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EFFECT OF FOLIAR NUTRITION WITH NITROGEN AND A MULTIPLE FERTILIZER ON MAIZE BY DISEASES, PESTS AND LODGING*

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A b s t r a c t. The objective of the present studies was to determinate the effect of foliar nutrition of maize with nitrogen and a multiple fertilizer (Basfoliar 6-12-6) on plant infestation by diseases, pests and lodging. A significantly higher percentage of plants infested by frit fly was found after an application of 180 kg N·ha^{-1} than the lowest dose 45 kg N·ha^{-1}. The highest number of plants damaged by frit fly was found in the case of foliar nutrient application of nutrients in the phase of 6-7 leaves. A delay of foliar nutrition with urea from the 4-5 leaves phase to the 9-10 leaves phase decreased the number of plants infested by fusarium. Foliar application of urea increased a number of lodging plants in comparison to the foliar use of a multiple fertilizer or to the use urea and Basfoliar together.

K e y w o r d s: maize, foliar nutrition, diseases, pests

INTRODUCTION

The basic method of supplying plants with nutritive components is soil fertilization which can be supplemented with leaf nutrition as a form of top dressing [1,2,4,5-7]. Such a method of fertilization insures a continuity in the dynamics of nutritive components by plants which is particularly important in the case of plants with a high yielding potential, such as maize [3]. Foliar application of fertilizers is particularly effective during the occurrence of periodical unfavourable soil nutrition conditions, e.g., during drought. Unfavourable environmental conditions can not only impede the uptake of nutritive components but contribute also to the intensification of features limiting the maize growth, development and yielding. Such characteristic features include lodging and infestation by diseases and pests.

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Therefore, it seems that an application of foliar nutrition balanced with soil fertilization should yield a positive effect both for yielding, ecology and plant resistance. The objective of the present work was to determine the effect of foliar plant nutrition with an urea solution and a multiple fertilizer on the infestation by diseases and pests and maize lodging. The results relating to maize yield are based on field experiments presented in earlier papers by the present author [9,10].

MATERIAL AND METHODS

The present studies were based on two exact experiments carried out in the years 1996-1998 in the ZDD Swadzim Experimental Farm near Poznań. Both experiments were established on grey-brown soil with mechanical composition of light medium sands located shallowly on sandy loam. The above soils belong to IVa soil class and a very good rye agricultural utility complex. They are characterized by a low to high phosphorus content (4.1-9.9 mg P in 100 g of soil), high to very high potassium content (17.1-21.9 mg K in 100 g of soil), medium content of magnesium (1.9-2.5 mg Mg in 100 g of soil) and slightly acidic reaction (pH = 6.6-6.6 in 1n KCl). Winter wheat was used as a forecrop and Mona (FAO 250) hybrid was applied in the experiment.

The first experiment (Table 1) included three variables in a randomly selected "split-plot" design:

- four levels of nitrogen supply: A1 – 45 kg $N \cdot ha^{-1}$, A2 – 90 kg $N \cdot ha^{-1}$, A3 – 135 kg $N \cdot ha^{-1}$ and A4 – 180 kg $N \cdot ha^{-1}$;
- two methods of 45 kg $N \cdot ha^{-1}$ supply: B1 – to the soil before sowing in the as urea, and B2 – to leaves as 8.15% urea solution on three dates of foliar fertilizer application;
- nutrition with a Basfoliar 6-12-6 fertilizer: C1 – without fertilizer and C2 – Basfoliar 6-12-6 as recommended by the producer, i.e., in the phase of 4-5 leaves, 10 days later and 10 days after the second spraying, each time in a dose of 9 $l \cdot ha^{-1}$.

The experimental scheme was supplemented with a control object without nitrogen. Basfoliar 6-12-6 is a multiple fertilizer recommended for maize; it is produced by ADOB Co. further to BASF licence. It contains the following weight proportions: 6% N, 12% P_2O_5, 6% K_2O, 0,01% MgO and chelated microelements such as: 0.05% Zn, 0.01% Cu, 0.01% Fe, 0.01% Mn, 0.01% B and 0.005% Mo.

The fertilization scheme in the second experiment was described in the paper: "Effect of the method and term of foliar nutrition with urea solution and a multiple fertilizer on nitrogen and dry mass content in maize" published in the present edition.

Table 1. Scheme of nitrogen and a multiple fertilizer application in first experiment

Objects			Fertilization in kg ha^{-1} to soil	Fertilization in kg ha^{-1} to leaves	urea in kg ha^{-1} N	Amount of components acc. to the scheme multiple fertilizer in g ha^{-1} N	P_2O_5	K_2O	MgO	Zn	Cu	Fe	Mn	B	Mo
A1	B1	C1	45	0	45	-	-	-	-	-	-	-	-	-	-
		C2	45	Basfoliar	45	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
	B2	C1	.0	45	45 .	-	-	-	-	-	-	-	-	-	-
		C2	0	45+Basfoliar	45	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
A2	B1	C1	90	0	90	-	-	-	-	-	-	-	-	-	-
		C2	90	Basfoliar	90	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
	B2	C1	45	45	90	-	-	-	-	-	-	-	-	-	-
		C2	45	45+Basfoliar	90	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
A3	B1	C1	135	0	135	-	-	-	-	-	-	-	-	-	-
		C2	135	Basfoliar	135	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
	B2	C1	90	45	135	-	-	-	-	-	-	-	-	-	-
		C2	90	45+Basfoliar	135	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
A4	B1	C1	180	0	180	-	-	-	-	-	-	-	-	-	-
		C2	180	Basfoliar	180	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
	B2	C1	135	45	180	-	-	-	-	-	-	-	-	-	-
		C2	135	45+Basfoliar	180	1620	3240	1620	2,7	13,5	2,7	2,7	2,7	2,7	1,35
Control			0	0	-	-	-	-	-	-	-	-	-	-	-

A, B, C – experimental factors.

The second experiment included two variables in a randomly selected "split-plot" design:

- three dates of foliar nutrition with urea and/or a multiple fertilizer: A1 – in the phase of 4-5 leaves, A2 – 10 days after the first term, A3 – 10 days after the second date,
- three variants of foliar nutrition with urea and/or with a multiple fertilizer: B1 – urea in the amount of 15 kg N·ha^{-1}, B2 – urea in the amount of 15 kg N·ha^{-1} + multiple fertilizer Basfoliar 6-12-6 in the dose of 9 l·ha^{-1}, B3 – multiple fertilizer Basfoliar 6-12-6 in the dose of 9 l·ha^{-1}.

Since the terms of maize foliar nutrition fell in the same developmental stages in all experimental years, they will be used in the further part of this paper for identification of treatment dates. The first spraying treatment was carried out in the phase of 4-5 leaves, the second spraying was in the phase of 6-7 leaves and the third one in the phase of 9-10 leaves. Urea was applied to leaves in a form of 8.15% solution. Total nitrogen fertilization (to soil and leaves) was levelled to a dose of 120 kg N·ha^{-1}. The experimental scheme was supplemented with a control object where only soil fertilization in an amount of 120 kg N ha^{-1} was applied.

In both experiments, an equal phosphorus fertilization (90 kg P_2O_5·ha^{-1}) was used in a form of triple superphosphate and potassium fertilization (120 kg K_2O·ha^{-1}) in a form of 50-60% potash salt applied in early spring under a cultivator. The presowing nitrogen doses were mixed with the soil using a cultivation unit.

The experimental years were characterized by weather conditions favourable for maize growth and development. The precipitation sum of the vegetation season (from April to October) in all experimental years was higher than the corresponding many years sum (355.1 mm) in the same period by 127.6 mm in 1996, by 102.8 mm in 1997 and by 70.6 mm in 1998. In respect to thermal conditions, the experimental years did not deviate from the norm and the year 1998 can be regarded as a particularly favourable one, mainly in the beginning of the vegetative season.

The experiments were carried out in 4 field replications. The results obtained were subjected to variance analysis for multiple experiments and hypotheses were tested at 0.05 probability level.

RESULTS

In the first experiment, the first diseases and pests that appeared in all three experimental years were: frit fly and fusarium. The number of plants infested by these pathogens depended primarily on the course of weather in years. Infestation by

frit fly was not high and showed the following values in individual years: in 1996 – 1.8%, in 1997 – 3.5% and in 1998 – 4.0%. The percentage of plants damaged by fusarium in 1997 (13.0%) was about twice as high as in 1998 (6.1%).

The factors studied did not exert any influence on the percentage of damaged plants either by frit fly or by fusarium (Table 2). Doses of nitrogen which changed significantly the number of plants damaged by frit fly were an exception. However, this effect was not explicit, even though higher percentage of infested plants was found in the case of a dose of 180 kg $N \cdot ha^{-1}$, and the lowest was observed after an application of 45 kg $N \cdot ha^{-1}$.

Among the diseases and pests observed during the second experiment, there occurred frit fly, common smut and fusarium. The number of plants damaged by frit fly depended also in this case on the course weather of during the experimental years. The highest number of plants damaged by this pest was found in 1997 (on average – 8.0%) and the least damages were found in 1996 (1.3%). In 1988, 3.5% of plants were infested. The percentage of plants attacked by frit fly on objects fertilized only to the soil (control) was the following: in 1996 – 1.1%, in 1997 – 6.2% and in 1998 – 3.9%.

Analysis of variance showed a relation between the number of plants infested by frit fly and the term of foliar nutrition irrespective of the year and the nutrition variant, i.e., only with urea, only with Basfoliar or with both these fertilizers together (Table 3). The least number of plants damaged by frit fly was found on the

Table 2. Percentage of plants damaged by frit fly (*Oscinella frit* L.) and fusarium (*Fusarium* ssp.)

Specification		Frit fly		Fusarium
		%	°Blissa	%
N rates in kg ha^{-1}	45	2.8	9.21	9.6
	90	3.0	9.98	10.7
	135	2.8	9.41	9.9
	180	3.6	10.50	8.0
	$LSD_{0.05}$	-	1.058	r.n.
Method of 45 kg ha^{-1} application	to soil	3.0	-	9.9
	to leaves	3.3	-	9.2
	$LSD_{0.05}$	r.n.	-	r.n.
Multiple fertilizer	-	3.1	-	9.7
	Basfoliar	3.1	-	9.4
	$LSD_{0.05}$	r.n.	-	r.n.
Control - without nitrogen		2.8	-	9.9

r.n. – non significant differences

latest, third date of foliar nutrition which, on average fell in the phase of 9-10 leaves. Foliar application of nutrients on the second date (in the phase of 6-7 leaves) significantly increased the percentage of plants damaged by frit fly. The number of plants attacked by frit fly in the case of foliar nutrition in the phase of 4-5 leaves (the first tern of spraying) did not differ significantly from the number of plants damaged in the case of foliar nutrition on second and third date.

The term of foliar nutrition as well as the variant of nutrient application did not exert any influence on the percentage of plants infested by fusarium (Table 4). A significance of the interrelation between dates of treatment and the variant of foliar nutrition only was detected. Foliar application of urea in an amount of 15 kg $N \cdot ha^{-1}$ significantly decreased the number of plants damaged by fusarium when the nutrition term was delayed from the phase of 4-5 leaves to the phase of 9-10 leaves. On the other hand, an addition of a multiple fertilizer to urea or an application of Basfoliar did not show any differences only between the number of plants damaged by fusarium as the foliar application date was delayed.

Infestation of maize by common smut was not high and it was independent of the factors investigated (Table 3). Similarly the number of lodged plants was not high and it did not exceed several percent. The analysis of variance showed the effect of the studied variants of foliar nutrition with urea and a multiple fertilizer on the number of lodged plants and it was independent of the date of application (Table 3). The highest percentage of lodged plants was found in the case of foliar nutrition with urea only (in an amount of 15 kg $N \cdot ha^{-1}$). An addition of a multiple fertilizer to urea or an application of a Basfoliar multiple fertilizer 6-12-6 significantly limited only maize lodging. The variants of foliar nutrition where a multiple fertilizer was applied did not differ significantly in respect to percentage of lodged plants. It is worth noticing that an application of nitrogen to the soil (control – 120 kg $N \cdot ha^{-1}$) decreased only the number of lodged plants as compared with the use of both types of fertilization to soil and to leaves.

DISCUSSION

The course of weather in the experimental years was a factor modifying the features analysed. It refers primarily to damages caused by frit fly and fusarium. A high variation in the number of plants infested by frit fly depending on the course of weather in individual years was found also by Lisowicz [11]. This last author reported that during 17 years of his studies the percentage of infested plants ranged from 1.9% in 1993 to 70% in 1998. Earlier studies of the present author [8]

Table 3. Percentage of plants damaged by frit fly (*Oscinella frit* L.), by common smut (*Ustilago maydis*) and lodging of plants in %

Specification		Frit fly		Common smut	Lodging	
		%	°Blissa	%	%	°Blissa
Variants of foliar nutrition with urea and/or multiple fertilizer	Mocznik	4,7	-	0,1	3,3	10,31
	Mocznik+Basfoliar	3,8	-	0,1	2,3	8,18
	Basfoliar	4,2	-	0,2	2,4	8,61
	$LSD_{0,05}$	r.n.	-	r.n.	-	1,577
Dates spraying	I spraying 4-5 leaves	4,3	11,22	0,1	2,7	-
	II spraying 6-7 leaves	4,5	11,43	0,1	2,1	-
	III spraying 9-10 leaves	4,0	10,62	0,1	3,2	-
	$LSD_{0,05}$	-	0,689	r.n.	r.n.	-
Control – only N fertilization to the soil		3,7	-	0,2	1,8	-

r.n.– non significant differences.

Table 4. Percentage of plants damaged by fusarium (*Fusarium ssp.*)

Variants of foliar nutrition with urea and/or multiple fertilizer		Terms of sprays I spray 4-5 leaves	II spray 6-7 leaves	III spray 9-10 leaves	Mean
Urea	%	22,7	16,8	15,8	18,5
	°Blissa	28,47	24,16	23,33	-
Urea+Basfoliar	%	19,7	15,4	19,4	17,9
	°Blissa	26,37	22,05	26,07	-
Basfoliar	%	19,1	23,0	18,9	20,3
	°Blissa	25,87	28,58	25,73	-
Średnio - Mean	%	20,5	18,1	18,0	-

$LSD_{0.05}$ for interaction of terms (A) and variants (B): A/B=3,472 °Blissa; B/A = 4,465 °Blissa

Control – N fertilization to soil only 20,4

indicated that moist and cool weather in the initial development phase of maize increases the number of plants infested by frit fly. The level of other features in the present studies, such as infestation by common smut or damages caused by lodging, were small enough not to permit a quantitative evaluation of their effect.

The level of nitrogen dose had an influence on the infestation of maize by frit fly. A significant difference in the percentage of damaged plants occurred only at the extreme doses. The highest percentage of infested plants was found with a dose 180 kg $N \cdot ha^{-1}$, and the lowest was with a dose of 45 kg $N \cdot ha^{-1}$. Earlier studies of the present author [8] showed that an increase of nitrogen dose increased the number of plants infested by frit fly but only in the years with an earlier spring favouring the feeding activity of the pest. In my present studies, the number of plants infested by frit fly depended also on the term of foliar nutrition. The highest percentage of plants damaged by frit fly was found in the case of foliar application of nutrients (urea, Basfoliar or urea + Basfoliar) in the phase of 6-7 leaves. A delay of foliar application to the phase of 9-10 leaves significantly decreased the number infested by that pest.

A decreasing tendency in the percentage of maize plants infested by fusarium was found when the term of spraying was delayed from the 4-5 leaf phase to the 9-10 leaf phase, irrespective the nutrition variant applied. This tendency was statistically confirmed only in the case of a single foliar application of urea alone an the amount of 15 kg $N \cdot ha^{-1}$. An addition of a multiple fertilizer to urea or an application of Basfoliar alone did not diversify the number of plants damaged by fusarium as the term of foliar application of these nutrients was delayed.

Foliar application of 15 kg $N \cdot ha^{-1}$ in the form of urea solution increased the number of lodged plants irrespective of the application term as compared to the use of a multiple fertilizer alone or of both fertilizers together (urea + Basfoliar). Infestation of maize by common smut was not high and it was independent of the factors studied.

CONCLUSIONS

1. The course of weather in the experimental years was a factor modifying maize susceptibility to fusarium and to frit fly infestation.

2. An increase of nitrogen nutrition increased the number of plants infested by frit fly. A significant difference occurred only between extreme doses of 45 and 180 kg $N \cdot ha^{-1}$.

3. A delay of the foliar urea application term from the phase of 4-5 leaves to the phase of 9-10 leaves decreased the number of plants infested by fusarium.

4. Foliar application of 15 kg $N \cdot ha^{-1}$ in form of urea solution increased the number of lodged plants in comparison to the application of multiple fertilizer (Basfoliar 6-12-6) or to the use of both these fertilizers (urea + Basfoliar 6-12-6).

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WPŁYW DOLISTNEGO DOKARMIANIA KUKURYDZY AZOTEM I NAWOZEM WIELOSKŁADNIKOWYM NA PORAŻENIE ROŚLIN PRZEZ CHOROBY I SZKODNIKI ORAZ WYLEGANIE

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S t r e s z c z e n i e. Celem przeprowadzonych badań było określenie wpływu dolistnego dokarmiania kukurydzy azotem i nawozem wieloskładnikowym (Basfoliar 6-12-6), na porażenie roślin przez choroby, szkodniki i wyleganie. Istotnie większy % roślin porażonych tym szkodnikiem stwierdzono po zastosowaniu 180 kg N ha^{-1}, niż przy nawożeniu najniższą dawką 45 kg N ha^{-1}. Najwięcej roślin uszkodzonych przez ploniarkę stwierdzono przy dolistnej aplikacji nawozów w fazie 6-7 liści kukurydzy. Opóźnianie terminu dolistnego dokarmiania roślin mocznikiem, od fazy 4-5 liści do fazy 9-10 liści, zmniejszało liczbę roślin porażonych fuzariozą. Zastosowanie dolistne mocznika, zwiększało liczbę roślin wyległych, w porównaniu do dolistnej aplikacji nawozu wieloskładnikowego względnie łącznego stosowania mocznika i Basfoliaru.

S ł o w a k l u c z o w e: kukurydza, dokarmianie dolistne, choroby, szkodniki