimatu a występowaniem ploniarki zbożówki

The extent of feeding of frit fly (*Oscinella frit* L.) in the authors' own research was also not dependent on the interaction of the type of nitrogen fertilizer and the type of maize hybrid. The use of ammonium saltpeter while fertilizing stay-green hybrid type resulted in a significantly higher damage of plants by this agrophage, compared with the traditional hybrid. Plants obtain nitrogen from the soil in the nitrate and ammonium form. After obtaining it, nitrogen is converted into amino acids, and plants synthesize protein from it. Usually, size of the root system is not a factor reducing nitrogen uptake, under conditions of high concentration of this element in the vicinity of the root system [Sinclair and Vaduz 2002]. However, when supplies of this macroelement in the soil are insufficient, and its movement is limited, e.g. by drought, nitrogen availability as a result of mass flow towards root may be insufficient. In such case, size of the root system will be very important for nitrogen uptake, especially nitrogen which has just been mineralized [Marschner 1998]. After supplying a plant with nitrogen, there occurs a quick growth in the root weight and assimilation surface area, as well as quick processing of carbohydrates and ammonia into protoplasm proteins. Usually, saltpeter form is uptaken the fastest, while ammonium form slower [Ladha *et al.* 2005]. According to Grzebisz [1990], increase and production of dry weight by a plant is a result of metabolic processes, whose continuity requires providing matter. Water and nutrients are provided from the soil, and their absorption (uptake) occurs through a root. Thus, the root, or more specifically surface of the root system, constitutes contact area of the plant with soil and mineral components. Production result of a widely spread root system in early development stages in stay-green hybrid type (Table 6, Figs. 4, 5), and at the same time high availability of nitrogen applied in a form of ammonium saltpeter resulted in a faster growth. Thus, it was an analogical situation to an increase in the extent of damage in maize plants caused by frit fly along with an increase in a nitrogen dose. Chun *et al.* [2005] state that under field conditions, maize hybrids characterized by a high usage of nitrogen per dose of a mineral fertilizer, have a significantly greater root system, compared with hybrids whose management of this macroelement is less effective. Moreover, ageing of roots in such types is slower.

Fig. 4. Maize root system in the 5-6 leaf stage (traditional hybrid on the left, stay-green type hybrid on the right)

Rys. 4. System korzeniowy kukurydzy w fazie 5-6 liści (z lewej mieszaniec tradycyjny, z prawej typu stay-green)

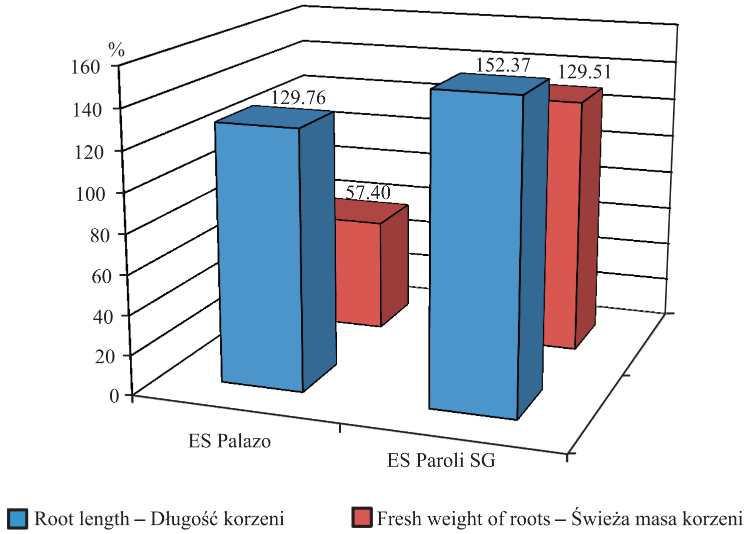


Fig. 5. Value increase in the root length and fresh weight of roots in considered development stages of both types of maize

Rys. 5. Przyrost wartości długości korzeni i świeżej masy korzeni w rozważanych fazach rozwojowych dwu typów kukurydzy

As frit fly larvae have an ability to digest parenterally through secreting enzymes to plant tissues, therefore walls of canals which are hollowed out by them become partially digested, and as a result they change color into a darker one, and their consistency into semifluid. According to Lisowicz [1982], this phenomenon increases harmfulness of larvae. However, most frequently larvae do not reach full development in maize, as quickly growing plants throw majority of them outside. Thus, one of the methods in integrated maize protection against this agrophage is selecting maize hybrids which are characterized by a quicker dynamics of their initial growth. This criterion is fulfilled by stay-green hybrid types [Szulc 2012, Szulc and Bocianowski 2012a, Szulc 2013]. Thus, it is not surprising to observe in the authors' own research that stay-green hybrid type was significantly less damaged by frit fly (in both field experiments), compared with the traditional hybrid.

Drzewiecki and Pietryga [2007] state that damage caused by the frit fly larvae results in growth inhibition, decrease in the vegetative weight and poorer formation of generative organs. Depending on the year, larvae of this pest may decrease quantity of maize yields within the range of 10% [Lisowicz 1983]. Also in the authors' own research it was proved that along with an increase in the extent of damage caused by frit fly, there occurred a decrease in the quantity of grain yield (Figs. 6A and 6B). However, it should be highlighted that this dependence was noted only in 2010 with cool spring.

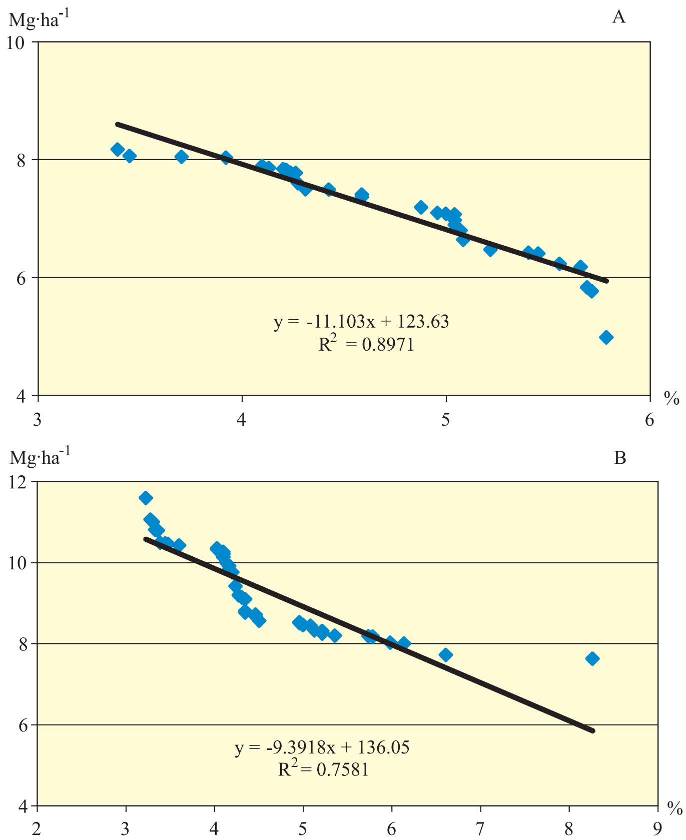


Fig. 6. Dependence of grain yield quantity on the extent of damage caused by the frit fly larvae in 2010 (A – experiment I, B – experiment II)

Rys. 6. Zależność wielkości plonu ziarna od wielkości uszkodzeń powodowanych przez larwy ploniarki zbożówki w roku 2010 (A – doświadczenie I, B – doświadczenie II)

CONCLUSIONS

1. The extent of damage caused by frit fly is dependent on the course of thermal and moisture conditions in the period from sowing to the stage BBCH 15/16. Cool spring increases pest pressure in maize.
2. Damage caused by the frit fly larvae is directly proportional to the size of a nitrogen dose.
3. Type of a nitrogen fertilizer is not a factor determining the extent of damage caused by frit fly.
4. The use of ammonium saltpeter while fertilizing maize hybrid which is characterized by quick vigor of the initial growth and by a well-developed root system, results in an increase in damage caused by frit fly.
5. Stay-green type compared with the traditional hybrid is more resistant to feeding of frit fly. Cultivation of such hybrids may be considered as an element of an integrated maize production.
6. ES Paroli SG hybrid in its initial stages was characterized by a more dynamic development of the root system, compared with ES Palazzo hybrid.

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PODATNOŚĆ MIESZAŃCÓW KUKURYDZY (*Zea mays* L.) NA PLONIARKĘ ZBOŻÓWKĘ (*Oscinella frit* L.) W WARUNKACH ZRÓŻNICOWANEJ ZASOBNOŚCI GLEBY W AZOT I RODZAJ NAWOZU AZOTOWEGO

Streszczenie. Doświadczenia polowe wykonano w Katedrze Agronomii Uniwersytetu Przyrodniczego w Poznaniu, na polach Zakładu Dydaktyczno-Doświadczalnego w Swadzimiu w latach 2009-2011. Oceniano występowanie ploniarki zbożówki (*Oscinella frit* L.) na roślinach kukurydzy charakteryzujących się różnym profilem genetycznym, w zależności od zasobności gleby w azot oraz od formy nawozu azotowego. Wykazano, że przebieg warunków meteorologicznych w okresie od siewu do fazy BBCH 15/16 wywierał istotny wpływ na wielkość uszkodzeń powodowanych przez ploniarkę zbożówkę. W latach o chłodnej wiośnie procent uszkodzonych roślin był większy. Uszkodzenia powodowane przez larwy ploniarki zbożówki były wprost proporcjonalne do wielkości zastosowanej dawki azotu. Rodzaj nawozu azotowego nie był czynnikiem kształtującym wielkości uszkodzeń powodowanych przez tego agrofaga. Uprawę odmian typu stay-green należy uznać za element integrowanej ochrony kukurydzy względem ploniarki zbożówki.

Słowa kluczowe: dawka N, *Oscinella frit*, ploniarka zbożówka, rodzaj nawozu azotowego, stay-green

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