The Influence of Mineral Fertilization on the Distribution of Nutrients in the Soil

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Abstract: An important factor in sustaining agricultural yield, mineral fertilization is at the same time one of the factors that causes changes in the chemical characteristics of the soils. Nutriment mobility in the soil is different: it is higher in the nitrogen case and lower in that of phosphorus’. We assessed the changes in the macroelement content of the upper soil horizon when applying mineral fertilizers on winter wheat crops. We tested different doses and combinations of complex mineral fertilizers, NPK (S) fertilizers with zinc [15/15/15(+3+Zn)] and ammonium nitrate (35:0:0). The determinations were made for two depths, 0 - 10 cm and 10 - 20 cm, in order to observe the mobility of the nutrients for each soil profile. Nitrogen content vacillates between 0.15 - 0.25% ± 0.008 for 0 - 10 cm depth and 0.16 - 0.23% ± 0.006. Phosphorus is found between 25.8 - 54.64 ppm ± 3.109 for a depth of 0 - 10 cm and 30.8 - 28.14 ppm ± 1.406 for 10 - 20 cm. Potassium content varies between 193.8 - 384.64 ppm ± 25.627 for the depth of 0 - 10 cm and 205.45 - 327.14 ppm ± 15.135 for the depth of 10 - 20 cm. While analysing the results on the macroelement content and mobility in the soil horizon under research in terms of multiple correlations, we got very strong positive correlation for nitrogen and potassium and weak correlation for phosphorus.

Key words: mineral fertilizers, mineral distribution, macronutrient mobility, soil, correlation, wheat

INTRODUCTION

Mineral fertilizers are an important factor for obtaining high agricultural yield and for maintaining the soil fertility. As a quasi-homogenous medium, soil absorbs a series of elements and integrates them in its own matrix.

Many studies have been focused on the necessary quantity of nutrients for field crops, the regime and interaction of macro and microelements in the soil and fertilization efficiency in relation to the type of fertilizer, soil and crop system, (Salardini et al. 1992, Trehan and Claassen 2000, Schneider et al. 2003, Marilena Marghităș and Rusu 2003, Su Chen et al. 2001, Römheld & Kirkby 2010, Hera 2011).

Researchers have made studies on nitrogen fertilization in various agricultural systems and they have emphasized the prompt response of the soil to average and long term nitrogen fertilization in what concerns the integration of nitrogen ions in the soil, changes in the agrochemical characteristics of soil and risks identification for the environment, (Hera and Eliade 1980, Gurdensen and Rasmussen 1995, Sala et al. 2010, Zhang et al. 2010).

Long term experiments involving fertilizers have shown the regime, dynamics and distribution of nutritive elements (phosphorus and potassium) in the soil, (Blake et al. 1999, 2000, Campbell et al. 2011). Xu Thang et al. (2009) made public the results of their research regarding the determination of the critical values of phosphorus in the soil for maize and wheat crops, in the conditions of long-term experiments. Wan-Tai Yu et al. presented in 2009 the results of their research on the effect of the nutriment circuit on the wheat crop and the balance of potassium in the soil.
Comparative analysis in the upper soil horizon or on soil profile in order to assess the mobility of nutrients, their distribution or the nutrient loss potential has been an important aspect in many researchers work, such as Chen et al. (2001), Wang et al. (2009), Ranjan Bhattacharyya et al. (2010). These aspects are to be taken into consideration because of the particularities of soil as a nutrition medium and because of the particularities of the fertilizers. These ones have a great impact on the nutrients distribution in the soil and their bioavailability for plants.

In the context of everything mentioned above, the influence of mineral fertilization on the distribution of nutrients in the soil, we analysed the macroelements mobility and distribution -in the soil in the conditions of mineral fertilization of the winter wheat crop on cambic chernozem found in the West Plain region.

MATERIALS AND METHODS

The natural frame for the experiment is given by the soil and climate conditions which are specific for the Banat Plain. The research was conducted at Timisoara Didactic Station, on cambic chernozem, with slight gleization, with neutral reaction (pH = 6.95-7.1), good supply of humus (H = 3.2), high base saturation degree (V > 85-87%), poor supply of mobile phosphorus (P_{AL} = 17-20 ppm) and average supply of potassium (K = 135-150 ppm).

The climate conditions specific for the area are characterized by average multiannual precipitations of 603.3 mm and average temperatures of 10.9°C. During the experiment, 2010 – 2011, the rainfall regime fell within the limits of the multiannual average, but with some uneven periods. In the period August 2011 -November 2011, we recorded a strong rainfall deficit.

The mineral used fertilizers were complex NPK (S) zinc fertilizers [15/15/15(+3+Zn)] and ammonium nitrate. The complex fertilizers are characterized by active element content of 15% total N (6% nitric N, 9% ammonium N ); 15% P_{2}O_{5} phosphates soluble in ammonium citrate and water (12% P_{2}O_{5} water-soluble phosphates); 15% K_{2}O, water-soluble potassium oxide; 3% S, (total sulphur, of which 2.7% is water soluble); 0.01% Zn. Ammonium nitrate contained 33.5% total N, of which 16.75% \(\text{NO}_{2}^{-}\) and 16.75% \(\text{NH}_{4}^{+}\).

The biological component was represented by wheat maize and sunflower crops; the determinations were made on the field cultivated with winter wheat, Alex variety. Stationary experiments were organized in randomized blocks, the area of the experimental variant covering 30 sqm, 11 variants in 4 repetitions.

Fertilizers were manually applied in two stages, autumn and spring. The samples were harvested in the first decade of March. We sampled two depths, 0 – 10 cm and 10 - 20 cm, in order to illustrate the distribution of nutrients in the upper horizon of soil for every experimental variant.

Total nitrogen was determined using Kjeldahl method, P-AL and K- AL (in acetate ammonium lactate extract) with Egner-Rhiem-Domingo method.

To interpret the data obtained were used variance method, statistical and mathematical comparison, linear regression.

RESULTS AND DISCUSSIONS

Soil, as a medium of growth for plants, receives a series of inputs which it integrates in its matrix at a different speed and intensity.
Complex fertilizers of the type NPK used in four doses on winter wheat crop, completed by simple nitrogen of the type ammonium nitrogen, had different types of interaction regarding the distribution of nutritive ions in the soil. In order to get an accurate picture of the macroelements distribution in the upper horizon, we determined the nutritive element content at two depths, 0 – 10 cm and 10 – 20 cm.

The quantities of nitrogen in the soil ranged from 0.15 – 0.25±0.08 % in the 0-10 cm layer and 0.16 – 0.23±0.06 % in the 10 – 20 cm; it represents the element with the best distribution in the studied area.

Total nitrogen content in the soil, 0 – 10 cm depth, is changed direct proportionally with the quantity of nitrogen in the fertilizers range between 0.00 – 0.02 units, which reflects the relative high mobility of nitrogen in the soil and the shifting of nitrogen ions from the area organized in the soil profile, Fig. 1.

![Fig.1. Distribution of nitrogen in the chernozem soil in relation to mineral winter wheat fertilization.](image)

The correlation between fertilizer doses and the nitrogen content in the 0 – 10 cm layer of soil under analysis, expressed by linear regression, is positive, the regression coefficient $R^2 = 0.9001$ which expresses strong correlation between the two variables, Fig. 2 a, b. The same type of analysis for the soil layer 10-20 cm shows a positive correlation but low intensity, the value of the correlation index is $R^2 = 0.6786$.

Phosphorus was introduced in the experiment through mineral fertilization applied in 4 doses: $P_0$, $P_{50}$, $P_{100}$ and $P_{150}$ kg active substance/ha. Depending on the doses of phosphorus, the content of mobile phosphorus in the soil decreased within the limits of 20.52 – 54.64 ppm in the 0 – 10 cm layer and 17.28 – 28.14 ppm in the 10 – 20 cm layer, fig. 3.

In the case of $P_{K0}$, the variation in the phosphorus content is slight: 0.72 – 5.00 units, the small differences being generated by the consumption of plants due to nitrogen fertilization, as the experiment is stationary. In the case where phosphorus was administered through complex fertilizers ($P_{50}$, $P_{100}$, $P_{150}$), the mobile phosphorus content in the upper horizon changes proportionally with the applied dose, within the limits of 26.24 – 54.64 ppm.

In the layer of 10 – 20 cm, in the case of the same fertilizer doses, mobile phosphorus content varies between 17.28 – 27.93 ppm. This means that there are differences from 8.96 to 26.71 units between the two analysed layers in what the phosphorus content is concerned, which reflects limited mobility of the phosphorus in the soil.
Fig. 2. Correlation between total nitrogen in the chernozem soil and fertilizer doses, (a – depth 0-10 cm, b – depth 10 – 20 cm).

Fig. 3. The distribution of mobile phosphorus and potassium in the chernozem soil under the influence of mineral fertilization of winter wheat, 2010 – 2011.

The correlation between the phosphorus provided by the fertilizer and the phosphorus content in the 0 – 10 cm soil layer that we analysed, expressed by the regression line, is positive. The regression coefficient, \( R^2 = 0.8319 \) expresses a strong correlation between the two variables, fig. 4, a, b. The same type of analysis for the layer of 10 – 20 cm shows weak correlation between the dose of fertilizer and the phosphorus content in the soil, as the value of the correlation coefficient is \( R^2 = 0.0316 \).
By applying phosphorus at the ground surface, the upper horizon has low benefit from that particular nutrient, and homogenization of the phosphorus content in the 0 – 20 cm layer (soil layer which is explored by the large volume of the roots of field plants) is achieved only through land works.

Fig. 4. Correlation between the content of mobile phosphorus in the chernozem soil and fertilizer doses, (a – depth 0-10 cm, b – depth 10 – 0 cm).

Potassium was present in the experiment in four variants, K₀, K₅₀, K₁₀₀ and K₁₅₀, being supplied via complex fertilizers. The potassium content in the soil fell within the limits of 152.86 – 384.64 ppm in the layer 0 – 10 cm and 173.76 – 327.14 ppm in the layer 10 – 20 cm, fig. 3.

In the case of PK₀, and having nitrogen variation between 0 and 200 kg/ha, the potassium content in the soil ranges from 152.86 to 199.42 ppm K in the 0 – 10 cm layer and from 173.76 ppm to 205.45 ppm K in the 10 – 20 cm layer, the average values being relatively close. Also, we noted a decrease in the potassium content in the soil under the given conditions, at the same time with an increase in the nitrogen dose, due to increased consumption by plants.

When potassium was applied in doses of 50, 100 and 150 kg/ha by complex fertilizers, the potassium content in the soil is increased, proportionally to the fertilizer doses. Thus, it ranges from 287.44 to 384.64 ppm K in the 0 – 10 cm layer and 241.72 – 327.14 ppm K in the 10 – 20 cm layer. Following the changes in the plant nutrition circumstances due to fertilization, nutrient consumption is also changed. When the doses of nitrogen are increased, wheat plants consume increased doses of potassium, the result being that in the case of PK₀ – 1₅₀ the potassium content of soil is reduced as the doses of nitrogen become larger, fig. 3.

The differences in the potassium content of the two layers of the analysed soil, in the same fertilization variants, are between 4.00 and 115.66 units.

The correlation between the potassium supplied by fertilizers and the potassium in the 0 – 10 cm soil layer, expressed by the regression line, is positive; the regression coefficient, \( R^2 = 0.839 \), expresses a strong correlation, fig. 5. a, b. The same type of analysis for the 10 – 20 cm layer shows a positive correlation between the same variables, too, but it is
not as strong as the one in the 0 - 10 cm layer, as the value of the correlation coefficient is $R^2 = 0.754$.

![Graph](image)

**Fig. 5.** Correlation between the content of mobile potassium in the chernozem soil and the fertilizer doses, (a – depth 0-10 cm, b – depth 10 – 0 cm).

**CONCLUSIONS**

Application of complex fertilizers of NPK type and ammonium nitrate on winter wheat crop on cambic chernozem determines a differentiated distribution and mobility of nutriments in the upper horizon of the soil.

Nitrogen is the most dynamic element, with relatively even distribution in the upper horizon of the soil. The correlation coefficient between fertilizer doses and the nitrogen content in the soil indicates a strong/moderate positive correlation, $R^2_{0-10 \text{ cm}} = 0.9001$, $R^2_{10-20 \text{ cm}} = 0.6786$.

Phosphorus has low soil mobility, as the distribution of the active element in the area where the fertilizer was applied is limited: thus, the differences between the phosphorus content in the two layers of analysed soil were of 8.96 to 26.71 units. The values of the correlation coefficient between the fertilizer doses and the phosphorus content in the layers of soil under study indicate a strong positive correlation for the 0 – 10 cm layer, $R^2_{0-10 \text{ cm}} = 0.8319$ and a weak positive correlation for the 10 – 20 cm layer, $R^2_{10-20 \text{ cm}} = 0.0316$.

In what potassium is concerned, there is a good distribution in the upper horizon of soil, the differences between the potassium content in the two layers of soil under analysis being between 4.00 and 115.66 units. The correlation coefficient between the fertilizer doses and the content of potassium in the soil indicates a strong/moderate positive correlation $R^2_{0-10 \text{ cm}} = 0.839$, $R^2_{10-20 \text{ cm}} = 0.754$. 

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