MINERAL FERTILIZATION EFFECT ON SOIL POTASSIUM AND CORN QUALITY AND YIELD

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Abstract: *Like nitrogen and phosphorus, potassium is major nutrition`s element contributing to large, steady an high quality crops. Potassium is a multifunctional and high mobility element with direct and indirect influence on almost all biochemical and physiological processes. Potassium is associated with movement of water, nutrients, and carbohydrates in plant tissue. If K is deficient or not supplied in adequate amounts, growth is stunted and yields are reduced. Various research efforts have shown that potassium stimulates early growth, increases protein production, improves the efficiency of water use and improves resistance to diseases and insects. The corn crop was grown on cambic chernozem, poorly glazed, the largest soil type on the USAMVB`s Research Station from Timisoara. The stationary experiment performed in the field was based on the rotation of the cultures wheat - corn – sun flower. Each plot was subdivised in four repetitions in liniar disposition, one after the other. The experiment was done on corn hybrid: Lovrin 400. Treatments applied were: 0, 50, 100, 150 and 200 kg·ha^{-1} nitrogen and 0, 50, 100 and 150 kg·ha^{-1} phosphorus and potassium. Soil potassium content was determined trough Egner – Rhiem – Domingo method (AL – K). Protein content of corn grains was determined with Kjeldahl method and starch content with Ewers – Grossfeld method. The experimental dates were estimated by multivariate analysis of variance (ANOVA). A rise in the level of mobile potassium in soil proportional to the increased dose of mineral fertilizers with phosphorus and potassium was recorded all through the research years. The levels of exchangeable potassium goes down while that of the nitrogen fertilizer dose goes up, the highest soil potassium content values occur when the nitrogen fertilizer does not apply. Unlike nitrogen fertilizers, fertilizers with phosphorus and potassium influence the amount of raw protein in the grain of corn to a smaller extend and when applied in larger quantities they entail their decrease. High doses of potassium and phosphorus on plots pre – fertilized with small and fairly large amounts of nitrogen (0 and 50 kg·ha^{-1}) lead to an increased level of starch in the grains of corn. For good soil potassium supply, high and quality corn yields we recommend annual application rates of 100 to 150 kg·ha–1 K alongside nitrogen and phosphorus.*

Key words*: fertilization, potassium, maize, raw protein, starch*

INTRODUCTION

Like nitrogen and phosphorus, potassium is major nutrition`s element contributing to large, steady and high crops. Crops need potassium and nitrogen in fairly comparable amounts however every day agriculture stands proof to a lack of balance in the intake of these nutrients to the detriment of the potassium (RADULOV, 2004).

Potassium is a multifunctional and high mobility element with direct and indirect influence on almost all biochemical and biophysiological processes. It catalyzes numerous enzyme reactions. It helps the formation, transport and deposit of the products of photosynthesis in fruits, grains, tubercles and contributes to their transformation in fibers, proteins, fats and vitamins.

Potassium increases root growth and improves drought resistance; maintains turgor; reduces water loss and wilting reduces respiration, preventing energy losses; enhances translocation of sugars and starch; produces grain rich in starch, increases protein content of plants, builds cellulose and reduces lodging, helps retard crop diseases. Potassium plays significant roles in enhancing crop quality. High levels of available K improve the physical quality, disease resistance, and shelf life of fruits and vegetables used for human consumption and the feeding value of grain and forage crops. Quality can also be affected in the field before harvesting such as when K reduces lodging of grains or enhances winter hardiness of many crops (REHM et.all., 1983).

Photosynthesis, control of plant N, formation of new proteins and tissues, and strength of cell walls and stalk tissues are all influenced directly by K nutrition. With a K deficiency, seasonal duration of leaf photosynthesis is shortened, transport of nutrients and sugars within the stem is hamstrung, plant integrity is compromised, starch formation is hindered, and use of N is limited. Stalk strength of annuals is favored by good K nutrition. Lodging of corn or small grains is often related to low K levels through reduced stalk strength and higher incidence of stalk disease (WELCH et. all, 1985). Because lodging increases the time involved in harvesting and reduces the yield, thereby adding to the next year's volunteer crop problem, greater stalk strength often increases the harvested yield at a lower cost (MOZAFFARI et. all, 2006).

The dynamics of the potassium in soil and, related to this, the potassium reserve supply accessible to plant in the soil depends on the inflow of the nutrients in the system formed by the clay mineral, the composition of the soil and the plant roots. To supply plants with potassium is crucial for the K ion to move from the surface of the clay minerals into the soil solution and thus become directly accessible to plants. The chemical weathering of minerals results in potassium ions which exist in various forms with different degrees of accessibility. They are: readily available potassium, slowly available potassium and unavailable potassium (RADULOV, 2004).

Unavailable potassium is represented by the potassium in the lattice of the primary and secondary minerals and represents the largest amount of potassium in soils. Slowly available potassium is the potassium form retained in the spaces between two layers of the clay minerals. Retention takes place by alternative moistening and drying of the soil when the clay layers distance from one another or move close and the potassium ions fill in this spaces with the water molecules satisfying the free negative valences resulting from the isomorphic substitution. Readily available potassium is represented by the potassium dissolved in the soil solution and potassium retained in ionic form by the negative charges of the soil colloids (clay and organic matter)

MATERIAL AND METHODS

A series of corn samples, hybrid Lovrin 400, fertilized with different fertilizers was studied, for ten years period, in pedoclimatical conditions from USAMVB Timisoara. The researches have been made on the cambic chernozem with middle texture, with following properties: total density ranged between 2.43 g|cmc and 2.58 g|cmc, total porosity has medium values, excepting the soil surface were total porosity has highest value: 47%; soil reaction is weakly acid, pH=6.18; humus content of soil is ranged between 3.28 si 2.10%, nitrogen index is ranged between 2.04 and 3.08 %; phosphorus soil content is low – 13.0 ppm, and potassium content of soil is medium– 184 ppm; the value of cationic exchange capacity of soil is 30.35 me/100g.

The samples were obtained from field plots receiving mineral fertilization: different doses of phosphorus and potassium P_0K_0 – control (0 kg P_2O_5 and $K_2O \cdot ha^{-1}$); $P_{50}K_{50}$ (50 kg P_2O_5 and $K_2O \cdot ha^{-1}$); $P_{100}K_{100}$ (100 kg P_2O_5 and $K_2O \cdot ha^{-1}$); $P_{150}K_{150}$ (150 kg P_2O_5 and $K_2O \cdot ha^{-1}$) on pre-fertilized plots with nitrogen N_0 – control (0 kg $N \cdot ha^{-1}$); N_{50} (50 kg $N \cdot ha^{-1}$); N_{100} (100 kg $N \cdot ha^{-1}$); N_{150} (150 kg $N \cdot ha^{-1}$); N_{200} (200 kg $N \cdot ha^{-1}$).

Soil samples were colected on 0-20 cm depth. Soil was air-dried and passed through a 2 mm sieve. The amount of available potassium was determined trough Egner – Rhiem –

Domingo method (AL – K). After extraction, potassium content of soil samples was determined by flame atomic absorption spectrometry (F-AAS, VARIAN SpectrAA-300)

The corn samples were finely ground and dried for 24 hours at 60°C . Raw protein content from corn grain was determined by Kjeldahl method, as Kjeldahl nitrogen multiplied with 6.25. Starch content was determinedwith Ewers – Grossfeld method.

All values are expressed on the basis of the moisture free samples. The original samples contained 13 to 14% moisture.

Data were evaluated by one - way ANOVA. T test was used for comparison of means and statistical significance of hypotheses was assessed at *P < 0. 05*.

RESULTS AND DISCUSSIONS

When applying potassium fertilizers, in soil occurs positive changes of his content according to the doses administered. Available potassium content determined after mineral fertilization is presented in Table 1.

Table 1

Mineral fertilization influence on soil potassium content (mg kg^{-1}), average values

Fertilization variant	kg ha^{-1} N				
	0	50	100	150	200
	mg kg^{-1} K				
0 kg ha^{-1} P_2O_5 and K_2O	188	186	184	171	168
50 kg ha^{-1} P_2O_5 and K_2O	189	186	185	179	172
100 kg ha^{-1} P_2O_5 and K_2O	197	196	188	187	181
150 kg ha^{-1} P_2O_5 and K_2O	211*	212*	201*	195	186

*indicate the effect of mineral fertilizers significant at *P = 0,05*

An increase of available potassium content is observed with increasing dose of phosphorus and potassium fertilizers, the highest values being determined at fertilization with $P_{150}K_{150}$. Exchangeable potassium content decreases with increasing nitrogen dose, the highest values being obtained when no nitrogen fertilizer was applied and the lower at application of 200 kg N · ha-1. The highest determined value was 212 ppm K, in variant were 200 kg · ha-1 P_2O_5 and K_2O and 50 kg N · ha-1 was applied.

After application of nitrogen fertilizer, ammonia form of nitrogen can be adsorbed and retained by soil colloidal matter. The soil that experiences were located, soil with a high cationic exchange capacity, has high ability to retain N-NH4+. Reversal of cationic retention processes is important in plant nutrition and fertilizer application. If the plants absorb from soil solution a certain species of cations, soil solution- solid phase equilibrium is restored by moving to soil solution a part of cation from the same species, existing in a state of adsorption. Mobility and the exchange of adsorbed cations in soil solution ensures continuous plant nutrition. Potassium ion has an antagonistic action to ammonium ion. If there are fixed potassium ions and in soil solution ammonium ions exists, ammonium ions prevents the release of potassium (desorption) and vice versa, if ammonia is penetrated between the clay layers, potassium penetration between the layers and its fixation are prevented. This lead to a decrease in available potassium content, with increasing dose of nitrogen. Plants needs in potassium become greater, as the higher quantities of NH4+ ions are in soil solution (GOIAN, 2000). A soil well supplied with potassium, if fertilized with too much nitrogen is deficient in potassium, so nitrogen fertilization should be accompanied by the potassium application. Similar results were obtained AILINCAI et al. , 2008, on a cambic chernozem of Moldova.

As a result of its high biological potential of yielding, to achieve harvest, corn will consume large amounts of nutrients. Nitrogen consumption of corn is higher than that of potassium, being expected that nitrogen fertilizers to have a higher efficiency than potassium fertilizers.

When soil release too small quantities of potassium in soil solution, crop quantity and quality decreases, and yield is exposed to biotic and abiotic stress, regardless of other nutrients supply. If plants supply with potassium is inadequate, nitrogen metabolism is prevented, crop quality and plant resistance to adverse climatic conditions, such as drought, is reduced.

On average, in years of experience, maize production ranged from 4265 kg· ha-1, in control variant, to 6156 kg · ha-1, in N200K100P100 variant. Application of 100, respectively 150 kg · ha-1 K_2O and P_2O_5 yielded the highest yields of maize whatever was the pre-fertilized plot with nitrogen, except plot pre-fertilized with 50 kg N·ha-1 where the maximum yield was determined from the application of 50 kg· ha-1 potassium and phosphorus.

Table 2

Mineral fertilization influence on corn yield (kg ha^{-1}), average values

Fertilization variant	kg ha^{-1} N				
	0	50	100	150	200
	Corn grain yield kg ha^{-1}				
0 kg ha^{-1} P_2O_5 and K_2O	4265	5157	5195	5273	5520
50 kg ha^{-1} P_2O_5 and K_2O	4326	5442	5532	5926*	5701*
100 kg ha^{-1} P_2O_5 and K_2O	4548	5164	5796*	5978*	6156*
150 kg ha^{-1} P_2O_5 and K_2O	4298	5171	5743*	5822*	5743*

*indicate the effect of mineral fertilizers significant at *P = 0,05*

At the same level of nitrogen fertilization, applying increasing doses of phosphorus and potassium do not cause significant increases in maize yield. The highest yield increases were observed after application of medium dose of phosphorus and potassium, 50 or 100 kg · ha-1. Compared with these doses, application of 150 kg · ha-1 phosphorus and potassium yielded lower values of maize yield, the differences from untreated variants with phosphorus and potassium ranging between 33 kg · ha-1, on plot untreated with nitrogen, and 223 kg · ha-1 in the variant fertilized with 200 kg · ha-1 N. Field experiments conducted at the Lon Mann Cotton Research Station (LMCRS) in Marianna, Ark., by MOZAFFARI et.al. showed that potassium fertilization did not increase corn grain yield at two sites that had soil K levels regarded as 'Medium' and 'Optimum' by current soil-test K interpretations. The grain yields at both sites were average to below-average suggesting that another factor was more limiting to corn yield than K or that available soil-K was enough to supply the needs for these corn yields. BRUNS and EBELHAR (2006) did not find K fertilization to improve grain yield, although they reported increased K tissue concentrations as a result of K fertilization. Part of the maize yield enhancement from K fertilization is because of a reduction in stalk lodging with the K fertilization, particularly when higher N rates are used (WELCH and FLANNERY 1985, PETTIGREW, 2008).

Among the main plant nutrients, potassium is known regarding its influence on production in general and especially crop quality. The influence of potassium on the crop quality is stronger than any other nutrient. While corn does not belong to the most demanding crops regarding fertilization with potassium, it is of real importance for increasing plant resistance to stresses caused by some excessive physical factors and their recovery after passing through periods of stress occurred both in winter (deep freeze ground bare of snow, cold dry winds, ice cover, incorporating water plant in the snow) and in the warm period (floods, drought, heat, storms). Because increase significantly plant resistance to disease attack of stem and foliage glean, potassium fertilizers reduce the damage they cause. It is well known effect of potassium fertilization to promote normal development and elasticity of stem tissue and to increase breaking strength of the plant. Reducing the incidence of leaf and stem diseases, potassium fertilizers had a notable contribution to the metabolite accumulation, especially in grain protein substances.

Potassium has a multiple and complex role in nitrogen metabolism. He promotes significantly plant protein and nitrogen content. Corn produces high yields but low grain protein, which decreases the nutritional value of feed and food. In the literature there are views that increasing potassium and phosphorus nutrition, due to high doses of nitrogen, can have positive influence on grain protein content (LIXANDRU şi colab., 1990).

Raw protein accumulated in maize kernels is correlated with the amount of fertilizer applied and with obtained yield.

Analyzing the average value obtained in the years of experience (table.3.), the highest percentage of raw protein was determined on plot pre- fertilized with 200 kg · ha-1 nitrogen, when 50 kg · ha-1 phosphorus and potassium were applied. (13,86%).

Table 3

Mineral fertilization influence on corn grains raw protein content (%), average values

Fertilization variant	kg ha^{-1} N				
	0	50	100	150	200
	Raw protein %				
0 kg ha^{-1} P_2O_5 and K_2O	9,46	10,02	11,29	12,02	12,56*
50 kg ha^{-1} P_2O_5 and K_2O	9,75	11,84	12,27*	12,74*	13,86*
100 kg ha^{-1} P_2O_5 and K_2O	9,54	10,97	11,45	12,12*	12,63*
150 kg ha^{-1} P_2O_5 and K_2O	9,65	10,95	11,43	11,87	12,23*

*indicate the effect of mineral fertilizers significant at $P = 0,05$

Potassium and phosphorus fertilization increased raw protein content of corn grain, in all the years of experimentation. However, the application of the maximum dose of potassium and phosphorus (150 kg· ha-1) lead to a decrease in raw protein content. This decrease in the percentage of raw protein content, at the application of high doses of potassium fertilizers, can be explained by the fact that while potassium is needed in large quantities for plant growth and protein biosynthesis, it stimulates more intense carbohydrate synthesis and transport than synthesis of nitrogen substances. Therefore when applying large amounts of potassium fertilizers carbohydrate synthesis and their transportation from other organs to grains is increased and protein content decreases. Potassium has an important role in protein metabolism. Plants insufficiently supplied with potassium contain high amounts of amino acids and amides. In such conditions their content of glycol, aspartic acid, arginine is greatly increased. The presence of soluble nitrogen fractions indicate high blocking of protein synthesis. In cereals, the grain harvest is represented in most of the carbohydrates. Their quantity and quality is correlated with nutritional factors. Potassium positively influences foliar surface and finally synthesis of carbohydrates. He participates in condensation of simple sugars forms (glucose, fructose), in complex carbohydrates (starch) and their migration to the reserve organs (seeds, roots). Potassium is needed for efficient movement of sugars from leaves, conversion of sugars into starch, and optimum grain fill. A severe shortage of potassium in corn can delay silk emergence, create pollination problems, and result in poorly filled grain on the tip-end of ears.

Table 4

Mineral fertilization influence on corn grains starch content (%), average values

Fertilization variant	kg ha^{-1} N				
	0	50	100	150	200
	Corn grains starch content %				
0 kg ha^{-1} P_2O_5 and K_2O	63,08	62,57	62,08	61,50	60,46
50 kg ha^{-1} P_2O_5 and K_2O	63,27	62,75	62,32	61,71	60,84
100 kg ha^{-1} P_2O_5 and K_2O	63,68	63,17	62,78	62,29	61,57
150 kg ha^{-1} P_2O_5 and K_2O	63,99	63,45	63,25	62,43	61,80

Research results on starch content of corn, presented in Table 4, shows that potassium and phosphorus fertilization in increasing doses, contributed to increase of the starch content from 60.46% starch, in $N_{200}K_0P_0$ variant, to 63,99% starch, in the variant fertilized with $N_0K_{150}P_{150}$, while nitrogen fertilization decreased the starch content.

High doses of potassium and phosphorus, on the plots fertilized with low and medium doses of nitrogen (0 and 50 kg ·ha-1) increases the starch content of corn as follows: percentage of starch increased from 62.57% starch the $N_{50}K_0P_0$ variant, to 63.99% starch in $N_0K_{150}P_{150}$ variant, which means an increase of 2.25%.

Starch content decreased with increasing doses of applied nitrogen, is explained by the metabolism of nitrogen, plants consume large amounts of energy which they obtain from the oxidation of carbohydrates.

Analyzing the mean content of corn starch (tabelul.4), there is an increase thereof, as increasing doses of potassium fertilizers. On all plots pre- fertilized with nitrogen, the highest proportions of starch was obtained from the application of 150 $kg \cdot ha^{-1}$ K_2O and P_2O_5. The application of high doses of potassium fertilizer is favored synthesis of carbohydrates and their migration occurs from other organs to the seeds, which accumulate more starch. Along with potassium, phosphorus in large quantities, increases the starch content of the grain, both through the phosphorylation and incorporation into starch.

Starch content of wheat grains was largely influenced by application of potassium and phosphorus fertilizers in inverse relationship to the protein.

CONCLUSIONS

1. Corn fertilization with foliar fertilizers containing different nitrogen, phosphorus and potassium dose reveals that the highest protein content, 9.31%, was determined in the plot treated with Fertitel, wich means a rise of 32,8% compared to the control.
2. Lowest protein content, 8%, was obtained in the plot fertilized with Phomak, fetilizer which containes only phosphorus and potassium.
3. Higest total amino acid content, 8,85%, was determined in plot fertilized with Fertitel, followed by Bionat with 8,09%.
4. The content of certain amino acids in the total proteins became greater as the percentage of total protein in corn increase, its the case of: leucine, histidine, methionine, lisine, proline, serin and tyrosine.
5. Fertilization with foliar fertilizers containing different N,P,K quantities not only increased the protein content of corn, but it also affected the relative proportion of the various amino acids in the raw protein of corn.

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