



ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2014
Volume 17
Issue 2

Topic:
Agronomy

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Szulc P., Rybus-Zajac M., Jagla M. 2014. INFLUENCE OF NITROGEN DOSE, TYPE OF NITROGEN FERTILIZER AND METHOD OF ITS APPLICATION ON PLANT HEALTH OF MAIZE HYBRIDS (*ZE A MAYS* L.), EJPAU 17(2), #10.
Available Online: <http://www.ejpau.media.pl/volume17/issue2/art-10.html>

INFLUENCE OF NITROGEN DOSE, TYPE OF NITROGEN FERTILIZER AND METHOD OF ITS APPLICATION ON PLANT HEALTH OF MAIZE HYBRIDS (*ZE A MAYS* L.)

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ABSTRACT

The field experiment was carried out in the years 2009–2011 in the Research and Education Unit in Swadzim near Poznań. Influence of nitrogen dose, type of nitrogen fertilizer and method of fertilizer application on plant health of two types of maize cultivars cultivated for grain was assessed in the study. Incidence of fusarium diseases (*Fusarium* spp.), corn smut (*Ustilago maydis*), and European corn borer (*Ostrinia nubilalis*) was noted. A significant influence of thermal and humidity conditions during vegetation seasons on harmfulness of the examined diseases and pest was demonstrated. “Stay-green” type hybrid exhibited significantly lower susceptibility to damage caused by European corn borer and infestation with diseases than the traditional cultivar. Hence cultivation of such cultivars should be considered an element of integrated maize protection, adopted in European Union countries since 1 January 2014. Row application of nitrogen at the dose from 50 to 150 kg N·ha⁻¹ caused a significant increase in the percentage of plants infected by fungi of *Fusarium* spp. genus. In turn, row nitrogen application combined with top-dressing reduced the size of maize infestation with this pathogen.

Key words: maize, nitrogen, method of fertilization, *Ostrinia nubilalis*, *Ustilago maydis*, *Fusarium* spp..

ABBREVIATIONS

SG – stay-green

INTRODUCTION

A right method of fertilizer application creates considerable possibilities to reduce doses of mineral fertilizers in maize cultivation [3, 9, 17]. In Poland, where fertilizers are still broadcasted, incorrect plant nutrition can be observed. It results from the fact that, depending on soil properties, some part of the nutrient introduced into soil as a fertilizer will be immobilized [9], or will be beyond reach of roots of a cultivated plant. In maize, which is sown in wide rows, primary root weight is developed directly beneath the row, while root development in the middle of the interrow is smaller and relatively late. Therefore, the developing root system of maize will find not enough available nutrients, which limits its growth [8]. In turn, when the root system is sufficiently developed to take up the nutrient efficiently, it is already unavailable. A better way to improve availability of the nutrient is placing the fertilizer close to the roots [14]. Such a method of application is called starter (row) or localized fertilization. However, it requires additional installation of an applicator for granulated fertilizer sowing on a fertilizer distributor. Then we can obtain placement of a fertilizer 5 cm deeper and 5 cm aside from seeds during one run of the fertilizer distributor. Fertilizer broadcasting favourably affects nutrient uptake by maize [2], which results in higher yielding [13].

Therefore one should ask if better nutrition of maize plants resulting from row application of the fertilizer affects prevalence of diseases and pests. The aim of the research was to determine influence of nitrogen dose, type of nitrogen fertilizer and method of fertilizer application on plant health of two types of maize cultivars cultivated for grain.

MATERIALS AND METHODS

The experiment was conducted in the Department of Agronomy of the Poznań University of Life Sciences, in the fields of the Research and Education Unit in Swadzim, in the years 2009–2011. The experiment was arranged in a split-split-split-plot design in 4 field repetitions. Examined factors included: level of nitrogen dose (50, 100, 150 kg N·ha⁻¹); type of nitrogen fertilizer: (ammonium nitrate (NH₄NO₃), Canwil nitrochalk (NH₄NO₃+CaCO₃+MgCO₃)); method of fertilizer application: (broadcasting (fertilizer dose prior to maize sowing), in rows (nitrogen dose applied together with seed sowing), in rows supplemented with top-dressing (50 kg N·ha⁻¹ simultaneously with seed sowing + the rest of N as top-dressing in the 5–6 leaf stage (BBCH 15/16) in accordance with the first experimental factor)); and type of maize hybrid: (ES Palazzo and ES Paroli “stay-green”). Apart from the experiment design, control object was established [0 kg N·ha⁻¹] for the two examined cultivar types. The same mineral fertilization was applied in the whole experimental field each year of the study before establishing the experiment at the dose of nitrogen according to the level of the first experimental factor, 80 kg P₂O₅·ha⁻¹ in the form of granular triple superphosphate 46% P₂O₅, 120 kg K₂O·ha⁻¹ in the form of 60% potassium salt.

Fusarium diseases (*Fusarium* spp.), corn smut (*Ustilago maydis*), and European corn borer (*Ostrinia nubilalis*) were found. Both in case of the diseases and the pest, only the number of plants infected or infested by a given pathogen was noted, and the result was given as a percentage. All the plants in the plot were analysed. Then the obtained results (percentages) were converted into Bliss degrees. Maize plant damage by European corn borer was assessed in the dough stage (BBCH 85). Prevalence of corn smut and fusarium diseases was determined before maize harvest (BBCH 99).

The obtained results were analysed with one-way analysis of variance for orthogonal factor experiments, and then synthesis for many-year experiments was performed. Significance of differences was estimated at the level $\alpha = 0.05$. The obtained results expressed as percentages were converted into Bliss degrees. STATPAKU application was used for statistical analysis of the data.

Thermal and humidity conditions during maize vegetation seasons and while the value of hydrothermal coefficient of water supply according to Sielianinov were presented in Table 1. The optimal value of the coefficient is 1. The amount of precipitation of the time period from April to September was 452.3 mm in 2009, and 500.7 mm in 2008. The calculated hydrothermal coefficients according to Sielianinov [7] enabled to state that during the field experiment, in 2009 periodic soil moisture deficits were observed in April and August (coefficient of 0.96 and 0.78, respectively), while in the year 2010 – in April and June (coefficient of 0.49 and 0.42, respectively). Mean daily air temperature measured at 2 m in the growing season of 2009 was 15.2°C, while of 2010 – 14.5°C.

Table 1. Air temperature and precipitation in vegetation seasons in Swadzim

Years	Temperature [°C]							
	IV	V	VI	VII	VIII	IX	X	Mean–Sum
2009	12.9	14.0	16.0	20.3	20.1	15.8	7.6	15.2
2010	9.3	12.2	18.4	22.6	19.2	13.0	7.0	14.5
2011	12.4	15.5	19.9	18.5	19.5	15.9	9.8	15.9
Years	Precipitation [mm]							
	IV	V	VI	VII	VIII	IX	X	Mean–Sum
2009	19.2	109.9	113.8	75.4	26.2	48.6	59.2	452.3
2010	26.8	110.5	43.4	97.5	143.5	69.9	9.1	500.7
2011	9.8	22.5	66.5	218.7	50.5	28.5	27.7	424.2
Years	The hydrothermal coefficient to secure with water according to Sielianinov [7]							
	IV	V	VI	VII	VIII	IX	X	Mean–Sum
2009	0.49	2.53	2.37	1.19	0.42	1.02	2.51	1.50
2010	0.96	2.92	0.78	1.39	2.41	1.79	0.42	1.52
2011	0.26	0.46	1.11	3.81	0.83	0.59	0.91	1.13

RESULTS AND DISCUSSION

Maize infestation with fungi of the *Fusarium* genus was determined by variable weather conditions in the years and type of maize hybrid (Tab. 2). On average for the years, irrespective of the examined experimental factors, the lowest infestation size was noted in 2010 (3.76%), and the highest in 2011 (15.2%). The result recorded in this study confirmed earlier literature reports indicating that the occurrence of *Fusarium* spp. was determined by variable environmental conditions in individual growing seasons [6, 10, 15, 16]. Synthetically for the years of the research, ES Paroli “stay-green” type hybrid was significantly less infested with *Fusarium* spp. genus when compared to ES Palazzo hybrid. The difference between the examined cultivar types amounted to 3.2%. The result obtained in the author's research confirmed earlier reports [11]. The study demonstrated that maize cultivar types differ in susceptibility to infestation with fungi of *Fusarium* genus.

Table 2. Maize infection by *Fusarium* spp.

Experimental factors	Years						Mean	
	2009		2010		2011			
	[°%]	[°Blissa]	[°%]	[°Blissa]	[°%]	[°Blissa]	[°%]	[°Blissa]

N dose in kg [N·ha ⁻¹]	50	13.71	20.51	3.17	9.18	14.80	21.40	10.56	17.03
	100	15.38	22.15	3.70	8.95	16.45	23.00	11.84	18.03
	150	14.57	21.40	4.40	10.80	14.35	21.25	11.11	17.82
LSD 0.05		—	n.s.	—	n.s.	—	n.s.	—	n.s.
Type of nitrogen fertilizer	ammonium nitrate	14.39	21.30	3.60	9.21	14.67	21.58	10.89	17.36
	Canwil nitro- chalk	14.72	21.41	3.91	10.08	15.73	22.19	11.45	17.89
LSD 0.05		—	n.s.	—	n.s.	—	n.s.	—	n.s.
Method of fertilization	broadcast	14.44	20.91	3.85	9.81	14.77	21.25	11.02	17.32
	in rows	13.74	20.71	3.77	9.49	14.54	21.35	10.68	17.18
	in rows + top – dressing	15.47	22.45	3.65	9.63	16.30	23.05	11.81	18.38
LSD 0.05		—	n.s.	—	n.s.	—	n.s.	—	n.s.
Cultivar	ES Palazzo	16.49	23.07	4.75	11.05	17.08	23.57	12.77	19.23
	ES Paroli “stay-green”	12.61	19.64	2.76	8.24	13.32	20.20	9.56	16.03
LSD 0.05		—	1.832	—	1.991	—	1.777	—	2.008
Control [0 kg N·ha ⁻¹]	ES Palazzo	10.25	—	6.30	—	16.24	—	10.93	—
	ES Paroli “stay-green”	7.32	—	4.17	—	9.55	—	7.01	—
Mean		14.55	21.35	3.76	9.65	15.20	21.88	11.17	17.63
n.s. non-significant differences									

In the author's research, the size of maize infestation with fungi of *Fusarium* spp. genus was a combined effect of nitrogen dose and method of its application (Fig. 1). Together with an increase in nitrogen doses ranging from 50 kg N·ha⁻¹ to 150 kg N·ha⁻¹, their row application caused a significant increase in the percentage of infected plants. In turn, row nitrogen application combined with top-dressing reduced the size of maize infestation with that pathogen. In case of nitrogen broadcasting, the size of nitrogen dose did not significantly affect the value of the trait (Fig. 1). Maize has a great natural ability to take up nutrients. Hence doses of mineral fertilizers, including nitrogen ones, should correspond to nutrient requirements taking into account the amount of nutrients which can be taken up from soil in accordance with the dynamics of the demand for them [18]. Row application of nitrogen (50 kg N·ha⁻¹ simultaneously with seed sowing) combined with top-dressing in the BBCH 15/16 stage contributed to better nitrogen nutrition of maize plants, which determined greater plant resistance to *Fusarium* spp. Right plant nutrition in the whole period of growth and development affects not only the size of obtained yield but also increases plant resistance to infestation with diseases and pest feeding. Marschner [5] stated that the degree of parasite pressure on a cultivated plant depended on external and internal susceptibility of attacked organism, which resulted from its nutritional status.

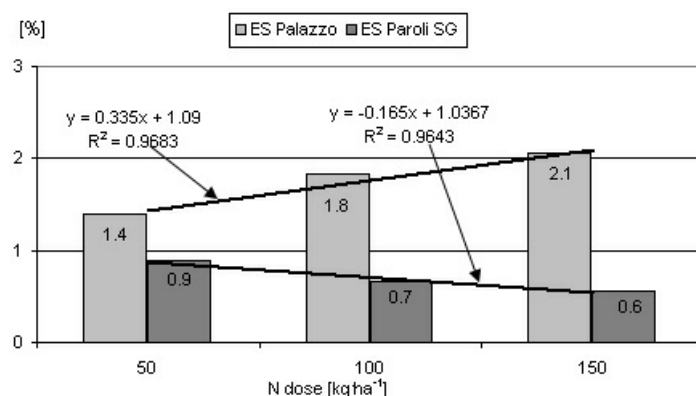


Fig. 1. Maize infestation with *Ustilago maydis* depending on nitrogen dose and type of maize hybrid (2009–2011)

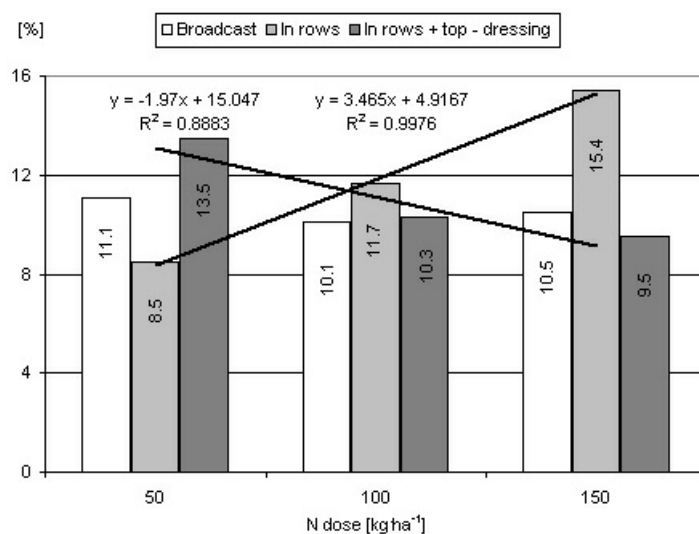
A toxic outcome of *Fusarium* spp. development is presence of products of its secondary metabolism, such as fumonisins [1]. Szulc et al. [12] showed that ES Paroli “stay-green” type cultivar was definitely more resistant to accumulation of fumonisins than traditional cultivar ES Palazzo.

Prevalence of corn smut in the presented research was low (Tab. 3). Irrespective of the examined experimental factors, the value of maize infestation with *U. maydis* ranged from 0.41% in 2011 to 2.39% in 2010 (Tab. 3). It should be noted that “stay-green” type cultivar was significantly less infested with this pathogen each year of the study (irrespective of the amount of precipitation and mean air temperature). It results from the fact that “stay-green” cultivars are more tolerant to stress conditions, such as drought [4], under which plants are more susceptible to the effect of pathogenic factors.

Table 3. Maize infection by *Ustilago maydis*

Experimental factors		Years						Mean	
		2009		2010		2011			
		[%]	[°Blissa]	[%]	[°Blissa]	[%]	[°Blissa]	[%]	[°Blissa]
N dose in kg [N·ha ⁻¹]	50	0.40	1.72	2.54	8.37	0.48	2.40	1.14	4.16
	100	0.95	3.19	2.46	8.06	0.34	1.66	1.25	4.31
	150	1.36	4.28	2.18	6.93	0.40	2.08	1.31	4.43
LSD 0.05		—	n.s.	—	n.s.	—	n.s.	—	n.s.
Type of nitrogen fertilizer	ammonium nitrate	0.68	2.51	2.80	8.67	0.36	1.65	1.28	4.27
	Canwil nitro-chalk	1.13	3.62	1.98	6.90	0.45	2.45	1.19	4.32
LSD 0.05		—	n.s.	—	n.s.	—	n.s.	—	n.s.
Method of fertilization	broadcast	0.62	2.21	2.73	8.36	0.27	1.43	1.21	4.00
	in rows	0.82	3.06	2.22	7.51	0.40	2.07	1.15	4.22
	in rows + top – dressing	1.27	3.92	2.23	7.49	0.55	2.64	1.35	4.68
LSD 0.05		—	1.263	—	n.s.	—		—	n.s.
Cultivar	ES Palazzo	1.62	5.33	3.14	9.33	0.51	2.64	1.76	5.77
	ES Paroli “stay-green”	0.19	0.79	1.64	6.24	0.30	1.46	0.71	2.83
LSD 0.05		—	1.213	—	1.115	—	1.059	—	1.941
Control [0 kg N·ha ⁻¹]	ES Palazzo	0.00	—	4.19	—	0.79	—	1.66	—
	ES Paroli “stay-green”	0.00	—	1.11	—	0.26	—	0.46	—
Mean		0.90	3.06	2.39	7.79	0.41	2.05	1.23	4.30
n.s. non-significant differences									

The present research demonstrated also a combined effect of nitrogen dose and type of maize hybrid on the size of plant infestation with *U. maydis* (Fig. 2). An increase in nitrogen dose for ES Paroli “stay-green” type cultivar caused a decrease in the size of infestation with the pathogen, while in case of ES Palazzo cultivar the relationship was opposite.

Fig. 2. Maize infestation with *Fusarium* spp. depending on nitrogen dose and method of its application (2009–2011)

The obtained results proved that weather conditions have a significant effect on the size of damage caused by *O. nubilalis* (Tab. 4). Significantly the highest percentage of plants with feeding symptoms of this pest was noted in 2010 (11.24%), while the lowest percentage was observed in the last year of the experiment (3.12%). Synthetically, a significant influence of maize hybrid type on the size of damage caused by European corn borer caterpillars was demonstrated (Tab. 4). ES Paroli “stay-green” type cultivar was significantly less damaged by the caterpillars when compared to ES Palazzo cultivar. The difference between the examined types of maize hybrids was 3.11%. The above relationship was found in every year of the research.

Table 4. Incidence of European corn borer

Experimental factors		Years						Mean	
		2009		2010		2011			
		[%]	[°Blissa]	[%]	[°Blissa]	[%]	[°Blissa]	[%]	[°Blissa]
N dose in kg	50	2.88	8.43	10.54	18.76	2.94	9.10	5.45	12.10

[N·ha ⁻¹]	100	4.07	10.84	10.93	19.14	3.32	9.67	6.11	13.21
	150	4.00	10.32	12.27	20.30	3.11	9.51	6.46	13.37
LSD 0.05		–	n.s.	–	n.s.	–	n.s.	–	n.s.
Type of nitrogen fertilizer	ammonium nitrate	3.46	9.48	11.58	19.70	3.17	9.56	6.07	12.91
	Canwil nitro-chalk	3.84	10.24	10.91	19.10	3.07	9.29	5.94	12.88
LSD 0.05		–	n.s.	–	n.s.	–	n.s.	–	n.s.
Method of fertilization	broadcast	3.33	9.22	11.48	19.60	3.62	10.33	6.14	13.05
	in rows	3.48	9.56	11.11	19.26	2.90	8.71	5.83	12.51
	in rows + top – dressing	4.14	10.81	11.14	19.3	2.84	9.23	6.04	13.02
LSD 0.05		–	n.s.	–	n.s.	–	n.s.	–	n.s.
Cultivar	ES Palazzo	5.22	12.30	12.11	20.20	3.96	10.86	7.10	14.45
	ES Paroli “stay-green”	2.08	7.43	10.38	18.59	2.28	7.99	4.91	11.34
LSD 0.05		–	1.533	–	0.807	–	1.606	–	2.729
Control [0 kg N·ha ⁻¹]	ES Palazzo	1.23	–	10.98	–	6.70	–	6.30	–
	ES Paroli “stay-green”	0.00	–	7.19	–	2.33	–	3.17	–
Mean		3.65	9.86	11.24	19.40	3.12	9.42	6.00	12.89
n.s. non-significant differences									

CONCLUSION

1. Weather conditions in the years of the research significantly affected the size of damage of maize plants by European corn borer and infestation with *Ustilago maydis* and fungi of *Fusarium* genus.
2. Cultivation of “stay-green” type cultivars may be considered an element of integrated maize protection due to greater resistance of such plants to pressure of diseases and pests in comparison with the traditional cultivar.
3. Row application of nitrogen ranging from 50 kg N·ha⁻¹ to 150 kg N·ha⁻¹ resulted in a significant increase in the percentage of plants infected by *Fusarium* spp. In turn, row nitrogen application combined with top-dressing in the BBCH 15/16 stage decreased the size of maize infestation with this pathogens. In case of nitrogen broadcasting, dose size did not significantly affect the value of the discussed trait.

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Accepted for print: 6.06.2014

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