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NITROGEN USE EFFICIENCY AND MAIZE YIELD RESPONSE TO NITROGEN RATE AND FOLIAR FERTILIZING

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Abstract

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Field experiment was conducted during 2009-2012 to evaluate the effect of nitrogen fertilization and new foliar products on grain yields and nitrogen use efficiency in maize. Foliar fertilizer Cereal mix (ME) was jointly applied with biostimulant Amalgerol in doses 3 (A3), 4 (A4) and 5 (A5) L/ha. The experimental design consisted of a fully randomized block design in four replications. The studied treatments were: 1. Control (no-fertilizing); 2. $N_{20}P_{15}K_{15}$; 3. $N_{20}P_{15}K_{15}$+ME+A3; 4. $N_{20}P_{15}K_{15}$+ME+A4; 5. $N_{20}P_{15}K_{15}$+ME+A5; 6. $N_{30}P_{15}K_{15}$.

Foliar products Cereal mix for maize and biostimulant Amalgerol demonstrated high efficiency under unfavorable climate conditions during maize vegetation. Integrated soil fertilization 200 kg $N.ha^{-1}$ and foliar top dressing (Cereal mix+Amalgerol) increased grain yield by 31% in average, compared with unfertilized plants. Applying rates $N_{200}P_{150}K_{150}$ combined with foliar products Cereal mix and Amalgerol significantly improved agronomic efficiency of nitrogen in comparison with soil fertilizing $N_{200}P_{150}K_{150}$ and $N_{300}P_{150}K_{150}$. Partial factor productivity of nitrogen decreased with increasing of N rate and did not depend on foliar fertilization.

Key words: maize, AE, PFP, foliar fertilizers

Abreviations: PFP_N – partial factor productivity; AE_N – agronomic efficiency of nitrogen

Introduction

With nitrogen prices on the rise, many farmers are looking at ways to cut back on expenses and still produce satisfactory maize yields (Baligar, 2001). Modern technologies for maize production require a soil fertilization to be combined with application of foliar fertilizers (Bruulsema et al., 2008; Chien et al., 2009). Soil fertilization, and particularly the nitrogen fertilization, may be reduced by means of additional application of foliar biologically active fertilizers (Fageria et al., 2008). Foliar fertilization is a widely used practice to correct nutritional deficiencies in plants caused by improper supply of nutrients to roots (Shaaban, 2001). Intensive agriculture and use of high productivity cultivars led to a continuous decrease in soil micronutrient content. In addition, unfavorable soil and climate conditions cause the less availability of these nutrients to plant roots and addition of micronutrients to soil proved to be less beneficial (Hirschi, 2009). Maize is a sensitive to micronutrient deficiency, especially manganese and zinc. High nitrogen rates generally increases crop susceptibility to pests and diseases (Reuveni and Reuveni, 1998). Applying foliar fertilizers, independently or together with pesticides, allow increasing the economic effect of mineral fertilization, to reduce the environment risk of pollution by reducing the rates of nutrients (Tejada and Gonzalez, 2003). This work was conducted to investigate the effect of soil and foliar fertilizing on the grain yields and nitrogen use efficiency in maize.

Materials and Methods

A field experiment with maize hybrid Kneza 509 was conducted during three years 2010 – 2012 on the location of Pazardjik, southern Bulgaria. Winter wheat was the precursor crop of maize. The soil type was Chromic luvisols (FAO, 2002) with pH=5.9. Mean contents of available nutrients in the arable layer before sowing were 27 mg $Nmin.kg^{-1}$, 7.8 mg $P_2O_5.100g^{-1}$, and 14 mg $K_2O.100g^{-1}$.

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Foliar fertilizer Cereal mix (ME) with micronutrients for maize was combined with biostimulant Amalgerol applied in three doses: 3 (A3), 4 (A4) and 5 (A5) L/ha. The experimental design consisted of field plots in a randomized complete block design in four replications and 25 m^2 harvested size of the plots. The studied variants were: 1). Control (no-fertilizing); 2). $N_{200}P_{150}K_{150}$; 3). $N_{200}P_{150}K_{150}$+ME+A3; 4). $N_{200}P_{150}K_{150}$+ME+A4; 5). $N_{200}P_{150}K_{150}$+ME+A5; 6). $N_{300}P_{150}K_{150}$. The phosphorus as triple superphosphate and potassium as KCL were applied before sowing. Nitrogen fertilization in the form of NH_4NO_3 was done before sowing (1/2) and as a dressing during the vegetation (1/2). Biostimulant Amalgerol contains extract of algae, herbs and plant oils. Foliar fertilizer Cereal mix is composed of micronutrients for maize in g/L: Mn – 300, Cu – 84, Zn – 200. The both products Cerel mix+Amalgerol were applied together in a phase 4 – 6 leaves developed of maize plants.

NUE was determined using the agronomic efficiency (AE) and partial factor productivity (PFP) indices (Snyder, 2009): AE=(Y – Yo)/F and PFP=Y/F, where F = amount of (fertilizer) nutrient applied (kg/ha); Y = Crop yield with applied nutrients (kg/ha) and Yo = crop yield (kg/ha) in a control treatment with no fertilization.

Meteorological conditions during maize vegetation are given in Figure 1. The summer of 2011 was hot and in 2012 was characterized like extraordinary hot (there were days with maximum temperature even over 40ºC). Experimental years were very different with respect to the amount and distribution of rainfall throughout the maize vegetation. There was registered 113 mm more rains than usual for vegetation period in 2010, but the sums of precipitation over the maize growth in 2011 and 2012 were below than average norm of the region. The lowest rainfalls sum during the period of April – September was observed in 2011.

All data were analyzed statistically according to the analysis of variance (ANOVA) procedure and significant differences ($p<0.05$) among treatment means were identified using Duncan's multiple range test.

Results and Discussion

The highest average grain yield of maize (11 050 $kg.ha^{-1}$) was obtained in 2010 (Table 1). The lowest average yields of studied variants were obtained during the experimental 2011 - 7940 $kg.ha^{-1}$, which was characterized by unfavorable hydrothermal conditions during the crop vegetation. The aver-

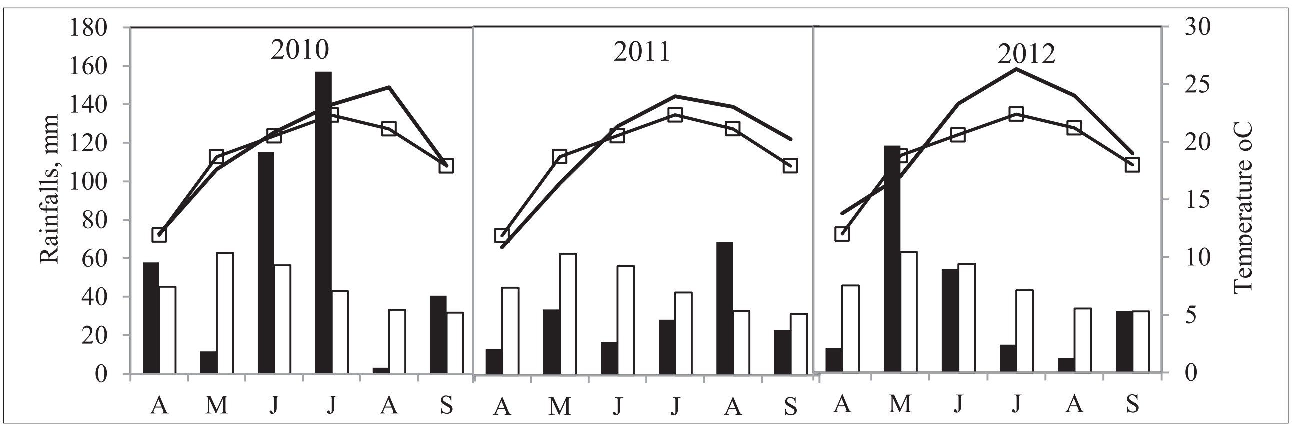

Fig. 1. Air temperature and rainfalls: white bars and lines with bars denote mean values of previous period of 70 years

Table 1
Maize grain yields in response of fertilization

Treatment \ Year	2010	2011	2012	Average	
	$kg.ha^{-1}$				%
1. Control	9500 c*	5400 d	8450 d	7780 ns	100
2. $N_{200}P_{150}K_{150}$	10660 b	7400 c	8880 c	8980	115.4
3. $N_{200}P_{150}K_{150}$+ME+A3	11050 b	8800 a	9850 ab	9900	127.2
4. $N_{200}P_{150}K_{150}$+ME+A4	11370 ab	8950 a	10000 a	10110	129.9
5. $N_{200}P_{150}K_{150}$+ME+A5	11710 ab	9000 a	10200 a	10300	132.4
6. $N_{300}P_{150}K_{150}$	12040 a	8100 b	9480 b	9870	126.9

*Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test age grain yield in harvested 2012 was lower by 16.4% compared to 2010, but exceeded with 19.2% the yield from the previous 2011. The studied variants of soil and soil + foliar fertilization had a proven positive effect on the productivity of maize during all studied period, compared to not fertilized crops.

During the favorable for the growth of maize 2010, the highest grain yield was obtained in variant $N_{300}P_{150}K_{150}$ and it exceeded the control variant with 27.0% (Table 1). Foliar fertilization with microelements and Amalgerol in doses 4 and 5 $L.ha^{-1}$ combined with a reduced nitrogen rate led to obtained of similar yields to variant $N_{300}P_{150}K_{150}$. The applied foliar products indicated a tendency to increase the yield, compared to variant with identical soil fertilization $N_{200}P_{150}K_{150}$, but proven differences was not found. Under unfavorable climate conditions (harvest 2011 and 2012) the most effective for the grain yield were the variants with foliar fertilization with Cereal mix and the biostimulant Amalgerol in doses 3-5 $L.ha^{-1}$. In variants with soil + foliar fertilization, the yields increased compared to not fertilized control average by 65.1% in 2011 and by 17.5% in 2012. In years with unfavorable hydrothermal conditions for the maize development nitrogen fertilization in rate N_{300} was less effective for the yield compared to the combination of rate 200 $kg.ha^{-1}$ with foliar fertilization with Cereal mix and biostimulant Amalgerol.

Average for the three-year studied period there was not mathematically proven effect of studied variants of fertilization. The main reason was the different climate conditions during the vegetation period. Despite this, jointly use of foliar fertilizer with microelements and Amalgerol increased grain yield in maize from 27.2 to 32.4%, compared to not fertilized crops. The positive effect of foliar products for the yield was similar to the effect from fertilization with increased nitrogen rate $N_{300}P_{150}K_{150}$.

The main indicators of the crop practice - partial factor productivity of nitrogen and agronomical nitrogen use efficiency (Delogua et al., 1998; Snyder, 2009), characterized the efficiency of fertilization. PFP_N represents the kg of grain harvested per kg of N fertilizer applied. It can be used as an index of total economic outputs relative to the use of all N sources - soil N and applied fertilizer (Weih et al., 2011). AE_N represents the kg of yield increase per kg of N fertilizer applied. The average PFP_N varied in dependence of year conditions with the lowest value 40 $kg.kg^{-1}$ in unfavorable 2011 (Table 2). In 2010 and 2012 were obtained productivity of N from fertilizers 53 $kg.kg^{-1}$ and 45 $kg.kg^{-1}$, respectively. Partial factor productivity decreased with increasing of N rate and did not depend on foliar fertilization.

Agronomic efficiency of nitrogen in 2010 slightly affected by the studied fertilizing treatments (Table 3). Proven differ-

Table 2
Partial factor productivity of nitrogen

Treatment \ Year	2010	2011	2012	Average	
	$kg.kg^{-1}$				%
1. $N_{200}P_{150}K_{150}$	53 a	37 a	44 a	45 ns	100
2. $N_{200}P_{150}K_{150}$+ME+A3	55 a	44 a	49 a	50	110.3
3. $N_{200}P_{150}K_{150}$+ME+A4	57 a	45 a	50 a	51	102.1
4. $N_{200}P_{150}K_{150}$+ME+A5	59 a	45 a	51 a	52	101.9
5. $N_{300}P_{150}K_{150}$	40 b	27 b	32 b	33	63.9

*Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test

Table 3
Agronomic efficiency of nitrogen

Treatment \ Year	2010	2011	2012	Average	
	$kg.kg^{-1}$				%
1. $N_{200}P_{150}K_{150}$	6 b*	10 b	2 b	6 b	100
2. $N_{200}P_{150}K_{150}$+ME+A3	8 ab	17 a	7 a	11 a	176.4
3. $N_{200}P_{150}K_{150}$+ME+A4	9 ab	18 a	8 a	12 a	193.6
4. $N_{200}P_{150}K_{150}$+ME+A5	11 a	18 a	9 a	13 a	210.0
5. $N_{300}P_{150}K_{150}$	8 ab	9 b	3 b	7 b	116.0

*Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test ences in AE_N was found only between the variant with soil fertilization $N_{200}P_{150}K_{150}$ and the same soil fertilization plus Cereal mix and Amalgerol 5 L.ha^{-1} ($N_{200}P_{150}K_{150}$+ME+A5). In less favorable for the maize growth years which was climate conditions during the experimental 2011 and 2012, foliar fertilization with Cerealmix and biostimulant Amalgerol in doses 3-5 L.ha^{-1} proven increased AE_N, compared to obtained values in variants of soil fertilization $N_{200}P_{150}K_{150}$ è $N_{300}P_{150}K_{150}$.

The integration of soil fertilization 200 kg N.ha^{-1} with foliar top dressing in phase 4 – 6 leaves developed with Cereal mix and Amalgerol increased grain yield 31% in average and significant improved agronomic efficiency of nitrogen in unfavorable climate conditions during the vegetation period of maize.

Conclusions

Foliar products Cereal mix for maize and biostimulant Amalgerol demonstrated high efficiency under unfavorable climate conditions during maize vegetation. Integrated soil fertilization 200 kg N.ha^{-1} and foliar top dressing (Cereal mix+Amalgerol) increased grain yield by 31% in average, compared with unfertilized plants. Applying rates $N_{200}P_{150}K_{150}$ combined with foliar products Cereal mix and Amalgerol significantly improved agronomic efficiency of nitrogen in comparison with soil fertilizing $N_{200}P_{150}K_{150}$ and $N_{300}P_{150}K_{150}$. Partial factor productivity of nitrogen decreased with increasing of N rate and did not depend on foliar fertilization.

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