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EFFECT OF THE METHOD AND TERM OF FOLIAR NUTRITION WITH UREA SOLUTION AND A MULTIPLE FERTILIZER ON NITROGEN AND DRY MASS CONTENT IN MAIZE*

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A b s t r a c t. The objective of the present studies was to determine the method and dates of foliar nutrition of maize with urea and a multiple fertilizer on the nitrogen and dry mass content. The methods and dates of foliar nutrition with urea and a multiple fertilizer had a minor effect on the content of nitrogen and dry mass in whole plants in the maize vegetative period similarly stover, cobs and grain. A possible reasons for the occurrence of no change in the content of N and dry mass was a too low dose of nitrogen applied to the leaves in a form of an urea solution. Especially with respect to the nitrogen content, the absence of changes can be explained by a too early date of foliar nutrition both with urea and multiple fertilizer.

K e y w o r d s: maize, foliar nutrition, nitrogen, microelements

INTRODUCTION

Maize belongs to plants strongly reacting to fertilization, particularly to nitrogen. Moreover, it is characterized by a specific dynamics of the nitrogen uptake. In the case of maize, nitrogen is not only one of the most yield generating elements but it also contributes to the quality of the biomass produced. On the other hand, the necessity to decrease production costs and ecological reasons make it necessary to look for fertilization techniques other than traditional. One of them can be foliar nutrition which should be regarded as a supplement to the basic soil fertilization [3-6,12,13]. An additional foliar nutrition is to supply nutritive components in the periods of an increased uptake or impede the uptake from the soil.

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Maize assimilates the majority of nutritive components, particularly nitrogen, in the period of its generative development. Therefore, it seems that an application of foliar nutrition with this component during the vegetative period should have a positive effect increasing not only the yield but also its quality [2-4,7,10,11]. The effectiveness of foliar nutrition depends, among others, on the date and method of its application [4,12]. In this connection, studies were undertaken to determine maize reaction to the method and term of foliar nutrition with urea and a multiple fertilizer (Basfoliar 6-12-6) expressed as accumulation dynamics of dry mass and total nitrogen. Results relating to maize yield as related to the method and dates of foliar nitrogen application or an application of a multiple fertilizer have been presented in earlier papers by the present author [8,9].

MATERIAL AND METHODS

Determination of the characteristics discussed in this paper was made in the years 1996-1998 on the basis of two identical field experiments carried out in ZDD Swadzim Experimental Farm near Poznań. Both experiments were established on grey-brown podzolic soil with mechanical composition of light medium sand shallowly spread on sandy loam. The soils belong to IVa soil class and a very good agriculture utility rye complex. The soils were characterized by a low to high content of phosphorus (4.1-9.9 mg P per 100 g of soil), high to very high potassium content (17.1-21.9 mg K per 100 g of soil), medium content of magnesium (1.9-2.5 mg Mg per 100 g of soil) and slightly acidic reaction (pH = 6.4-6.6 in 1 n KCl).

The first experiment was established as one-factor experiment in a random block design. It included 7 method of foliar nutrition with urea: once, twice and three times in three dates, i.e., in the stage of 4-5 leaves, 10 days after the first spray (6-7 leaves) and 10 days after the second spray (9-10 leaves). The scheme was supplemented by a control object without N fertilization and 2 objects where urea was used only to the soil in doses of 60 and 120 kg N ha^{-1}. Total fertilization in the objects where foliar nutrition was applied, was balanced to a doses of 120 kg N ha^{-1}. Urea was applied to leaves at 8,15% concentration.

The second experiment (Table 1) included two variables randomly selected in the "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 dates, A3 – 10 days after the second date;

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

Objects		To soil kg N ha^{-1}	To leaves in kg N ha^{-1} Terms of application			urea kg N ha^{-1}	Amount of components acc. to the scheme in kg ha^{-1} multiple fertilizer in g ha^{-1}									
			4-5 leaves	10 days after the first spraying	10 days after 2 nd spray		N	P_2O_5	K_2O	MgO	Zn	Cu	Fe	Mn	B	Mo
A1	B1	105	15	-	-	120	-	-	-	-	-	-	-	-	-	-
	B2	105	15+Basfoliar	-	-	120	540	1080	540	0.9	4.5	0.9	0.9	0.9	0.9	0.45
	B3	120	Basfoliar	-	-	120	540	1080	540	0.9	4.5	0.9	0.9	0.9	0.9	0.45
A2	B1	105	-	15	-	120	-	-	-	-	-	-	-	-	-	-
	B2	105	-	15+Basfoliar	-	120	540	1080	540	0.9	4.5	0.9	0.9	0.9	0.9	0.45
	B3	120	-	Basfoliar	-	120	540	1080	540	0.9	4.5	0.9	0.9	0.9	0.9	0.45
A3	B1	105	-	-	15	120	-	-	-	-	-	-	-	-	-	-
	B2	105	-	-	15+Basfoliar	120	540	1080	540	0.9	4.5	0.9	0.9	0.9	0.9	0.45
	B3	120	-	-	Basfoliar	120	540	1080	540	0.9	4.5	0.9	0.9	0.9	0.9	0.45
Control		120	-	-	-	120	-	-	-	-	-	-	-	-	-	-

A, B – experimental factors

- three variants of foliar nutrition with urea and/or with a multiple fertilizer: B1 – urea in an amount of 15 kg $N \cdot ha^{-1}$, B2 – urea in an amount of 15 kg $N \cdot ha^{-1}$ + a multiple fertilizer Basfoliar 6-12-6 in a dose of 9 $l \cdot ha^{-1}$, B3 – Basfoliar multiple fertilizer 6-12-6 in the dose of 9 $l \cdot ha^{-1}$.

Since the dates 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 to define dates of treatment. The first spraying was carried out in the phase of 4-5 leaves, the second in the phase of 6-7 leaves and the third spraying 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 to leaves) was balanced to a dose of 120 kg $N \cdot ha^{-1}$. The scheme was supplemented by a control object with soil fertilization only in an amount of 120 kg $N \cdot ha^{-1}$. Basfoliar 6-12-6 is the multiple fertilizer recommended for maize and produced by ADOB Co. to BASF licence. It contains the following weight proportions of elements: 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.

In all experimental years, in both experiments, winter wheat was used as a forecrop grown after winter rape fertilized with one half of the manure dose. Phosphorus fertilization (90 kg $P_2O_5 \cdot ha^{-1}$) was applied in a form of triple superphosphate, and potasium fertilization (120 kg $K_2O \cdot ha^{-1}$) was used in a form of 60% potash salt. Both fertilizers were applied in early spring under cultivator. Pre-sowing doses of nitrogen were mixed with soil using a cultivator unit. Mona (FAO 250) hybrid was the experimental plant.

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

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

RESULTS

In the first experiment, the weather course in the experimental years represented an element significantly affecting total nitrogen content in whole plants during vegetation and in stover, cobs and grain during harvest. However, the differences between particular individual years in nitrogen content in the individual sampling terms were not high and did not exceed 0.5%. The highest difference between the years was related to total N content in maize in the phase of 4-5 leaves (mean values only for soil fertilization). A highest N content in whole plants of this phase (amounting to 5.0%) was found in 1998. A high N content in the above year was caused by warm and dry weather in May. In the remaining years, N content remained the same, i.e. 4.5%. Successive greater differences between individual years in with respect to the content of nitrogen were related to cobs and grain. The content of total nitrogen was the highest in 1998 in the above plant parts with showing the following proportions: for cobs 1.5% and for grain 1.7%.

Analysis of variance revealed a significant diversity in the content of total N in whole plants under the influence of the dates and methods of nitrogen application studies, but it appeared only 10 days after the last spraying, i.e. after implementation of the full fertilization scheme (Table 2). Nitrogen content in stover, cobs and grain did not change under the influence of the levels of the factors studied (Table 2). The lowest significant N content 10 days after the third spraying was shown by plants fertilized without nitrogen, i.e., in control object (3.1%). On the other hand, the highest N content was found in plants fertilized to the soil with a dose 105 kg $N \cdot ha^{-1}$ and additionally given one single leaf nutrition of 15 kg $N \cdot ha^{-1}$. The content of total N in the plants of those objects increased when the term of spraying was delayed showing the following values: for the third date 3.8%, for the second date 3.7% and for the first date 3,6%. In the developmental phase, the object with a soil dose of 75 kg $N \cdot ha^{-1}$ and a leaf dose of 45 kg $N \cdot ha^{-1}$ applied on three dates to leaves (3.6%) created a homogenous group with the highest N content in the developmental phase. The above indicates that the highest content of total N in whole plants 10 days after the application of a full fertilization scheme was obtained in the case of combined fertilization both to the soil and to leaves but only when high soil doses (105 kg $N \cdot ha^{-1}$) were combined with single leaf nutrition (15 kg $N \cdot ha^{-1}$) or low soil doses (75 kg $N \cdot ha^{-1}$) were combined with three a supplementary leaf nutrition (45 kg $N \cdot ha^{-1}$).

Also in the second experiment, the weather course in the experimental years exerted a significant effect on total nitrogen content in plants as determined 10

T a b l e 2. Content of total nitrogen in % of dry matter (the first experiment)

N doses in kg·ha^{-1}				Sampling dates							
soil fertilization	foliar nutrition			I spraying 4-5 leaves [1]	II spraying 6-7 leaves [2]	III spraying 9-10 leaves [3]	10 day after III spraying [4]	silking [4]	during harvest		
	I spraying 4-5 leaves	II spraying 6-7 leaves	III spraying 9-10 leaves						stover	cobs	grain
0	-	-	-	3.9	3.9	3.2	3.1	1.8	0.7	1.2	1.3
60	-	-	-	4.5	3.9	3.5	3.5	2.0	0.8	1.3	1.5
120	-	-	-	4.8	4.0	3.8	3.5	2.0	0.9	1.4	1.5
105	15	-	-	4.7	4.0	3.7	3.6	1.9	0.9	1.4	1.5
105	-	15	-	4.9	4.1	3.6	3.7	2.0	0.8	1.2	1.5
105	-	-	15	4.9	4.1	3.7	3.8	2.0	0.9	1.3	1.5
90	15	15	-	4.8	3.9	3.8	3.5	2.0	0.8	1.3	1.5
90	15	-	15	4.9	4.0	3.8	3.5	2.0	0.8	1.4	1.6
90	-	15	15	4.8	4.1	3.7	3.5	2.0	0.9	1.4	1.5
75	15	15	15	4.5	3.9	3.6	3.6	2.0	0.9	1.3	1.6
	$LSD_{0.05}$			r.n.	r.n.	r.n.	0.29	r.n.	r.n.	r.n.	r.n.

r.n. – non significant differences, [1] concerns only soil fertilization, [2] concerns soil and foliar fertilization applied on the first term, [3] concerns soil and foliar fertilization applied on the first and the second term, [4] fertilization according to the scheme

days after the third spraying the beginning of silking and at harvest in cobs and grain. However, no significant differences were found between the particular years in N content in stover in individual years. The highest content of total N in the above ground plant mass and in stover, cobs and grain after an introduction of the full experimental scheme was found in 1998. The lowest content of nitrogen in plants was found 10 days after the third spraying, in the cobs silking phase of and in stover in 1996. On the other hand, N content in cobs and grain was the same in 1996.

The dates and variants of foliar nutrition with urea and/or a multiple fertilizer investigated did not exert any essential effect on the total N content in plants (Table 3). Nitrogen content in plants of the experimental objects was similar to the content in the control objects where only soil fertilization was applied at a dose of 120 kg $N \cdot ha^{-1}$. The initial N content in plants, i.e., before the first spraying (4-5 leaves) in the experimental objects (4.7%) and in the control (4.6%) was similar. Nitrogen content in plants during an introduction of experimental factors (the second and third terms of spraying) was significantly higher in objects with leaf nutrition (on the second date by 4.2% and on the third date 3.6% on average), than an average percentage for the remaining objects where leaf nutrition was not applied (on the second term 4,0% and on the third term 3.4%). In the control objects, i.e., after the application of 120 kg $N \cdot ha^{-1}$ to the soil, N content in plants on the second date of spraying was 4.2% and on the third date 3.5%.

Dry mass content in plants on all sampling term depended on years. The highest content of dry mass in the initial growth periods was shown in 1997. On the other hand, during harvest, the highest amount of dry mass in stover, cobs and whole plants was found in 1998. The terms and methods of nitrogen fertilization of maize investigated did not exert any effect on dry mass content in whole plants or stover, cobs and grain during harvest (Table 4). On all sampling terms, dry mass content both in the objects fertilized with nitrogen and in control without nitrogen was similar.

The terms and variants of maize fertilization with nitrogen and a multiple fertilizer studied did not exert any effect on the content of dry mass in whole plants in different terms during vegetation or in individual plant parts during harvest. Effect of terms of foliar nutrition (urea and Basfoliar) on dry mass content 10 days after the last (third) spray was an exception. The highest dry mass content in the whole above ground plant part in this development phase was found in the second term of spraying (6-7 leaves) and a significantly lower level was found when foliar nutrition was applied on the earliest dates (4-5 leaves).

T a b l e 3. Content of total N in % of dry matter (the second experiment)

Specification		Sampling dates during vegetative season – whole plants					Sampling dates during harvest		
		I spraying 4-5 leaves	II spraying 6-7 leaves	III spraying 9-10 leaves	10 days after III spray	silking	stover	cobs	grain
Means for terms of foliar nutrition	I spray	-	4.2	3.6	3.3	1.9	0.9	1.4	1.5
	II spray	-	-	3.6	3.3	1.9	0.8	1.4	1.5
	III spray	-	-	-	3.2	1.9	0.8	1.4	1.5
$LSD_{0,05}$		-	-	-	r.n.	r.n.	r.n.	r.n.	r.n.
Means for variants of foliar nutrition	urea	-	-	-	3.4	1.9	0.9	1.4	1.5
	urea+Basfoliar	-	-	-	3.2	1.9	0.8	1.4	1.5
	Basfoliar	-	-	-	3.3	1.9	0.8	1.4	1.5
$LSD_{0,05}$		-	-	-	r.n.	r.n.	r.n.	r.n.	r.n.
Control – N fertilization to soil only		4.6	4.2	3.5	3.3	1.8	0.9	1.3	1.6

r.n. - non significant differences

Table 4. Content of dry matter in %

N doses in kg ha^{-1}				Sampling dates							
soil fertilization	foliar nutrition			I spraying 4-5 leaves [1]	II spraying 6-7 leaves [2]	III spraying 9-10 leaves [3]	10 days after III spraying [4]	silking [4]	during harvest		
	I spraying 4-5 leaves	II spraying 6-7 leaves	III spraying 9-10 leaves						stover	cobs	grain
0	-	-	-	14.7	13.8	12.4	10.6	13.6	32.8	63.7	46.0
60	-	-	-	14.6	14.0	12.5	10.5	13.4	32.9	64.1	45.1
120	-	-	-	14.1	14.5	12.7	10.8	14.0	33.6	64.7	46.1
105	15	-	-	14.4	14.1	12.7	10.6	13.6	33.2	62.9	46.3
105	-	15	-	14.9	14.6	12.8	10.7	13.6	33.5	64.7	46.9
105	-	-	15	14.8	13.7	13.0	10.7	13.3	33.4	65.3	46.1
90	15	15	-	14.4	14.8	12.8	11.3	13.9	33.8	65.3	46.7
90	15	-	15	14.6	14.4	13.0	11.1	13.4	33.0	65.1	46.2
90	-	15	15	14.6	13.9	12.9	10.8	13.6	32.5	65.4	45.7
75	15	15	15	14.7	13.9	12.9	11.1	13.3	32.9	64.7	47.4
$LSD_{0.05}$				r.n.	r.n.	r.n.	r.n.	r.n.	r.n.	r.n.	r.n.

r.n. – non significant differences, [1] concerns only soil fertilization, [2] concerns soil and foliar fertilization applied on the first term, [3] concerns soil and foliar fertilization applied on the first and second term, [4] fertilization according to the scheme

DISCUSSION

Weather course during the experiment modified the observed maize most characteristics. It refers both to the content of nitrogen and dry mass in the total above ground plant part in the vegetative period as well as to the content of these components in grain and cobs. On the other hand, the N content in stover was the least diversified variable influenced by weather during the experimental years. Effect of years on the above feature was visible only in the first experiment where an effect of dates and methods of foliar urea application urea was studied. It is worth noticing that all experimental years were favourable to maize and yielding, there occurred a strong plant reaction to various conditions in the individual years. It may be a proof of a strong species reaction to environmental conditions in individual stages of its ontogenetic development. It should be assumed that even minor changes (not perceivable when only temperature and precipitation are measured) in unfavourable environmental factors disturb the rhythm of maize growth and development influencing the level of features characteristics.

Factors, methods and terms of the foliar application of urea and a multiple fertilizer studied in the two experiments had only a minor effect on the content of total nitrogen in whole plants in the vegetative period in stover, cobs and grain during harvest. The relations observed were occasional and therefore seem accidental. One of the above exception is the effect of the method and date of foliar application of urea on the content of total N 10 days after the third date of spraying, i.e., after an implementation of the full fertilization scheme. The highest content of nitrogen in whole plants was ensured by fertilization applied to the soil and to leaves provided high soil doses (105 kg $N \cdot ha^{-1}$) plus a single foliar nutrition (15 kg $N \cdot ha^{-1}$) were used irrespective of the term of their application; or in the case of low doses applied to the soil (75 kg $N \cdot ha^{-1}$) plus three foliar nutrition with urea (45 kg $N \cdot ha^{-1}$). Total nitrogen content in plants of the control objects where no N fertilization was applied, deviated from the N content in the experimental objects by 0.6-1.0% in the period of initial plant development. This difference diminished as the vegetation cycle progressed.

The absence of the effect of foliar application of a multiple fertilizer on the chemical composition of grain, cobs and stover was found also by Machul [10]. This above result was confirmed by Bellow *et al.* [1] who did not find any changes in the content of maize grain under the influence of a multiple fertilizers. However, these last authors observed an increase in the nitrogen content of grain under the influence of foliar nutrition with urea. In the present studies, no such dependence

was found. Earlier works cited by Byszewski *et al.* [4] indicated a relation between nitrogen content and terms of spraying. Protein content in grain increased under the influence of spraying carried out in the period of milk maturity of maize. On the other hand, earlier spraying had no effect on this feature. In this connection, in the present studies, too early dates of spraying could have been responsible for the absence of maize reaction to foliar application of urea and a multiple fertilizer as expressed in changes of nitrogen and dry mass content. Another reason for no changes in the N content could have been a too small amount of nitrogen supplied in the fertilizers.

CONCLUSIONS

1. Weather course in the experimental years exerted the strongest effect on the total nitrogen content in plants during the whole vegetative period.

2. The factors studied: fertilization methods, dates of fertilization with urea and a multiple fertilizer had a minor effect on the total nitrogen content in whole plants during maize vegetative period or in stover, cobs and grain during harvest.

3. In effectiveness of maize foliar nutrition resulted from too low doses of nitrogen used for leaves or too early dates of application.

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WPLYW SPOSOBU I TERMINU DOLISTNEGO DOKARMIANIA KUKURYDZY ROZTWOREM MOCZNIKA I NAWOZEM WIELOSKŁADNIKOWYM NA ZAWARTOŚĆ AZOTU I GROMADZENIE SUCHEJ MASY

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S t r e s z c z e n i e. Celem przeprowadzonych badań było określenie wpływu sposobów i terminów dolistnego stosowania mocznika i nawozu wieloskładnikowego na zawartość azotu i suchej masy. Sposoby i terminy stosowania dolistnego mocznika i nawozu wieloskładnikowego, w niewielkim stopniu wpływały na zawartość azotu i suchej masy w całych roślinach w okresie wegetacji kukurydzy jak również w słomie, kolbach i ziarnie. Prawdopodobnymi przyczynami nie wystąpienia zmian w zawartości azotu i suchej masy, była zbyt mała dawka azotu stosowanego dolistnie w postaci roztworu mocznika, a szczególnie odnośnie zawartości azotu, zbyt wczesne terminy dolistnej aplikacji zarówno mocznika jak i nawozu wieloskładnikowego.

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