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# ESTIMATION OF SOIL NITROGEN AVAILABILITY

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**Abstract**: Our research has been made on brown forest soil that is used in long-term experiments. The soil we used had a certain crop rotation (wheat-corn) and had been fertilized according to a certain system for 30 years. In the experiment, quantities of nitrogen fertilizers were gradually increased, after which samples were taken from 0 to 30 cm depths in order to establish plant and soil parameters for assessing the applied methods. Two experiments were made: one in the field and one in a controlled environment. On grounds of the established correlation interdependence between the methods applied (the total and easily hydrolyzed nitrogen) and the plant and soil parameters, in both field and pots, one can conclude that the methods of total and easily hydrolyzed nitrogen, from the standpoint of nitrogen availability in soil, are reliable. In the method of total nitrogen assessment, one should rely on the parameters regarding plants and soil in the field. In the method of easily hydrolyzed nitrogen, the parameters regarding plants and soil, in both the field and pots, are the same.

**Key words:** methods, nitrogen availability, total nitrogen, easily hydrolyzed nitrogen, plant and soil parameters, organic carbon.

## Introduction

Presently, there is no generally adopted and completely reliable method for establishing the availability of nitrogen in soil (Goh and Haynes, 1986). This statement is based on the well- known fact that soil nitrogen is found primarily in its organic form and that it is available to plants only after its mineralization has been completed.

The purpose of this research was to establish whether the total and easily hydrolyzed nitrogen content in the soil in which the experiment was made could be used to indicate nitrogen availability in soil.

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In this experiment we also tried to establish which plant and soil parameters (both in the field and in the controlled environment) can be considered reliable in evaluating the applied methods, since they are directly used for the assessment.

## Material and Methods

Brown forest soil used in long-term experiments was used in this research. It had a certain crop rotation (wheat-corn) and for 30 years had been subject of a fertilization system.

The experiment was made on experiment variants with an increasing dose of nitrogen fertilizer applied.

Soil samples were taken three times a year (in March, July and October) from the following experiment variants:

– control (Ø)
– $N_1P_2K_2$ ($N_1$-60, $P_2$-120, $K_2$-120 kg/ha)
– $N_2P_2K_2$ ($N_2$-90 kg/ha)
– $N_3$ $P_2K_2$ ($N_3$-120 kg/ha)
– $N_4P_2K_2$ ($N_4$ 150 kg/ha)

The stated quantities of phosphorus and potassium in the year of the research regard autumn, at the time of the sowing of wheat, when 1/3 of the planned nitrogen dose ($NH_4H_2PO_4$ and KCl) was introduced. The remaining quantities of nitrogen fertilizer were applied in spring for spring dressing (urea).

#### a) Methods applied for establishing chemical properties of soil

In the long-term experiment a general agrochemical analysis was made of soil samples taken in spring (March) by applying the following methods:

– Soil reaction (pH - $H_20$ and 1 M KCl);
– Organic carbon and humus (Tjurin, modification of Simakov),
– Total nitrogen (semi-micro Kjeldeh, Bremner, 1965),
– Available phosphorus (Al-method, Egner-Reihem, 1960);
– Available Ca and Mg (extraction with 1 N ammonia acetate method and AAS);
– Adsorptive soil complex (Knappen method);
– Content of available microelements (Fe, Mn, Yn, Cu) extraction with DTPA and AAS;
– Content of available boron (method with curcurmine);
– Mobile Al (Sokolov method);
– Available nitrogen (distillation method, Bremner, 1965).
– Easily hydrolyzed nitrogen (method of Tjurin and Kononova, 1934).

**b) Experiment in pots**

Plastic pots, each containing 2 kg of the 0-30 cm layer of soil, were used in the experiment under controlled conditions. The soil was taken in spring (March) from labeled experiment variants in the field. Prior to sowing, the soil was mixed with fertilizers that had previously been dissolved in water, i.e. with: $NH_4NO_3$, $KH_2PO_4$ and KCL. The ammonium nitrate used was labeled with a stable isotope $^{15}N$ (11,8%).

The vegetation experiment was performed with two fertilizing variants, the PK and NPK. In the PK variant 50 mg of $P_2O_5$ and $K_2O$/kg of soil was used, and in the NPK variant 50 mg of N, $P_2O_5$ and $K_2O$/kg of soil was used.

Ten plants of oats per pot were used in the experiment. The plants were grown to the phase when plants blade.

Throughout the experiment in pots the humidity level ranged from 60 to 80% WHC.

**c) Methods for assessment of nitrogen availability in soil**

- Total nitrogen

The content of total nitrogen was established in samples taken in spring (March). They were taken only in this period because the total nitrogen value does not change throughout the year.

- Easily hydrolyzed nitrogen

The easily hydrolyzed nitrogen content was established in all three terms of sample taking, in March, July and October.

**d) Plant and soil parameters in pots and field**

Bearing in mind the objective of the research, a selection of parameters to be used in assessing the value of applied method was required.

The most commonly applied were plant parameters for plants grown in pots (Keeney and Bremner, 1966; Sirota, 1973; Baerug et al., 1973; Confort and Walmsley, 1971; Peterson et al., 1960; Stevanović, 1978) and occasionally parameters of plants in the field (Carpenter et al., 1952, Spencer et al. 1966).

Bearing in mind the most commonly applied parameters and Sapožnjikov's proposals (1973) the assessed parameters were classified into two groups:

***I Parameters of plants and soil in pots***

*1) Plant parameters*

a) Yield of oats in the NPK experiment variant
b) Yield of oats in the PK experiment variant

c) Relative increase in yield (PK=100)
d) relative increase in yield in the NPK variant (Ø 100)
e) relative increase in yield in the PK variant (Ø 100)
f) difference in yield (NPK-PK)
g) difference in yield (NPK- Ø)
h) difference in yield (PK – Ø)
i) content of nitrogen in cultivated oats (NPK)
j) content of nitrogen in cultivated oats (PK)

*2) Soil parameters*
a) total uptake of nitrogen (NPK)
b) uptake of soil nitrogen (NPK)
c) uptake of fertilizer nitrogen (NPK)
d) ratio of soil and fertilizer nitrogen uptake
e) soil nitrogen uptake (PK)

***II Parameters of plants and soil in field***

*1) Plant parameters*
a) yield of grain
b) yield of straw
c) total yield in wheat (grain + straw)
d) relative increase in yield (Ø =100)
e) difference in yield (variants - Ø )
f) content of nitrogen in the wheat grain
g) content of nitrogen in straw

*2) Soil parameters*
a) uptake of nitrogen - (grain)
b) uptake of nitrogen - (straw)
c) total uptake of nitrogen - (grain + straw)

**e) Statistic analyses of methods and criteria used in evaluating reliability of the applied methods**

Apart from the experiment in pots, where nitrogen isotopes were used, an experiment in the field was made too. The main purpose of these experiments was to establish the largest number of plant and soil parameters that determine the value of the methods applied regarding availability of nitrogen in soil.

A simple linear correlation analysis was used to establish plant and soil parameters, both in the pot and field, i.e. to evaluate the availability of nitrogen in soil. This statistic analysis enabled the establishment of the correlation coefficient value (Pirson s) that deals with the degree of similarity, i.e. the interdependence of the two compared values.

The percentage of established correlative dependence for r=0.50-0.99 was calculated on grounds of the correlation coefficient values, with the significance probability level 0.05-0.01 and in cases when r ≥ 0.70 in the probability level 0.01.

This calculation was made to help define which of the applied nitrogen availability methods in the examined soils can be considered reliable, and also which group of the used plant and soil parameters (in pots and field) is considered best when determining reliability of a certain method.

Those methods where the comparison between the used plant and soil parameters in ≥ 50.0% cases showed a correlative dependence with a correlation coefficient r = 0.50-0.99 and the probability significance level 0.01-0.05, and also those methods where in ≥ 50.0% cases there was a correlative dependence with a correlation coefficient r = 0.70 and probability level at 0.01 were, according to our criteria, considered reliable ones regarding soil nitrogen availability. The same criteria are applicable when evaluating the applied soil and plant parameters.

## Results and Discussion

### Chemical properties of the examined soils

Primary chemical characteristics of the examined brown forest soil are presented in tables 1, 2, 3 and 4.

Tab. 1. - Chemical properties of the examined brown forest soil

| Experiment variants | pH | | Humus (%) | Total nitrogen (%) | C/N | Available | | CEC (m.ekv./100g) |
|---|---|---|---|---|---|---|---|---|
| | $H_2O$ | n KCl | | | | $P_2O_5$ (mg/100g) | $K_2O$ (mg/100 g) | |
| Control | 5.40 | 4.60 | 1.43 | 0.098 | 8.5 | 6.4 | 16.2 | 26.7 |
| $N_1P_2K_2$ | 5.10 | 4.30 | 1.67 | 0.111 | 8.7 | 18.0 | 21.8 | 27.4 |
| $N_2P_2K_2$ | 5.00 | 4.20 | 1.81 | 0.113 | 9.3 | 14.4 | 21.8 | 25.8 |
| $N_3P_2K_2$ | 4.90 | 4.15 | 1.85 | 0.113 | 9.5 | 16.0 | 25.0 | 26.7 |
| $N_4P_2K_2$ | 5.00 | 4.05 | 1.88 | 0.116 | 9.4 | 12.5 | 21.8 | 25.8 |

According to the obtained soil pH values (nKCl), one can conclude that the examined soil belongs to the acid, or very acid soil category, and that the long-term application caused the increse of soil acitity.

According to the humus content, the examined soils belong to the poor humus soil, and according to the total nitrogen content, it is within the limits of poor content.

The C/N relation was somewhat lower than in standard arable soil (less than 10).

The content of available phosphorous varied in the field variants. The lowest was in the control variant (6.4 mg/100 g) and the highest in the variant $N_1P_2K_2$

(18 mg/100 g), hence the soil belongs to the poor soil category, i.e. to the medium supportive.

The content of available potassium was similar in all variants of the experiment, and the soil was well supportive, while the control variant was medium supportive.

According to the established absorbing capacity (CEC), the examined soil belongs to the medium clay soils.

The adsorptive complex soil composition results and the content of exchangeable aluminum in brown forest soil are presented in table 2.

Tab. 2 - Adsorptive complex soil composition and content of mobile aluminum in brown forest soil

| Experiment variants | H (m.ekv/100g) | S (m.ekv/100g) | T (m.ekv/100g) | V (%) | Mobile aluminium (mg/100g) |
|---|---|---|---|---|---|
| Control | 3.6 | 18.3 | 21.9 | 83.4 | 0.2 |
| $N_1P_2K_2$ | 5.4 | 16.7 | 22.1 | 75.7 | 0.5 |
| $N_2P_2K_2$ | 5.1 | 17.5 | 22.6 | 77.3 | 0.9 |
| $N_3P_2K_2$ | 5.6 | 17.5 | 23.0 | 75.8 | 1.0 |
| $N_4P_2K_2$ | 5.1 | 16.3 | 21.5 | 76.0 | 2.2 |

Occurrence of $H^+$ ions in the soil adsorptive soil complex confirms presence of the souring process.

Regarding the alkaline saturation degree, there is no need for calcification in this soil.

Apart from the existing souring process, the exchangeable aluminum content is below FAR the toxic limits.

The content of available alkali found in the extract with 1 M ammonium acetate is presented in table 3.

Tab. 3 – Content of available alkali in brown forest soil

| Experiment variants | Ca (mg/100g) | Mg (mg/100g) | Ca : Mg (m.ekv/100g) | K : Mg (m.ekv/100g) |
|---|---|---|---|---|
| Control | 320 | 60.0 | 3.2 | 0.08 |
| $N_1P_2K_2$ | 340 | 60.0 | 3.3 | 0.11 |
| $N_2P_2K_2$ | 310 | 55.0 | 3.4 | 0.12 |
| $N_3P_2K_2$ | 327 | 60.0 | 3.3 | 0.11 |
| $N_4P_2K_2$ | 345 | 57.5 | 3.7 | 0.11 |

The available alkaline kations confirm sufficient presence of potassium, significant presence of magnesium, and the favorable Ca:Mg and K:Mg ratio.

The results for available presence of microelements in brown forest soil are presented in table 4.

The examined brown forest soil has a favorable ferric and manganese availability content (medium and high).

Tab. 4. – The content of available microelements in brown forest soil

| Experiment variants | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) | B (ppm) |
|---|---|---|---|---|---|
| Control | 20.9 | 107 | 1.1 | 8.5 | 0.32 |
| $N_1P_2K_2$ | 21.1 | 92 | 0.6 | 7.9 | 0.34 |
| $N_2P_2K_2$ | 22.4 | 93 | 0.6 | 7.9 | 0.32 |
| $N_3P_2K_2$ | 24.7 | 99 | 0.6 | 7.9 | 0.32 |
| $N_4P_2K_2$ | 25.1 | 104 | 0.5 | 7.2 | 0.28 |

Regarding the presence of available zinc, the soil is moderately supported, though according to a detailed classification (Kruglov, 1975) this could be considered a low content.

On grounds of the availability of copper, the examined soil can be categorized as well supportive.

According to the presence of boron level, the soil is on the limit value separating low and medium content. Thus, its content is insufficient for sensitive plants and medium for the less sensitive ones.

**Vegetation experiment in pots**

In order to determine plant and soil parameters for evaluating the reliability of applied methods, an experiment was made under controlled conditions (in pots). Labeled nitrogen isotopes as well as phosphorus and potassium (NPK variant in pots) and phosphorus and potassium (PK – variant in pots) were used. Oats were the bred culture.

Tab. 5 – Dry content yield in oats (g/pot), relative yield increase in dry content of oats (%) and the difference in the yield (g/pot)

| Experi-ment variants | Yield NPK | Yield PK | Relative yield increase PK=100 | Difference in the yield NPK-PK | Relative yield increase ∅ = 100 | | Difference in the yield | |
|---|---|---|---|---|---|---|---|---|
| | | | | | NPK | PK | NPK-∅ | PK-∅ |
| Control | 10.26 | 2.25 | 456 | 8.01 | 100 | 100 | - | - |
| $N_1P_2K_2$ | 10.84 | 3.58 | 303 | 7.26 | 106 | 159 | 0.58 | 1.33 |
| $N_2P_2K_2$ | 10.86 | 4.18 | 260 | 6.68 | 106 | 186 | 0.60 | 1.93 |
| $N_3P_2K_2$ | 11.22 | 4.69 | 239 | 6.53 | 109 | 208 | 0.96 | 2.44 |
| $N_4P_2K_2$ | 11.10 | 6.36 | 174 | 4.74 | 108 | 283 | 0.84 | 4.11 |

The yield of plants grown under controlled conditions is the most commonly used parameter for determining the quality of the applied methods. The results for dry oat mass per pot, for both the NPK and PK pot experiment variants, are presented in table 5 as well as the relative increase in yield (PK=100 and control=100) and the difference in yield (NPK-PK, NPK-control and PK-control).

Isotope labeled ammonium nitrate was used in this experiment. The labeled nitrogen in plants was controlled to establish both the total uptake of nitrogen by oat plants and the presence of soil and fertilizer nitrogen, as well as the ratio. Since the PK variant was also used in pots, the uptake of nitrogen was established in this experiment variant too. These research results are presented in table 6.

Tab. 6. – Total nitrogen, soil nitrogen and nitrogen of fertilizer uptake by oat plants in the NPK variant in pots, and the nitrogen uptake in the PK variant in brown forest soil (mg/pot)

| Experi-ment variants | Total uptake nitrogen NPK | Uptake of soil nitrogen NPK | Uptake of fertilizer nitrogen NPK | Ratio of soil and fertilizer nitrogen uptake | Soil nitrogen uptakePK |
|---|---|---|---|---|---|
| Control | 90.0 | 58.1 | 31.9 | 1.8 | 18.5 |
| $N_1P_2K_2$ | 105.8 | 72.4 | 33.4 | 2.2 | 22.9 |
| $N_2P_2K_2$ | 118.0 | 83.8 | 34.2 | 2.4 | 30.3 |
| $N_3P_2K_2$ | 110.1 | 78.0 | 32.1 | 2.4 | 30.1 |
| $N_4P_2K_2$ | 115.1 | 84.4 | 30.7 | 2.7 | 48.5 |

**Vegetation experiment results in field**

Parameters of plants grown in the field are rarely used for evaluating the applied method, because they most frequently give low correlative dependence. However, there are cases where these interdependences are significant (Sapožnjikov, 1973; Robinson, 1968; Fox and Piekielek, 1978, Saito and Ishii, 1987). One can conclude that the greater the discrepancy, i.e. the differences in the field and laboratory conditions, the smaller the correlative dependence between the plant parameters and applied methods.

Brown forest soil used in long-term experiments was used in this research. In the year when the soil samples were taken wheat (the variety named Balkan) was grown in the field. The wheat yield results are presented in table 7.

Tab. 7. - Wheat yield in the field on brown forest soil (mc)

| Experiment variants | Yield of grain | Yield of straw | Total yield |
|---|---|---|---|
| Control | 9.54 | 12.11 | 21.65 |
| $N_1P_2K_2$ | 39.01 | 60.85 | 99.86 |
| $N_2P_2K_2$ | 43.78 | 63.04 | 106.82 |
| $N_3P_2K_2$ | 49.67 | 62.09 | 111.76 |
| $N_4P_2K_2$ | 51.31 | 67.73 | 119.04 |

**Method of total nitrogen**

The total content of nitrogen in soil as well as the percentage of organic carbon and the C/N relation are usually determined. Knowing this value, the potential soil capacity to provide the plant with nitrogen can be established.

The total nitrogen method for determining nitrogen availability in soil is one of the oldest methods commonly used in the past. For some time in certain western countries (Holland) total nitrogen has not been determining for this purpose (Jelenić et al, 1968).

Nowadays, it is very often found in literature that total nitrogen in soil does not indicate the actual availability of nitrogen in soil. To support such statements, mountain soil with high total nitrogen content is usually given as an example in which plants react markedly to added mineral fertilizers (Rajković, 1978). However, this approach can be considered a one-sided approach since total nitrogen in soil, i.e. organic nitrogen, which prevails, is the main available nitrogen source. On the other hand, all other methods used to assess availability of nitrogen in soil in fact deal with the part of total, i.e. organic nitrogen. Hence, when using the total nitrogen method one must first take into consideration the soil it is to be applied to and whether it is suitable for it or not. It should be especially stressed that both the total nitrogen method and the other methods concerning nitrogen availability in soil have been more or less reliable in many researches (Baeurg et al., 1973; Conforth and Walmsley, 1971; Peterson et al., 1960; Carpenter et al., 1962, Spencer et al., 1966).

In our research the total nitrogen content was determined in spring (March) for all field experiment variants, and its values and percentage of organic carbon, as well as the C/N relation, are presented in table 8.

Tab. 8. - Total nitrogen, organic carbon and C/N content in brown forest soil

| Experiment variants | Total nitrogen (%) | Organic C (%) | C/N |
|---|---|---|---|
| Control | 0.098 | 0.83 | 8.5 |
| $N_1P_2K_2$ | 0.111 | 0.97 | 8.7 |
| $N_2P_2K_2$ | 0.113 | 1.05 | 9.3 |
| $N_3P_2K_2$ | 0.113 | 1.07 | 9.5 |
| $N_4P_2K_2$ | 0.116 | 1.09 | 9.4 |

Correlation coefficient values between plant and soil parameters (both in pot and field) and the total nitrogen, organic carbon and C/N relation in the soil are presented in table 9.

A high correlation value (r=0.79**) of high statistic significance has been found between the PK variant yield in pots and the total nitrogen content in soil. A medium correlation dependence, on the other hand with lower statistic significance to the yield (r=0.57*), was found in the NPK variant. A high negative correlation dependence (r=-0.88**) was determined between the relative yield increase (PK=100) and total nitrogen, and a medium negative correlation value (r=-0,67**) was found in the difference between the yield (NPK-PK). Other relative parameters and difference parameters showed no major statistic correlation dependence.

T a b . 9. - Correlation coefficient values between plant and soil parameters and the total nitrogen, carbon and C/N content in brown forest soil

| Parameters of plants and soil (pot) | Total nitrogen | Organic carbon | C/N |
|---|---|---|---|
| Yield (NPK) | 0.57* | 0.60* | NS |
| Yield (PK) | 0.79** | 0.78** | NS |
| Relative increase in yield (PK=100) | -0.88** | - 0.85** | NS |
| Relative increase in yield (NPK) (∅=100) | NS | NS | NS |
| Relative increase in yield (PK) (∅=100) | NS | NS | NS |
| Difference in yield (NPK-PK) | -0.67** | -0.67** | NS |
| Difference in yield (NPK-∅) | NS | NS | NS |
| Difference in yield (PK-∅) | NS | NS | NS |
| % N plans (NPK) | NS | NS | NS |
| % N plans (PK) | NS | NS | NS |
| Total uptake of nitrogen (NPK) | 0.79** | 0.75** | NS |
| Uptake of soil nitrogen (NPK | 0.83** | 0.83** | NS |
| Uptake of fertilizer nitrogen (NPK) | NS | NS | NS |
| Uptake of soil nitrogen/fertilizer | 0.84** | 0.87** | 0.60* |
| Soil nitrogen uptake (PK) | 0.69** | 0.70** | NS |
| **Parameters of plans and soil (field)** | | | |
| Yield of grain | 0.77** | 0.81** | 0.58** |
| Yield of straw | 0.75** | 0.77** | NS |
| Total yield | 0.76** | 0.79** | 0.56** |
| Relative increase in yield (∅=100) | 0.60* | 0.66* | NS |
| Difference in yield (NPK-∅) | 0.65* | 0.74** | 0.52* |
| % N in grain | NS | 0.89* | NS |
| % N in straw | 0.97** | NS | NS |
| Uptake of nitrogen-grain | 0.70** | 0.75** | 0.54* |
| Uptake of nitrogen-straw | 0.73** | 0.80** | 0.58* |
| Total uptake of nitrogen | 0.71** | 0.76** | 0.55* |

** significant for probability level 0.01
* significant for probability level 0.05
NS - no statistic value

On the basis of these coefficients, it can be concluded that data on yield in controlled conditions can be a good indicator of total nitrogen value. This concerns cases when the breeding time of the culture is not short and when few factors influence the yield. Concerning the influence of factors, the main one is a relative optimal supply with macro and microelements since under these circumstances the influence of nitrogen on soil is more transparent.

As seen in table 9, the highest correlation coefficient values were reached between the pot soil parameters and total nitrogen. No statistically significant correlation dependence was found in the uptake of fertilizer nitrogen. The highest correlation coefficient value was found in the relation of soil nitrogen uptake and fertilizer nitrogen uptake (r=0.84**) and a somewhat lower value for soil nitrogen uptake (NPK) (r=0.83**). The results achieved match those in Sapožnjikov's researches (1973), who suggested that the value of a certain method should be measured by using soil parameters, in the first place the uptake of soil nitrogen and the relation between the uptake of soil and fertilizer nitrogen. A somewhat lower correlation coefficient was found in total uptake of nitrogen (r=0.79**). The soil nitrogen uptake in the PK variant had a correlation coefficient value of 0.69**, and when compared with the yield correlation coefficient in the same variant in pots, the conformity is evident. This conformity is significant since it indicates that soil nitrogen limited the yield, which once again confirms the value of the yield in pots and presents a parameter for assessment of the total nitrogen method in the examined brown forest soil. There was no such dependence in the NPK experiment variant, which indicates possible depressive influence of the added nitrogen on the yield, so the nitrogen surplus presented a limiting factor to the yield.

The uptake of nitrogen (NPK) in the tested brown forest soil proved to be a better parameter in evaluating the applied total nitrogen value method than the yield in pots. This was confirmed by the researches of Spožnjikov, 1973; Sirot, 1973; Baerus, 1973; Conforth and Walmsley, 1971.

The least used parameter for a method evaluation, including total nitrogen, is the yield in field, since very often low correlation coefficients are determined because of the numerous factors influencing yield in the field.

Statistically significant correlation coefficient dependence in all parameters was found between the plant parameters in the field and the total nitrogen content, except for the nitrogen content in grain. Thus, a significant correlation coefficient was found between the grain yield (r=0.77**), straw yield (r=0.75**) and total yield (r=0.76**) with the total nitrogen in soil. A somewhat lower correlation coefficient was found in nitrogen uptake of grain (r=0.70**), nitrogen uptake in straw (r=0.73**) and total nitrogen uptake (r=0.71**). No significant statistic correlation coefficient was found between the nitrogen content in grain and the total nitrogen in brown forest soil compared to the nitrogen content in straw, where the correlation coefficient value was the greatest (r=0.97**). The relative increase in yield (Ø100) and difference in yield (NPKØ ) with total nitrogen in soil produced medium correlative dependence with lower statistic significance (r=0.60*, and r=0.65*).

On grounds of the presented results (table 10) and in accordance with the adopted criteria, one can conclude that:

a) the total nitrogen method is reliable when establishing nitrogen availability in brown forest soil;

b) field plant and soil parameters can be considered reliable when evaluating the applied method;

Tab. 10. - Correlation coefficient percentage in r=0.50-0.99 (** and *) and for r≥0.70** between plant and soil parameters and total nitrogen, organic carbon content and C/N relation in brown forest soil (March)

| Parameters | Percentage of correlation coefficient for r=0.50-0.99 (** and *) | Percentage of correlation coefficient for r≥0.70** |
|---|---|---|
| | Total nitrogen | |
| Plant and soil parameters in pot and field | 68.0 | 48.0 |
| Plant and soil parameters in pot | 53.3 | 33.3 |
| Plant and soil parameters in field | 90.0 | 70.0 |
| | Organic carbon | |
| Plant and soil parameters in pot and field | 68.0 | 52.0 |
| Plant and soil parameters in pot | 53.3 | 40.0 |
| Plant and soil parameters in field | 90.0 | 70.0 |
| | Relation C/N | |
| Plant and soil parameters in pot and field | 28.0 | 0.0 |
| Plant and soil parameters in pot | 6.7 | 0.0 |
| Plant and soil parameters in field | 60.0 | 0.0 |

In the soil, nitrogen is usually present in its organic form, so apart from the total nitrogen content the organic carbon content is measured too. Since the total nitrogen content in brown forest soil proved to be reliable when determining availability of soil nitrogen, in our research, despite being a non-standard procedure, we determined the dependence between the proposed parameters (plants and soil in pots and field) and organic carbon content in soil (table 9).

On grounds of the presented correlation coefficient (table 9) found between the field and pot soil parameters and the organic carbon content, we can conclude that they are identical to the correlation coefficient and have the same statistic significance for the same parameters and for the total nitrogen in soil.

The most important were the results regarding the field soil and plant parameters, whereby even higher correlation coefficient values were reached for yield and uptake of nitrogen than in total nitrogen.

According to these results (table 10) and in compliance with the adopted criteria, it can be concluded that:

a) the organic carbon content could be considered a reliable value in determining soil nitrogen availability in brown forest soil;

b) when evaluating the applied value the field plant and soil parameters can be considered reliable;

Whether the organic compound mineralization process or the immobilization process will prevail in some soil, depends on the C/N relation in the mineralizing organic material.

The immobilization process appears in cases where the C/N ratio is above 30. When this ratio is within the 20-30 limits there is equilibrium between these two processes, and in cases when the C/N ratio is below 20 there is a mineralization process (Tisdale and Nelson, 1975).

Of course, this should be taken with constraint because it is well-known that old, stable humus despite its rather narrow C/N ratio is resistant to disintegration and gives small quantities of non-organic nitrogen.

In all field experiment variants the C/N ratio in the examined brown forest soil was below 10, i.e. somewhat lower than the standard values for arable land. (table 8).

Since both the contents of nitrogen and organic carbon in brown forest soil showed good correlation coefficient results in plant and soil parameters, and since both methods regarding availability of nitrogen in the examined soil can be considered reliable, and, on the other hand, bearing in mind the fact that the C/N ratio tells us about the organic nitrogen mineralization process, a correlation analysis was made for this relation too (table 9).

A statistically significant correlation dependence between the soil and plant in pots and the C/N ratio in brown forest soil was found only in the ratio of soil and fertilizer nitrogen uptake.

Generally, moderate correlation dependence with low statistic significance in the parameters of field plants and in the C/N ratio was found.

According to both the presented data (table 10) and adopted criteria, it can be concluded that:

a) the C/N ratio is an unreliable factor in determining nitrogen availability in soil in brown forest soil.

#### Easy hydrolyzing nitrogen method

The easy hydrolyzing method and the total nitrogen method are among the oldest methods used in determining soil nitrogen availability. This procedure was generally applied by Russian scientists (Tjurin and Kononova, 1934; Poljakov, 1970; Sirota, 1973; Kajumov, 1982). Contrary to other biological and chemical methods, the soil nitrogen uptake coefficient by plants was determined only for the easily hydrolyzed nitrogen (Tjurin and Kon, 1934). Therefore, data on the easily hydrolyzed nitrogen content are directly used to calculate the required fertilizer nitrogen content. Kajumov (1982) uses only the easily hydrolyzed nitrogen content, i.e. its 25% uptake coefficient, in calculating the required nutrient quantities (nitrogen) for winter wheat in order to determine the capability of soil to provide plants with nitrogen.

In March, July and October the easily hydrolyzed nitrogen content increased, ranging from the control experiment variants to the variants where largest nitrogen quantities were applied (table 11).

With this method the available nitrogen in soil as well as the organic nitrogen that easily mineralizes are determined. In March most of the easily hydrolyzed nitrogen is in the form of available nitrogen, and in July most of it are organic fractions that easily mineralize (table 11).

Tab. 11. – Easily hydrolyzed nitrogen content in brown forest soil (ppm)

| Experiment variants | March | July | October |
|---|---|---|---|
| Control | 42.2 | 41.6 | 39.0 |
| $N_1P_2K_2$ | 46.5 | 45.6 | 46.9 |
| $N_2P_2K_2$ | 46.5 | 46.7 | 49.2 |
| $N_3P_2K_2$ | 57.7 | 70.1 | 62.0 |
| $N_4P_2K_2$ | 80.4 | 101.1 | 65.8 |

In October the easily hydrolyzed nitrogen content gradually increased from the control variant to the $N_4P_2K_2$ variant, and the established quantity of easily hydrolyzed nitrogen in all field experiment variants generally indicated the organic nitrogen quantity that will mineralize the fastest.

Tab. 12. - Correlation coefficient values between plant and soil parameters and the easily hydrolyzed nitrogen in brown forest soil

| Parameters of plants and soil (pot) | March | July | October |
|---|---|---|---|
| Yield (NPK) | NS | NS | 0.62* |
| Yield (PK) | 0.92** | 0.91** | 0.93** |
| Relative increase in yield (PK=100) | -0.77** | -0.76** | -0.88** |
| Relative increase in yield (NPK) (∅=100) | NS | NS | NS |
| Relative increase in yield (PK) (∅=100) | 0.95** | 0.95** | 0.87** |
| Difference in yield (NPK-PK) | -0.86** | -0.86** | -0.81** |
| Difference in yield (NPK-∅) | NS | NS | NS |
| Difference in yield (PK-∅) | 0.95** | 0.95** | 0.87** |
| % N plans (NPK) | NS | NS | NS |
| % N plans (PK) | NS | NS | NS |
| Total uptake of nitrogen (NPK) | NS | NS | 0.59** |
| Uptake of soil nitrogen (NPK | 0.58** | 0.56* | 0.70** |
| Uptake of fertilizer nitrogen (NPK) | NS | NS | NS |
| Uptake of soil nitrogen/fertilizer | 0.84** | 0.82** | 0.88** |
| Soil nitrogen uptake (PK) | 0.94** | 0.92** | 0.86** |
| **Parameters of plans and soil (field)** | | | |
| Yield of grain | 0.66** | 0.65** | 0.80** |
| Yield of straw | NS | NS | 0.70** |
| Total yield | 0.56* | 0.55* | 0.74** |
| Relative increase in yield (∅=100) | 0.62* | 0.61* | NS |
| Difference in yield (NPK-∅) | 0.72** | 0.75** | 0.63* |
| % N in grain | NS | NS | 0.92* |
| % N in straw | 0.99** | NS | 0.99** |
| Uptake of nitrogen-grain | 0.91** | 0.89** | 0.88** |
| Uptake of nitrogen-straw | 0.87** | 0.86** | 0.89** |

** significant for probability level 0.01
* significant for probability level 0.05
NS - no statistic value

In March generally a very high correlation dependence is found between the pot plant parameters and the easily hydrolyzed nitrogen content (yield (PK) – r = 0.92**; relative yield increase (PK) (Ø)100) – r = 0.95** and the difference in yield (PK - Ø – r = 0.95** ) or high negative (relative yield increase (PK=100) – r = -0.77** and difference in yield (NPK-PK) – r = -0.86**) with high statistic significance (table 12). No significant statistically correlation dependence was found in other plant parameters with this method. The highest correlation coefficient in the soil in pots parameters was found between the soil nitrogen uptake in the PK variant and the easily hydrolyzed nitrogen content (r = 0.94**). The relation between the soil and fertilizer nitrogen uptake with easily hydrolyzed nitrogen showed high correlation dependence (r = 0.84**), and a medium correlation dependence (r = 0.58*) with low statistic significance was found between the soil nitrogen uptake (NPK) and this method. With the easily hydrolyzed nitrogen method the field plant parameters generally showed medium correlation dependence. However, a very high correlation dependence (r = 0.99**) with high statistic significance was found between the content of nitrogen and wheat straw, on one side, and the easily hydrolyzed nitrogen, on the other. The uptake of nitrogen in field (grain - r=0.91**, straw - r=0.87** and total uptake of nitrogen - r=0.90**) with easily hydrolyzed nitrogen content showed both very high and high correlation coefficients and high statistic significance.

The parameters in July and March, showed significant correlation dependence between plant and soil parameters in pots and the easily hydrolyzed nitrogen. Even the correlation coefficient values and statistic significance were identical or almost identical. The same pattern was found in correlation coefficient values determined between the plant and soil in field and the easily hydrolyzed nitrogen, only this time there was no significant statistic correlation dependence found in July between the nitrogen content in wheat straw and the easily hydrolyzed nitrogen.

In October, compared to March and July, in most of the cases a high statistic correlation dependence was found between the used plant and soil parameters (in pots and field) and the easily hydrolyzed nitrogen, though no greater difference was found between the same correlation coefficient parameters as those established in March and July.

On grounds of the presented results (table 13) and in accordance with the adopted criteria, it can be concluded that:

a) the easily hydrolyzed nitrogen is a reliable method for determining nitrogen availability in brown forest soil:

b) in the evaluation of the applied method, plant and soil parameters, for both pots and field, can be used.

The determining of easily hydrolyzed nitrogen method reliability regarding nitrogen availability in brown forest soil is very important since, apart from total nitrogen, it is the only method where nitrogen uptake coefficient from soil has been determined. Thus, the easily hydrolyzed nitrogen values in this soil can be used in prognosis of nitrogen fertilizer application.

T a b . 13. - Correlation dependence percentage for cases r=0.50-0.99 (** and *) and for r ≥0.70** between plant and soil parameters and easily hydrolyzed nitrogen in brown forest soil

| Parameters | Percentage of correlation coefficient for r=0.50-0.99 (** and *) | Percentage of correlation coefficient for r≥0.70** |
|---|---|---|
| | March | |
| Plant and soil parameters in pot and field | 64.0 | 48.0 |
| Plant and soil parameters in pot | 53.3 | 46.7 |
| Plant and soil parameters in field | 80.0 | 50.0 |
| | July | |
| Plant and soil parameters in pot and field | 60.0 | 44.0 |
| Plant and soil parameters in pot | 53.3 | 46.7 |
| Plant and soil parameters in field | 70.0 | 40.0 |
| | Octobar | |
| Plant and soil parameters in pot and field | 72.0 | 52.0 |
| Plant and soil parameters in pot | 66.7 | 53.3 |
| Plant and soil parameters in field | 80.0 | 50.0 |

## Conclusion

On grounds of the presented results, the following can be concluded:

1) The total nitrogen method is a reliable method in determining availability of soil nitrogen in examined brown forest soil.

2) When evaluating the applied method, the plant and soil parameters in field can be considered reliable, while the plant and soil parameters in pots are not reliable.

3) The content of organic carbon can be considered a reliable factor in estimating nitrogen availability of soil in brown forest soil.

4) In evaluating the applied factor (organic carbon) field plant and soil parameters are considered reliable.

5) The C/N ratio is an unreliable factor in determining nitrogen availability of soil in brown forest soil.

6) The easily hydrolyzed nitrogen method is reliable in evaluating nitrogen availability in brown forest soil.

7) In both pots and field, the plant and soil parameters can be used to evaluate the applied method.

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# OCENA PRISTUPAČNOSTI ZEMLJIŠNOG AZOTA

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## R e z i m e

Cilj ovog istraživanja je bio da se utvrdi da li se sadržaj ukupnog i lakohidrolizujućeg azota može koristiti kao merilo pristupačnosti azota zemljišta, kao i da se utvrdi koji se parametri biljaka i zemljišta (polje i kontrolisani uslovi) mogu smatrati pouzdanim za ocenu vrednosti korišćenih metoda.

Istraživanja su obavljena na gajnjači koja se koristi u okviru stacionarnog ogleda već 30 godina. Za ova istraživanja su korišćeni uzorci zemljišta sa varijanti ogleda gde je primenjena rastuća doza azota djubiva. Uzorci zemljišta su uzimani sa dubine 0-30 cm, pri čemu su radi utvrdjivanja što većeg broja parametara biljaka i zemljišta izvedena dva ogleda i to ogled u sudovima i u polju.

Na osnovu utvrdjenih korelativnih zavisnosti izmedju korišćenih metoda i parametara biljaka i zemljišta u kontrolisanim uslovima i polju može se zaključiti da se metode ukupnog i lakohidrolizujućeg azota mogu smatrati pouzdanim za ocenu pristupačnosti azota zemljišta. Pri čemu kod vrednovanja metode ukupnog azota treba koristiti parametre biljaka i zemljišta u polju, a kod metode lakohidrolizujućeg azota ravnopravno i parametre biljaka i zemljišta u polju i kontrolisanim uslovima.

Utvrdjene vrednosti korelacionh koeficijenata su pokazale da se i organski ugljenik može koristiti kao veličina koja govori o pristupačnosti azota zemljišta, dok se odnos C/N smatra nepouzdanom veličinom.


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