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AGROCHEMICAL STUDY ON MAIZE (*Zea mays* L.) GROWN UNDER DIFFERENT VARIANTS OF NITROGEN FERTILIZATION

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Abstract

Basic agrochemical characteristics were studied in maize grown under different variants of nitrogen fertilization. The maize hybrid P0216 of Pioneer Company was studied, grown under irrigation conditions, following the conventional adopted technology in our country. The hybrid is characterized by high productivity and drought resistance. The trial was set by the block-plot method with a plot size of 21 m^2. Nitrogen (2.4 kg N/ha) was applied in the following variants: 1. Untreated control; 2. NH_4NO_3 - pre-sowing application of the whole rate; 3. NH_4NO_3 - split application: ½ pre-sowing and ½ at 5th leaf; 4. NH_4NO_3 - 1/3 pre-sowing application, 1/3 - at 5th leaf and 1/3 - at tasseling stage; 5. NH_4NO_3 - ¼ pre-sowing application, ¼ - at 5th leaf, ¼ - at 12th leaf and ¼ - at tasseling stage; 6. $CO(NH_2)_2$ - pre-sowing application of the whole rate; 7. $CO(NH_2)_2$ - ½ pre-sowing and ½ at 10th leaf; 8. $CO(NH_2)_2$ - ½ pre-sowing and NH_4NO_3 - ½ at 10th leaf; 9. $CO(NH_2)_2$ - ½ pre-sowing and NH_4NO_3 - ½ at tasseling stage. Export of nutrients and their use efficiency per production unit are important agrochemical indicators for maize. Their values vary according to the genotype, soil and climatic conditions, the predecessor and fertilization. Nitrogen export varies greatly depending on the fertilization rate and phosphorus and potassium export - depending on the genotype and climatic conditions during the year.

Key words*: maize, nitrogen fertilization, climatic conditions.*

INTRODUCTION

Maize is a crop highly responsive to nitrogen fertilizer, as its productivity after treatment increases proportionally. The importance of the nitrogen absorbed before flowering is extremely important and it promotes the development of the cob, affecting the number and size of the grains. Nitrogen can influence the leaf area development and maintenance, as well as photosynthetic efficiency (Arduini et al., 2006) and dry matter partitioning to the reproductive organs (Prystupa et al., 2004; Vouillot & Devienne-Barret, 1999). Grain is the most active acceptor of carbon and nitrogen assimilates at post-anthesis stage. Detailed studies in the recent years showed that the nitrogen needed for grain filling, originates from both remobilized nitrogen from leaves, stems and ears and continued nitrogen uptake from soil (Burzaco et al., 2013; DeBruin et al., 2013; Duffy, 2014; Haegele et al., 2013). In addition, phosphorus affects the number of grains and the grain yield and diminishes biomass accumulation in a different fashion than N (Batten, 1992; Prystupa et al., 2004). Prevailing scientific opinion is that nitrogen uptake occurs predominantly prior to anthesis and it is the major determinant of 75-90% of the final N content in the grain (Cox et al., 1985a; 1985b). The degree of nitrogen accumulation is determined by the relationship between plant capacity to absorb and remobilize nitrogen (Fageria & Baligar, 2005).

Phosphorus uptake occurs throughout the life cycle of the plants and unlike nitrogen uptake, it continues until physiological maturity (Batten, 1992). Remobilization of phosphorus depends on the genotype, mobile phosphates in soil, growing conditions (drought, high temperatures, salinization) and crop density. Scarce studies have been conducted in the world on donor-acceptor processes related to phosphorus, especially under field conditions (Masoni et al., 2007; Prystupa et al., 2004).

MATERIALS AND METHODS

The study was carried out during the period 2015-2016 at the Department of Farming and Weed Science at the Agricultural University of Plovdiv, on Molic fluvisoil soil type. The trial was set by the block-plot method in 4 replications, with a plot size of 21 m^2. The following nitrogen fertilization variants were studied: 1. Untreated control; 2. NH_4NO_3 - pre-sowing application of the whole rate; 3. NH_4NO_3 - split application: ½ pre-sowing and ½ at 5th leaf; 4. NH_4NO_3 - 1/3 pre-sowing application, 1/3 - at 5th leaf and 1/3 - at tasseling stage; 5. NH_4NO_3 - ¼ pre-sowing application, ¼ - at 5th leaf, ¼ - at 12th leaf and ¼ - at tasseling stage; 6. $CO(NH_2)_2$ - pre-sowing application of the whole rate; 7. $CO(NH_2)_2$ - ½ pre-sowing and ½ at 10th leaf; 8. $CO(NH_2)_2$ - ½ pre-sowing and NH_4NO_3 - ½ at 10th leaf; 9. $CO(NH_2)_2$ - ½ pre-sowing and NH_4NO_3 - ½ at tasseling stage. The agrotechnical activities were carried out following the adopted maize cultivation technology.

Soil analyses

Mineral nitrogen (ammonium nitrate) in extraction with 1% KCl;

Mobile phosphates by Egner-Reim method;

Digestible potassium in extraction with 2N HCl acid;

Soil reaction (pH) - potentiometrically in water extraction.

Plant analyses

Plant samples were taken from the above-ground part of the plants at milk maturity stage of the maize hybrid P0216. They were divided into grain and leaf-and-stem biomass, then dried, weighed, ground and analyzed for the content of major nutrients. An aliquot part of the dry plant samples was mineralized with concentrated H_2SO_4, with H_2O_2 catalyst, and the total nitrogen content was determined (distillation in Parnas-Wagner apparatus); total phosphorus content (colorimetrically, using Camspec M105 spectrophotometer) and total potassium content (using PFP-7 flame photometer).

Plant analyses include a study of:

- grain yield and leaf-and-stem yield (kg/ha);
- NPK export (kg/ha);
- NPK use efficiency (kg per 100 kg of grain).

Soil and climatic characteristics

The soil in the Training-and-Experimental Fields of the Agricultural University of Plovdiv is alluvial-meadow. Geographically the site is located in the Thracian-Strandja region. The alluvial-meadow soils are formed on sandy-loam and sandy-gravel quaternary deposits. According to the International Classification of FAO they refer to Mollic fluvisol.

They are formed on alluvial deposits, they have a well-formed humus-accumulative horizon, which gradually passes into C horizon and a gleization process is observed deeply down (below 100 cm) in the soil forming material - the A-C-G profile. The humus content is usually not high - no more than 1-2%.

The content of the mobile nutrient elements nitrogen, phosphorus and potassium before the beginning of the experiment and the soil reaction are presented in Table 1.

On the basis of the generally accepted limit values for the content of macroelements in soil, it was found that it is poorly supplied with nitrogen and very well-supplied with phosphorus and potassium.

Table 1. Soil reaction, mineral nitrogen content and mobile forms of phosphorus and potassium

Depth, cm	pH_{water}	NH_4-N mg/kg	NO_3-N mg/kg	Nmin mg/kg	P_2O_5 mg/100g	K_2O mg/100 g
0-30	8.09	9.8	11.2	21.0	32.0	46.2

The climate in the region of Plovdiv is transitional-continental.

The agrometeorological conditions during the experimental period did not show significant deviations from the norms for the region, which made it possible to compare the effect of the different fertilization variants.

The sum of the monthly precipitation provided a relatively good moisture content for the plants.

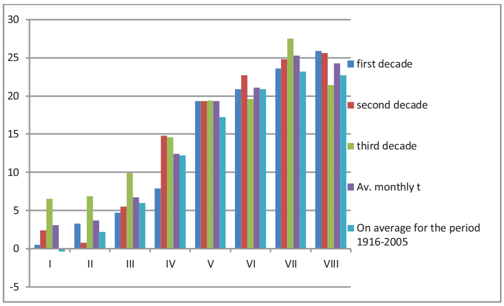

Figure 1. Average monthly temperatures during the study period

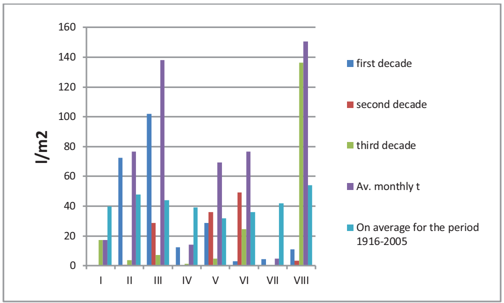

Figure 2. Amount of monthly precipitation during the study period

RESULTS AND DISCUSSIONS

Maize productivity in Bulgaria, depending on the mineral nutrition, was the subject of study by a number of authors (Petrov & Georgiev, 2009; Basitov & Gospodinov, 2007; Toncheva et al., 2006; Dimitrova & Borisova, 2001 etc.). On average for the study period, grain yields from the maize hybrid P0216 (Table 2) varied between the separate fertilization variants from 3080 kg/ha in the control variant to 12450 kg/ha in Variant 4 (NH_4NO_3 1/3 pre-sowing, 1/3 at 5th leaf and 1/3 at tasseling stage). The three-fold application of nitrogen and the plant growth stage had the most significant effect on maize productivity. Relatively higher yields were reported in the second experimental year compared to the first. The highest maize productivity was reported in Variant 4 - 11640 kg/ha in 2015 and 13260 kg/ha in 2016, and, the lowest - in the control variant - 3910 kg/ha and 2250 kg/ha, respectively. The maize hybrid demonstrated a good productive capacity on average for the experimental period after fertilizing with urea, applied twice at the following rates: ½ of the fertilizer rate - pre-sowing and ½ at 10th leaf (Variant 7) - 11340 kg/ha. The increase in grain yield compared to the control ranged from 51.8 kg/ha to 93.7 kg/ha. Applying nitrogen fertilization (NH_4NO_3 - the whole rate pre-sowing) in the maize cultivation technology led to an increase in grain yield of 6793.5 kg/ha compared to the untreated control. The lowest values of the additional yield over the control were reported at pre-sowing urea application (Variant 6) - 5180 kg/ha.

The fertilization scheme had a lesser effect on the produced leaf-stem biomass (Table 3). On average for the experimental period, the results of that characteristic ranged from 3785 kg/ha in the untreated control variant to 12450 kg/ha in Variant 4. The maize hybrid accumulated significant amounts of net biomass at three-fold application of ammonium nitrate - 1/3 pre-sowing, 1/3 at 5th leaf and 1/3 at tasseling stage. In the other fertilization variants, the values of that characteristic were approximately the same. The additional straw yield over the control variant ranged from 5640 kg/ha to 8780 kg/ha. The application of the whole nitrogen rate as urea (Variant 6), compared to the untreated variant, resulted in the formation of the least leaf-stem biomass - 5640 kg/ha on average for the study period.

Table 2. Grain yield (kg/ha)

Variants	Study period		On average for the study period	Additional yield over the control
	2015	2016		
1	3910	2250	3080	-
2	9740	10007	9873,5	6793,5
3	10003	10000	10001,5	6921,5
4	**11640**	**13260**	**12450**	**9370**
5	10080	10250	10129	7049
6	8210	8310	8260	5180
7	10020	12660	11340	8260
8	10040	10510	10275	7195
9	10080	10380	10230	7150

Table 3. Leaf-stem biomass yield (kg/ha)

Variants	Study period		On average for the study period	Additional yield over the control
	2015	2016		
1	4250	3320	3785	-
2	11140	11260	11200	7415
3	11230	11190	11210	7425
4	**12050**	**13080**	**12565**	**8780**
5	11200	12004	11602	7817
6	9560	9290	9425	5640
7	11200	12140	11670	7885
8	11210	11630	11420	7635
9	11930	12020	11975	8190

Determining the optimal crop nutrition regime requires the estimation of the nutrient export with the harvest and their balance in the different soil types in the country, thus avoiding the negative effects of improper fertilization (Basitov, 1998). Nitrogen export during vegetation is a result that varies greatly depending on the concentration of nitrogen in plant biomass and the dry matter formed. On the other hand, the nitrogen content in the vegetative biomass and the accumulation of dry

matter are influenced by the genetic type, development stage, climatic conditions over the years and nitrogen fertilization (Yordanova, 2012). Each kilogram of additionally imported nitrogen per decare leads to an increase of nitrogen export from 0.94 kg/da on average in Prelom cultivar to 1.62 kg/da in Sadovo 1 cultivar (Tomov et al., 2005).
During the experimental period, differences in the export of macroelements by the maize plants were established in the fertilization variants applied. Including nitrogen nutrition in the maize cultivation technology resulted in a significant increase in nutrient export and, therefore, to increased grain yields. In the first experimental year, nitrogen export ranged from 56 kg N/ha in the control variant to 232 kg N/ha in Variant 4; the phosphorus export ranged from 27 to 94 kg P/ha and the potassium export - from 89 to 291 kg K/ha, respectively. The lowest values of that characteristic were established in the control and the highest - after three-fold application of ammonium nitrate - 1/3 pre-sowing, 1/3 at 5th leaf and 1/3 - at tasseling stage. Similar results were also reported during the second year of study. On average for the study period, no significant differences were found between the tested fertilization variants with respect to the consumption of macroelements.

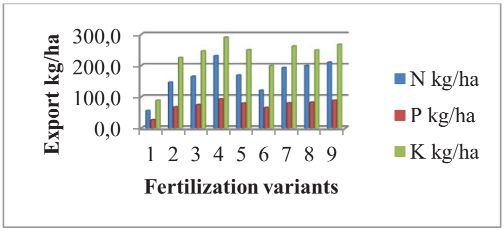

Figure 3. Export of NPK kg/ha (2015)

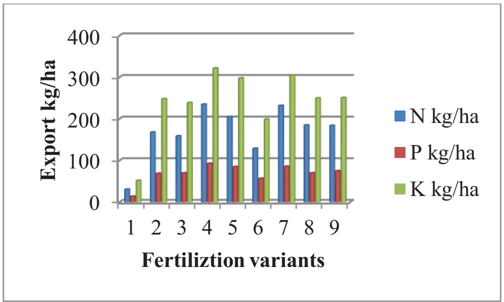

Figure 4. Export of NPK kg/ha (2016)

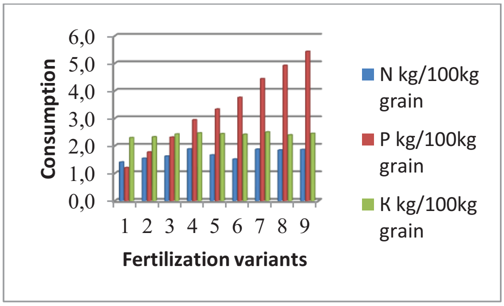

Figure 5. NPK efficiency - kg/100 kg grain on average for the study period

CONCLUSIONS

The results obtained showed that the three-fold nitrogen application as ammonium nitrate: 1/3 pre-sowing, 1/3 at 5th leaf and 1/3 at tasseling stage, has the most significant effect on the productivity of maize, hybrid PO216, the increase in grain yield compared to the control variant being 9370 kg/ha.
The studied crop demonstrated well its productive capacity after fertilizing with urea, split application at the following rates: ½ of the rate applied pre-sowing and ½ - at 10th leaf (Variant 7) - 11340 kg/ha.
The increase in grain yield compared to the control ranged from 5180 kg/ha to 9370 kg/ha.
Including nitrogen fertilization (NH_4NO_3 - the whole rate pre-sowing) in the maize cultivation technology resulted in an increase in productivity by 6793.5 kg/ha compared to the control variant.
The export of nitrogen, phosphorus and potassium with the crop is significantly affected by the applied nitrogen nutrition.
The highest values of the characteristic were reported in Variant 4.
On average for the period, the export of nitrogen increased compared to the control variant from 81 kg/ha to 190 kg/ha, export of phosphorus from 41 to 73 kg/ha and potassium - from 129 to 236 kg/ha, respectively.
In contrast to export, the nitrogen fertilization scheme did not have a significant effect on the efficiency use of macroelements.

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