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# DETERMINING FERTILIZER QUANTITIES REQUIRED FOR WHEAT

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**Abstract:** In this experiment we used brown forest soil that has been used in long-term experiments, for 30 years, with increasing doses of introduced nitrogen fertilizer in variants.

In order to determine the quantities of nitrogen fertilizer required for wheat, a calculation model has been applied. This calculation requires not only a reliable method for determining soil nitrogen availability (both the total and easily hydrolyzed nitrogen method were used), but also a reliable method for determining the coefficient of nitrogen utilization from soil as well as data on the coefficient of nitrogen utilization from fertilizer ($N_{ani}$) for the added quantities of nitrogen fertilizer.

**Key words:** model, soil nitrogen, fertilizer nitrogen, total nitrogen, easily hydrolyzed nitrogen, wheat.

## I n t r o d u c t i o n

The determining of nitrogen fertilizer quantities that need to be added to soil in order to reach a prognosed yield presents a complex and difficult research objective.

Presently, there are two approaches to solving this problem i.e.: first, by applying the mathematical models, and, second, by applying simplified models.

Mathematical methods resulted, first of all, from the inability to follow soil nitrogen in all its transformation phases within the plant-soil-fertilizer system. The basic principle used in mathematical models is to simplify the entire system and its elements so as to follow the complex processes. However, this simplification sometimes gives inappropriate results (T a n j i, 1982). In this simplification of the system and its elements, generally, the soil parameters

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determined with difficulty or dependent on the influence of many variables are treated as constant values. Nevertheless, the application of mathematical models requires the determining and measuring of numerous parameters in a longer period of time.

The solution to the problem of determining nitrogen quantities required by plants can be simplified by applying simplified models i.e. the most frequently used simple calculations with an effort to measure as much variables as possible or to evaluate them by measuring (Kajumov, 1982, Hart and Goh, 1980, Stanford, 1972, 1977, Carter et al., 1974, Needham, 1982, Scharpp and Nehrann, 1978, Bogdanovic, 1985).

In these researches a simplified model was used to determine the required quantities of nitrogen fertilizer for plants. The calculation for this model is simple. However, the determining of parameters on the grounds of which the calculation is made is a complex and difficult research task. To be able to apply it, one must first find a reliable method for determining availability of soil nitrogen and then determine the coefficient of nitrogen utilization from soil for the method found to be reliable. The quantity of soil nitrogen considered available to plants is determined on the basis of the established coefficient of nitrogen utilization from soil. In addition, the proposed model includes one parameter more – the fertilizer, from both the aspect of its utilization and fertilizer influence on the activation of soil nitrogen.

In this research two methods were used for determining the quantities of fertilizer required: the total nitrogen and the easily hydrolyzed nitrogen method, whose reliability in determining nitrogen availability in brown forest soil has been established and the respective results were presented in our research paper also published in this journal (Vol. 48, No. 1).

## Material and Methods

In this experiment we used brown forest soil that has been used in long-term experiments, with a certain crop rotation and fertilization system running for 30 years. Experiment variants with increasing doses of nitrogen fertilizer doses were used.

In the paper “Availability of Soil Nitrogen” published herein, the applied methods are described in detail, and this paper presents a continuation of the previous one.

## Results and Discussion

From the analytical point of view it is important to establish the reliability of the methods used to determine soil nitrogen availability, and this presents the most elaborate and complex part of the procedure for calculating the required quantities of fertilizer.

Regardless of all the difficulties in establishing the reliability of some method (choice of the methods and parameters for their evaluation, complex analytical procedures and elaborate time required for establishing their reliability), the registered reliability itself is of little significance. It is significant only when used as a basis for evaluating soil nitrogen quantities considered available to plants.

**Determining Coefficient of Nitrogen Utilization from Soil**

As already presented and established in the paper "Estimation of Soil Nitrogen Availability " the total nitrogen and easily hydrolyzed nitrogen methods can be considered reliable. It has been stated in the paper that the total nitrogen method proved reliable in samples taken in spring (March), and in case of easily hydrolyzed nitrogen method, in those taken in March and October.

Since both the total nitrogen and easily hydrolyzed nitrogen methods proved reliable in early spring (March), the prognosis for the added fertilizer will be given for nitrogen fertilizer quantities for spring dressing, and in case of easily hydrolyzed nitrogen that proved reliable in autumn (October) the calculation will be given for the entire vegetation period.

**Total Nitrogen Method**

In case of total nitrogen, the coefficient of nitrogen utilization from soil is a known value i.e. nitrogen quantities considered available to plants are known.

When applying this method in prognosing the use of nitrogen fertilizer, the already known coefficient of nitrogen utilization from soil can be applied. Obviously, the conditions in the soil directly determine the coefficient of nitrogen utilization for the method (bottom, average and top values).

In case of total nitrogen, 1% has been taken to be the bottom value for coefficient of nitrogen utilization from soil for brown forest soil, bearing in mind its content, existing unfavorable conditions in the soil regarding the mineralization and nutrition process, and hence the poor fertility of the soil.

According to this calculation, on the grounds of total nitrogen in soil content, one can conclude that the quantities of soil nitrogen considered available to plants in brown forest soil ranged within 44.1-52.2 kg/ha (table 1).

T a b. 1.- Quantities of nitrogen available to plants in relation to total nitrogen content in brown forest soil (kg/ha)

| Field variants | Total nitrogen | | |
|---|---|---|---|
| | Total nitrogen content (kg/ha) | Coefficient of nitrogen utilization (%) ($K_{z1}$) | Quantity of nitrogen considered available to plants (kg/ha) |
| Control | 4410 | 1.0 | 44.1 |
| $N_1P_2K_2$ | 4995 | 1.0 | 49.9 |
| $N_2P_2K_2$ | 5085 | 1.0 | 50.8 |
| $N_3P_2K_2$ | 5085 | 1.0 | 50.8 |
| $N_4P_2K_2$ | 5220 | 1.0 | 52.2 |

Data regarding total nitrogen can be used in another way, whereby both the establishment of coefficient of nitrogen utilization from soil for conditions in brown forest soil and subsequently the establishment of nitrogen quantities considered available to plants is required.

In our research the percentage of available nitrogen was established on the grounds of calculation as proposed by Mihailov and Kniper (1971).

According to these authors, the procedure first requires establishment of the percentage coefficient of nitrogen utilization by applying the formula:

$$K = \frac{a}{b} \cdot 100$$

where:
K – presents percentage i.e. coefficient of nitrogen utilization (%)
a – presents nitrogen utilization uptake (grain and straw) (kg/ha)
b – presents quantity of nitrogen in soil established by applied method (kg/ha)

The coefficients of nitrogen utilization in brown forest soil are presented in table 2.

T a b. 2**.** - Coefficient of nitrogen utilization from soil in relation to total nitrogen in brown forest soil (%)

| Field variants | Total nitrogen content (kg/ha) | Nitrogen uptake trough yield (kg/ha) | Coefficient of nitrogen utilization ($Kz_2$) (%) |
|---|---|---|---|
| Control | 4410 | 14.35 | 0.32 |
| $N_1P_2K_2$ | 4995 | 72.95 | 1.46 |
| $N_2P_2K_2$ | 5085 | 105.37 | 2.07 |
| $N_3P_2K_2$ | 5085 | 134.21 | 2.64 |
| $N_4P_2K_2$ | 5220 | 149.89 | 2.87 |

The established coefficient concerns both soil and fertilizer nitrogen. In order to determine the percentage of soil nitrogen utilization versus the total nitrogen, it is necessary to know the coefficient of nitrogen utilization from fertilizer.

According to literature, the percentage of nitrogen utilization from fertilizer varies significantly. Sapoznjikov and Krilov (1969) applied the coefficient ranging from 50-60% for winter wheat. According to Ivovic's et al. results (1978), regarding the long-term experiment in Mladenovac where this research has been made, in a ten-year period the coefficient of nitrogen utilization from added fertilizer ranged within the 68.04-87.87%. Contrary to these researches, Zeravica (1971) quoted coefficient of nitrogen utilization values for fertilizer that ranged from 27.4-49.1%, depending on the dose applied.

Such significant variations in the coefficient of nitrogen utilization from fertilizer are the result of various factors, such as: type of soil, applied fertilizer doses, amount of rainfall, and methods applied for calculation of this coefficient (method with isotope $^{15}N$ and the difference method).

In order to establish the uptake of nitrogen from soil, in this research we adopted 50% to be the average coefficient of nitrogen utilization from fertilizer (Sapoznjikov and Krilov, 1969). This was determined by applying $^{15}N$ isotope in micro-field experiments.

By applying 50% as the coefficient of nitrogen utilization from fertilizer, the establishing of the coefficient of nitrogen utilization from soil, according to the content of total nitrogen, is performed by the procedure explained further in the text.

Bearing in mind that in autumn during the sowing of wheat 1/3 of the prescribed dose of nitrogen fertilizer is added i.e. $N_1$-20, $N_2$-30, $N_3$-40 and $N_4$-50 kg/ha, already contained in the established total nitrogen, and also bearing in mind the uptake by the grown culture as well as the losses, only quantities used in the spring dressing i.e. $N_1$-40, $N_2$-60, $N_3$-80 and $N_4$-100 kg/ha are considered. Since 50% has been adopted as the coefficient of nitrogen utilization from fertilizer, then the uptaken quantity of nitrogen should be reduced by this amount and the quantity of nitrogen utilization by plants from soil (table 3) should be calculated.

T a b. 3.- Calculation to establish the coefficient of nitrogen utilization from soil for the achieved yield

| Field variants | Nitrogen uptake trough yield (kg/ha) | | Nitrogen fertilizer dose reduced for 50% (kg/ha) | | Nitrogen uptake from soil (kg/ha) |
|---|---|---|---|---|---|
| Control | 14.35 | - | 0 | = | 14.35 |
| $N_1P_2K_2$ | 72.95 | - | 20 | = | 52.95 |
| $N_2P_2K_2$ | 105.37 | - | 30 | = | 75.37 |
| $N_3P_2K_2$ | 134.21 | - | 40 | = | 94.21 |
| $N_4P_2K_2$ | 149.89 | - | 50 | = | 99.89 |

After establishing the quantity of soil nitrogen uptaken by plants, the percentage of soil nitrogen utilization compared to total nitrogen can be established, and these values are presented in table 4.

T a b. 4.- Coefficient of nitrogen utilization from soil in relation to total nitrogen content for the coefficient of nitrogen utilization value 50% in March

| Field variants | Total nitrogen (kg/ha) | Nitrogen uptake from soil (kg/ha) | (K) (%) |
|---|---|---|---|
| Control | 4410 | 14.35 | 0.32 |
| $N_1P_2K_2$ | 4995 | 52.95 | 1.46 |
| $N_2P_2K_2$ | 5085 | 75.37 | 2.07 |
| $N_3P_2K_2$ | 5085 | 94.21 | 2.64 |
| $N_4P_2K_2$ | 5220 | 99.89 | 2.87 |

The coefficient of nitrogen utilization from soil in relation to the total nitrogen content in brown forest soil ($K_{z1}$ and $K_{z2}$), as well as the soil nitrogen content considered available to plants for different coefficient of nitrogen utilization from fertilizer, are presented in table 5.

T a b. 5.- Coefficient of nitrogen utilization from soil in relation to total nitrogen for various coefficients of nitrogen utilization from fertilizer

| Field variant | Total nitrogen (kg/ha) | $K_{z1}$ (%) | Soil nitrogen available to plants (kg/ha) | $K_{z2}$ (%) | Soil nitrogen available to plants (kg/ha) |
|---|---|---|---|---|---|
| Control | 4410 | 1.0 | 44.10 | 0.32 | 14.35 |
| $N_1P_2K_2$ | 4995 | 1.0 | 49.95 | 1.06 | 52.95 |
| $N_2P_2K_2$ | 5085 | 1.0 | 50.85 | 1.48 | 75.37 |
| $N_3P_2K_2$ | 5085 | 1.0 | 50.85 | 1.85 | 94.21 |
| $N_4P_2K_2$ | 5220 | 1.0 | 52.00 | 1.91 | 99.89 |

According to the presented results, ranging from the control experiment variant to the one where the largest quantity of fertilizer was applied, it is characteristic for both coefficients of nitrogen utilization from soil that the quantity of nitrogen in soil considered available to plants was increasing. The differences in the established available soil nitrogen quantities between the field experiment variants were less for the coefficient of nitrogen utilization from soil $K_{z1}$ than for coefficient $K_{z2}$.

From the coefficients used, the coefficient $K_{z2}$ can be considered more realistic, since the coefficient of nitrogen utilization from fertilizer was used in its determination, whilast for $K_{z1}$, the coefficient of nitrogen utilization from fertilizer was not considered.

In our research of brown forest soil we established that the total nitrogen method can be considered reliable for determining availability of soil nitrogen, after which for each field experiment variant the coefficient of nitrogen utilization from soil in relation to total nitrogen was determined. The next question is which of the established soil nitrogen quantities can be used as data for prognosis of fertilizer nitrogen application. Logically, it would be the soil nitrogen quantity established in the experiment control variant, since in all other cases, especially in variants where larger doses of fertilizer nitrogen were applied, the effect of added fertilizer was present. However, a long-term experiment was used in this research lasting for over 30 years. Thus, an unusually low coefficient of nitrogen utilization from soil was established in the control variant of the experiment, i.e. a very small quantity of soil nitrogen that can be used in the final calculation for the prognosed nitrogen fertilizer quantity. This can be considered normal, bearing in mind the length of the experiment and the fact that there had been no fertilizing whatsoever, which in this variant resulted in a major impoverishment of soil

regarding nitrogen. Because of this, one can wonder whether the experiment control variant really presents the available soil nitrogen under the same or similar conditions.

Since in all other field experiment variants fertilizer nitrogen was added, and the effect of added fertilizer was present in all of them, the most acceptable quantity of soil nitrogen considered available to plants is the one from the experiment variant in which the lowest dose of nitrogen fertilizer had been applied, i.e. the variant $N_1P_2K_2$ (60 kg/ha), because in this case the added fertilizer had the least influence.

On the grounds of what has been presented so far, one can conclude that in the experimental brown forest soil approximately 53.0 kg N/ha can be considered available to plants, and further calculation for prognosed quantities of nitrogen fertilizer for spring dressing is based on this quantity of soil nitrogen, established on the grounds of total nitrogen content and the coefficient of its utilization, which is 1.06%.

**The Easily Hydrolyzed Nitrogen Method**

In their system of field experiments Tjurin and Kononova established that the coefficient of nitrogen utilization from soil presents 20-30 % of the easily hydrolyzed nitrogen, while in his calculations regarding required nitrogen fertilizer for winter wheat Kajumov (1982) used the coefficient 25% of the easily hydrolyzed nitrogen.

In our research, both for the total nitrogen and easily hydrolyzed nitrogen, we considered conditions existing in the brown forest soil. Hence the coefficient of nitrogen utilization that we used was 20%. This presents the bottom value established by Tjurin and Kononova and it is lower than the one used by Kajumov (1982).

Table 6 presents the easily hydrolyzed nitrogen content, the coefficient of nitrogen utilization from soil in relation to the easily hydrolyzed nitrogen content as well as the soil nitrogen content considered available to plants, which derives from the two former values.

T a b. 6.- Quantities of nitrogen available to plants in relation to the easily hydrolyzed nitrogen in brown forest soil (kg/ha)

| Field variants | Easily hydrolyzed nitrogen | | |
|---|---|---|---|
| | Easily hydrolyzed nitrogen (kg/ha) | Coefficient of nitrogen utilization (%) | Quantity of nitrogen considered available to plants according to easily hydrolyzed nitrogen (kg/ha) |
| Control | 192.15 | 20.0 | 38.43 |
| $N_1P_2K_2$ | 298.25 | 20.0 | 41.85 |
| $N_2P_2K_2$ | 209.25 | 20.0 | 41.85 |
| $N_3P_2K_2$ | 259.65 | 20.0 | 51.93 |
| $N_4P_2K_2$ | 361.80 | 20.0 | 72.36 |

On the grounds of calculation and the easily hydrolyzed nitrogen, one may conclude that the quantity of nitrogen considered available to plants ranged within the 38.4 – 72.4 kg/ha limits.

By applying the Mihailov and Knipper (1971) calculation, as done with total nitrogen, the coefficient of nitrogen utilization values for easily hydrolyzed nitrogen are presented in table 7.

T a b. 7. - Coefficient of nitrogen utilization from soil in relation to the easily hydrolyzed nitrogen content in brown forest soil

| Field variants | Easily hydrolyzed nitrogen (kg/ha) | Nitrogen uptaken through yield (kg/ha) | K (%) |
|---|---|---|---|
| Control | 192.15 | 14.35 | 7.47 |
| $N_1P_2K_2$ | 209.25 | 72.95 | 34.86 |
| $N_2P_2K_2$ | 209.25 | 105.37 | 50.36 |
| $N_3P_2K_2$ | 259.65 | 134.21 | 51.69 |
| $N_4P_2K_2$ | 361.80 | 149.89 | 41.43 |

The established coefficient concerns both the soil and fertilizer nitrogen. In order to establish the percentage of soil nitrogen utilization versus the easily hydrolyzed nitrogen, it is necessary further in the calculation to consider the coefficient of nitrogen utilization from fertilizer.

The adopted coefficient of nitrogen utilization from fertilizer is 50% and the calculation for this coefficient, for determining the uptaken soil nitrogen through the achieved yield, is presented in table 3.

On the grounds of established quantity of soil nitrogen uptaken by plants, the percentage of uptaken soil nitrogen compared to easily hydrolyzed nitrogen and its values is presented in table 8.

T a b. 8. - Comparison of coefficient of nitrogen utilization from soil in relation to the easily hydrolyzed nitrogen (for coefficient of nitrogen utilization from fertilizer value 50%)

| Field variants | Easily hydrolyzed nitrogen (kg/ha) | Nitrogen uptaken through yield (kg/ha) | K (%) |
|---|---|---|---|
| Control | 192.15 | 14.35 | 7.47 |
| $N_1P_2K_2$ | 209.25 | 52.95 | 25.30 |
| $N_2P_2K_2$ | 209.25 | 75.37 | 36.02 |
| $N_3P_2K_2$ | 259.65 | 94.21 | 36.28 |
| $N_4P_2K_2$ | 361.80 | 99.89 | 27.61 |

According to the presented calculation, it can be concluded that the coefficient of nitrogen utilization from soil, from the easily hydrolyzed nitrogen

in brown forest soil, is 25.3%. This coefficient is considered corresponding to the coefficient 20.0% (Tjurin and Kononova), since it was established for conditions existing in the experimental brown forest soil, and in its calculation the coefficient of nitrogen utilization from fertilizer was considered. In the experiment variant where the first doses of the nitrogen fertilizer ($N_1P_2K_2$) were added, the coefficient of nitrogen utilization was taken for both total nitrogen and for easily hydrolyzed nitrogen. Finally, we can conclude that regardless of the fact that the found coefficients of nitrogen utilization from soil in relation to the total and easily hydrolyzed nitrogen range within the average limits found in literature, the coefficients should nevertheless be established for each new soil and grown culture.

**Reliable Method for Determining Coefficient of Nitrogen Utilization From Soil in October**

It was established that the easily hydrolyzed nitrogen method is reliable in October, too. As with the total and easily hydrolyzed nitrogen methods that proved reliable in March, this method also required an assessment of soil nitrogen available to plants. The established nitrogen value was further used for the prognosis of nitrogen fertilizer application in the following vegetation season for winter wheat.

**The Easily Hydrolyzed Nitrogen Method**

Bearing in mind the coefficient of nitrogen utilization from soil that was proposed by Tjurin and Kononova, the calculation for nitrogen quantities available to plants in brown forest soil in October is presented in table 9.

T a b. 9. - Quantities of nitrogen available to plants in relation to the easily hydrolyzed nitrogen content in brown forest soil (kg/ha)

| Field variants | Easily hydrolyzed nitrogen (kg/ha) | K (%) | Nitrogen quantities considered available to plants (kg/ha) |
|---|---|---|---|
| Control | 175.50 | 20.0 | 35.10 |
| $N_1P_2K_2$ | 211.05 | 20.0 | 42.21 |
| $N_2P_2K_2$ | 221.40 | 20.0 | 44.28 |
| $N_3P_2K_2$ | 279.00 | 20.0 | 55.80 |
| $N_4P_2K_2$ | 296.10 | 20.0 | 59.29 |

According to the presented results, in can be concluded that in autumn the quantity of 42.21 kg N/ha can be considered available to plants.

Mihailov and Knipper (1971) proposed another form of this calculation i.e. by applying the quantity of nitrogen uptaken through yield. In our case it would be the yield achieved in the previous year (July).

The results of this calculation are presented in table 10.

T a b. 10. - The coefficient of nitrogen utilization from soil in relation to the easily hydrolyzed nitrogen in brown forest soil

| Field variants | Easily hydrolyzed nitrogen (kg/ha) | Nitrogen uptaken through yield (kg/ha) | K (%) |
|---|---|---|---|
| Control | 175.50 | 14.35 | 8.18 |
| $N_1P_2K_2$ | 211.05 | 72.95 | 34.56 |
| $N_2P_2K_2$ | 221.40 | 105.37 | 47.59 |
| $N_3P_2K_2$ | 279.00 | 134.21 | 48.10 |
| $N_4P_2K_2$ | 296.10 | 149.89 | 50.62 |

The established coefficient values refer to both the soil and fertilizer nitrogen, and in order to establish the percentage of nitrogen utilization from soil in relation to the easily hydrolyzed nitrogen, the coefficient of nitrogen utilization from fertilizer is considered further in the calculation. As with the previous calculation, the coefficient of nitrogen utilization from fertilizer value was 50.0%. Since the applied nitrogen doses for grown wheat were for $N_1$-60, $N_2$-90, $N_3$-120, and for $N_4$-150 kg N/ha, and having in mind that the coefficient of nitrogen utilization from fertilizer is 50.0%, the nitrogen quantity uptaken by plants should be reduced by 30.0 ($N_1$), 45.0 ($N_2$), 60.0 ($N_3$), and 75.0 kg N/ha ($N_4$) in order to establish the quantity of nitrogen uptaken through yield.

In contrast to the calculation used in the spring dressing of wheat, in this case the entire quantity of added nitrogen fertilizer has to be considered, since the calculation for applied fertilizer estimation in October refers to the forthcoming vegetation season, where data from the previous year are used in the calculations. The calculation results are presented in table 11.

T a b. 11. - Calculation for establishing quantities of soil nitrogen utilization for the yield

| Field variants | Nitrogen uptake by plants grown (kg/ha) | | Fertilizer nitrogen dose (kg/ha) | | Nitrogen uptake from the soil (kg/ha) |
|---|---|---|---|---|---|
| Control | 14.35 | - | 0 | = | 14.35 |
| $N_1P_2K_2$ | 72.95 | - | 30 | = | 42.95 |
| $N_2P_2K_2$ | 105.37 | - | 45 | = | 60.37 |
| $N_3P_2K_2$ | 134.21 | - | 60 | = | 74.21 |
| $N_4P_2K_2$ | 149.89 | - | 75 | = | 74.89 |

After establishing soil nitrogen quantities uptaken by plants, one can establish the percentage of soil nitrogen utilized in relation to the easily hydrolyzed nitrogen, and the values are presented in table 12.

Hence, it was established that the coefficient of nitrogen utilization from soil in relation to easily hydrolyzed nitrogen in brown forest soil is 20.35%.

Hastly, one can conclude that by applying both procedures almost identical quantities of nitrogen were found to be available to plants. Therefore, under the same or similar conditions the average coefficient of nitrogen utilization from soil values in relation to easily hydrolyzed nitrogen content, determined by Tjurin and Kononova, can be used. This procedure is simpler since it does not require data on the uptaken quantities of nitrogen in the previous year. It only requires data on the easily hydrolyzed nitrogen content.

T a b. 12. - Coefficient of nitrogen utilization from soil in relation to easily hydrolyzed nitrogen (for the coefficient of nitrogen utilization from fertilizer value of 50% in October)

| Field variants | Easily hydrolyzed nitrogen (kg/ha) | Nitrogen uptake through yield (kg/ha) | K (%) |
|---|---|---|---|
| Control | 175.50 | 14.35 | 8.18 |
| $N_1P_2K_2$ | 211.05 | 42.95 | 20.35 |
| $N_2P_2K_2$ | 221.40 | 60.37 | 27.27 |
| $N_3P_2K_2$ | 279.00 | 74.21 | 26.60 |
| $N_4P_2K_2$ | 296.10 | 74.89 | 25.29 |

Table 13 presents the coefficient of nitrogen utilization values from soil according to reliable methods for assessment of soil nitrogen availability in brown forest soil. Apart from the coefficient of nitrogen utilization from soil, quantities of soil nitrogen considered available to plants in March and October are presented, too. The established values are calculated for the coefficient of nitrogen utilization from fertilizer value 50%, and they are used to calculate the prognosed quantities of fertilizer required for spring dressing and fertilizing in the next vegetation season.

T a b. 13. - Coefficient of nitrogen utilization from soil and nitrogen quantities considered available to plants according to the methods considered reliable in soil nitrogen availability assessment

| | March | | October | |
|---|---|---|---|---|
| | Coefficient of nitrogen utilization from soil (K%) | Soil nitrogen quantities considered available to plants (kg/ha) | Coefficient of nitrogen utilization from soil (K%) | Soil nitrogen quantities considered available to plants (kg/ha) |
| Total nitrogen | 1.06 | 52.95 | - | - |
| Easily hydrolyzed nitrogen | 25.30 | 52.95 | - | - |
| Easily hydrolyzed nitrogen | - | - | 20.35 | 43.95 |

**Calculation for Assessment of Nitrogen Fertilizer Quantities Required for Spring Dressing of Wheat**

On the grounds of established soil nitrogen quantities considered available to plants (according to methods proved to be reliable) and on the grounds of the quantities of uptaken nitrogen through prognosed yield as well as the coefficient of nitrogen utilization from fertilizer, it is possible to assess nitrogen fertilizer quantities that need to be added to the soil by applying the following calculation:

$$N_{f_1} = \frac{N_u - N_m}{E_f} \cdot 100$$

where:

$N_{f1}$ – presents quantities of nitrogen fertilizer for spring dressing (kg/ha)
$N_u$ – presents plant's need for nitrogen (kg/ha)
$N_m$ – presents quantities of soil nitrogen that will be uptaken by plants and that can be considered available to plants (kg/ha)
$E_f$ – presents the coefficient of nitrogen utilization from fertilizer (%)

According to this formula, the first element taken into account in the proposed calculation is the plant's need for nitrogen. The plant's need is determined by the uptaken nitrogen quantities, calculated from the quantity of nitrogen utilization by plants for a 1 mc yield and the prognosed yield (mc/ha). The quantities of nitrogen uptaken by plants per yield unit are generally known values. Nevertheless, the planning of a yield is not simple.

The planning of a yield probably presents the weakest link in any proposed calculation of nitrogen fertilizer quantities that need to be added to the soil. Thus, any proposed calculation model can be incorrect. Danke and Johanson (1990) point out that the main problem regarding yield is what yield should be planned, whether an average, low or high. If the nitrogen quantities to be uptaken by the plants are determined on the grounds of a high yield, then the quantities of nitrogen to be added will be higher i.e. the quantities of nitrogen fertilizer should be larger. Such planning of yield has sense only under presumption that the year in which the plants will be grown will be a favorable one, especially regarding the amount and distribution of rainfall. If not so, most of the added fertilizer will not be used, and every model will prove inefficient. The same results will be achieved when planning a lower yield in a year favorable in quantities and distribution of rainfall, since lower yield than possible will be achieved because of the low quantities of added nitrogen fertilizer. On the grounds of all this, it is obvious that the determining of required nitrogen fertilizer quantities mostly presents prognosis or evaluation and not a precise determination.

Planning of yield is only one side of the problem. The other side is related to the planning of yield in relation to the conditions existing in the soil in which the

plants are grown. Namely, it is a question whether the so called planned yield can be planned on every soil i.e. whether it is rational to plan a high yield and achieve it by applying high doses of mineral fertilizers on soil that has limited capabilities. A high yield should be treated as a relative matter, since a high yield in brown forest soil is considered low in case of chernozem.

When considering this, one must first of all bear in mind the fact that soil does not present an inert system, and the use of only mineral fertilizers in a longer period and in unfavorable conditions affects it. The complexity of yield planning and determining of nitrogen fertilizers that should be introduced to the soil is best seen in brown forest soil in Mladenovac, where this research was done. Namely, according to the general characteristics of the examined brown forest soil in the beginning of the experiment (1963) this soil had characteristics of a poor loessial soil with low acid reaction (nKCl 5.20) with total nitrogen content of 0.12% and humus content of 2.61% (Ivović et al. 1973). Thirty years later the same soil can be categorized as loessial brown forest soil. According to its pH value, it belongs to the acid or very acid soils (for all experiment variants where the applied nitrogen fertilizer pH in nKCl was below 4.5), the content of total nitrogen is generally 0.11%, and the humus content is below 2.0%. The reduction of pH values and deterioration of general characteristics of the soil were mostly the result of the applied mineral fertilizer doses, as well as the types of fertilizer (only mineral fertilizers being used which do not contain potassium). This example demonstrates that under such and similar conditions one should not plan a yield that requires introduction of significant quantities of nitrogen fertilizer. In case one does, then all required soil protection measures should be provided. This long-term experiment in brown forest soil proved that for a certain period of time a high yield can be achieved. However, after 30 years the former production on this soil would not be possible.

Hastly, one can conclude that the planning of yield is not a simple matter, as usually considered, regardless whether the planning concerns a short period (a vegetation season) or a long period of soil utilization. Namely, the main goal in yield planning, year after year, has to be at least the preservation of the initial soil fertility if not its improvement.

The second element taken into account in the proposed calculation is the nitrogen quantity considered available to plants, according to the method found to be reliable regarding the availability of soil nitrogen. In the entire calculation the determining of this parameter presents the most difficult and elaborate part of the research. However, once its reliability is established it provides application of the method for a longer period of time.

The third element is the coefficient of nitrogen utilization from fertilizers. This value depends on many factors such as: the type of soil, applied fertilizer dose, amount of rainfall, method applied for calculation of this coefficient, types

of plants. Since numerous factors have influence, it would be best to determine the values of this coefficient at least for the types of soil. This requires long-term experiments and we propose values 50-60% to be used, generally considered average values.

The effect of added nitrogen fertilizer on soil nitrogen are well - known, whereby the introduction of nitrogen fertilizers to soil increases the uptake of soil nitrogen by plants, and this increases with the increasing quantities of fertilizer applied. Thus, when calculating the required quantities of nitrogen fertilizer for spring dressing it is not sufficient to just consider the coefficient of nitrogen utilization from fertilizer but also the effect that the applied quantity of fertilizer will have on the soil nitrogen. Therefore, further in the calculation the activation effect values should be considered too, which means that when determining the required nitrogen fertilizer quantities for spring dressing the following formula should be applied:

$$N_{f2} = N_{f1} - N_{ani}$$

where:

$N_{f2}$ – presents the quantity of nitrogen fertilizer for spring dressing in spring for prognosed yield (kg/h)
$N_{ani}$ – presents the quantity of soil nitrogen that will be activated by the planned fertilizer quantity $N_{f1}$ – (kg/ha).

Although we did not use isotopically labeled nitrogen, in our research we reached the $N_{ani}$ values and the calculation results are presented in table 14.

T a b. 14. - Calculation for quantities of activated soil nitrogen in relation to the fertilizer introduced to the brown forest soil

| Field variants | Uptaken soil nitrogen | Activation effect according to $N_1P_2K_2$ (kg/ha) | Quantity of nitrogen fertilizer applied for spring dressing (kg/ha) | Quantity of soil nitrogen activated by 10 kg of nitrogen fertilizer (kg/ha) |
|---|---|---|---|---|
| $N_1P_2K_2$ | 52.95 | - | - | - |
| $N_2P_2K_2$ | 75.37 | 22.42 | 60 | 3.74 |
| $N_3P_2K_2$ | 94.21 | 41.26 | 80 | 4.69 |
| $N_4P_2K_2$ | 99.87 | 46.94 | 100 | 5.16 |

It was possible to determine the $N_{ani}$ values, since an increasing dose of nitrogen fertilizer, with known values of soil nitrogen uptake, as well as known quantities of fertilizer nitrogen used for spring dressing, were used in this research.

The activation effect values were not determined, as is usually the case, on the grounds of the PK variant, since there was no such variant in the field

experiment, nor was it done on the grounds of the control variant, but according to the variant where the least quantities of nitrogen fertilizers had been added ($N_1P_2K_2$) and in the final calculation of this research it was treated as the starting point.

The quantities of activated soil nitrogen for every 10 kg N of added fertilizer ranged from 3.74 to 4.69 kg/ha, the average value being 4.52 or approximately 4.5 kg/ha.

This means that under the same or similar conditions to those in the experimental brown forest soil the $N_{ani}$ value is 4.5 kg/ha for introduced 10 kg/ha nitrogen fertilizer.

The accuracy of the proposed method was checked in the long-term experiment in Mladenovac, where the research was done. The calculation was made for methods that proved reliable regarding availability of soil nitrogen in spring for spring dressing. The results as well as the proposed calculation are presented in table 15.

The quantities of nitrogen fertilizer for spring dressing applied in the year of this research are presented in column 11 of table 15 and quantities of nitrogen fertilizer that should be applied for spring dressing in the proposed model are presented in column 10 of the same table.

When the quantities of nitrogen fertilizer for spring dressing of wheat are determined according to the proposed model and the total and easily hydrolyzed nitrogen methods are compared with the nitrogen fertilizer quantities actually applied in the field one can conclude that the differences are minimal (table 15). Thus, in the $N_2P_2K_2$ experiment variant, a 5.63% kg N/ha larger quantity per proposed model was established in relation to the actually added quantity i.e. 9.38% higher. In the $N_3P_2K_2$ variant this quantity was 1.34 kg N/ha less i.e. 1.67%, and in the last experiment variant it was 2.95 kg N/ha, or 2.95% higher.

On the grounds of what has been presented, one can conclude that the proposed model for prognosis for fertilizer nitrogen required for spring dressing is acceptable, and that this calculation once again confirms reliability of the methods applied for evaluating availability of soil nitrogen.

**Calculation for Prognosed Quantities of Nitrogen Fertilizer to be Added to the Soil in the Wheat Vegetation Period (During Sowing and for Spring Dressing)**

In order to determine the quantity of nitrogen fertilizer that needs to be added to the soil for the whole vegetation period of the winter wheat, we applied the same calculation procedure as for the spring dressing of wheat.

Since it was found that in October the easily hydrolyzed nitrogen method can be considered reliable regarding availability of soil nitrogen, when calculating required quantities of fertilizer nitrogen, the values of available soil nitrogen determined according to this method, were used as a basis for the proposed calculation. The results as well as the calculation procedure are presented in table 16.

T a b. 15. – Provera obračuna za predloženi model prognoze upotrebe azota djubriva u gajnjači za prihranu pšenice

| **Varija-nte ogleda u polju** | Metode | Iznešena količina azota ostvarenim prinosom ($N_u$)(kg/ha) | Koeficijent iskorišćavanja azota iz zemljišta prema pouzdanoj metodi (%) | Koeficijent iskorišćavanja azota iz djubriva ($E_f$) | Količina azota zemljišta koja se može smatrati pristupačnom biljkama ($N_m$) (kg/ha) | Obračun po formuli: $N_{f_1} = \frac{N_u - N_m}{E_f} \cdot 100$ | $N_{f1}$ (kg/ha) | Količina aktiviranog azota zemljišta za primenjenu količinu azota djubriva ($N_{ani}$) (kg/ha) | $N_{f_2} = N_{f_1} - N_{ani}$ (kg/ha) | Stvarno unešene količina azota djubriva za prihranu (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| $N_2P_2K_2$ | ukupni azot | 105.37 | 1.06 | 50.0 | 52.95 | $=\frac{105.37-52.95}{50}\cdot 100$ | 104.84 | 39.21 | 65.63 | 60.0 |
| | lakohidrolizujući azot | | 25.30 | | | | | | | |
| $N_3P_2K_2$ | ukupni azot | 134.21 | 1.06 | 50.0 | 52.95 | $=\frac{134.21-52.95}{50}\cdot 100$ | 162.52 | 83.86 | 78.66 | 80.0 |
| | lakohidrolizujući azot | | 25.30 | | | | | | | |
| $N_4P_2K_2$ | ukupni azot | 149.89 | 1.06 | 50.0 | 52.95 | $=\frac{149.89-52.95}{50}\cdot 100$ | 193.88 | 90.93 | 102.95 | 100.0 |
| | lakohidrolizujući azot | | 25.30 | | | | | | | |

T a b. 16. – Provera obračuna za predloženi model prognoze upotrebe azota djubriva u gajnjači za pšenicu

| Varija-nte ogleda u polju | Metode | Iznešena količina azota ostvarenim prinosom ($N_u$)(kg/ha) | Koeficijent iskorišćavanja azota iz zemljišta prema pouzdanoj metodi (%) | Koeficijent iskorišćavanja azota iz djubriva ($E_f$) | Količina azota zemljišta koja se može smatrati pristupačnom biljkama ($N_m$) (kg/ha) | Obračun po formuli: $N_{f_1} = \frac{N_u - N_m}{E_f} \cdot 100$ | $N_{fl}$ (kg/ha) | Količina aktiviranog azota zemljišta za primenjenu količinu azota djubriva ($N_{ani}$) (kg/ha) | $N_{f_2} = N_{f_1} - N_{ani}$ (kg/ha) | Stvarno unešene količina azota djubriva za prihranu (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| $N_2P_2K_2$ | lakohidrolizujući azot | 105.37 | 20.35 | 43.33 | 42.95 | $=\frac{105.37-42.95}{43.33}\cdot 100$ | 144.40 | 54.00 | 90.40 | 90.0 |
| $N_3P_2K_2$ | lakohidrolizujući azot | 134.21 | 20.35 | 43.33 | 42.95 | $=\frac{134.21-42.95}{43.33}\cdot 100$ | 210.62 | 108.68 | 101.94 | 120.0 |
| $N_4P_2K_2$ | lakohidrolizujući azot | 149.89 | 20.35 | 43.33 | 42.95 | $=\frac{149.89-42.95}{43.33}\cdot 100$ | 246.80 | 115.75 | 131.05 | 150.0 |

This calculation was performed in the same way as the calculation for quantities of nitrogen fertilizer that should be added to the soil for spring dressing (table 15), only in this calculation a lower coefficient of nitrogen utilization from fertilizer was used (43.33%). This coefficient is determined approximately, whereby in the winter period a lower value was used (30%), since in this period the losses are more prominent and for the period spring-summer the coefficient 50% was applied. By knowing the quantities of nitrogen fertilizer applied in the vegetation period of the grown wheat in the year of the research, a 43.33% coefficient of nitrogen utilization from fertilizer was determined.

On the grounds of the results presented in columns 10 and 11 of table 16, one can conclude that there are no significant differences between the determined nitrogen fertilizer quantities in the presented model and the actually applied quantities. The differences range from 0.4-18.95 kgN/ha, which proves accuracy of the proposed calculation for the entire vegetation period for wheat (sowing + spring dressing). This calculation again proved that the applied method can be considered reliable regarding nitrogen availability in the experimental brown forest soil.

## C o n c l u s i o n

On the grounds of the presented results, one can conclude:

1. A simplified calculation was applied to determine required quantities of nitrogen fertilizer for wheat in the experimental brown forest soil. Its application requires establishing of the plant's needs for nitrogen, the determining of a reliable method in assessment of soil nitrogen availability, the establishing of the coefficient of nitrogen utilization from soil for the reliable method, knowledge of the coefficient of nitrogen utilization from fertilizer, and knowledge of activated soil nitrogen values for the added quantities of fertilizer.
2. For equal or similar conditions in experimental brown forest soil one can use the 50% coefficient of nitrogen utilization from fertilizer, when calculating for spring dressing, and when calculating required quantities of nitrogen fertilizer for the entire vegetation period, the value of this coefficient is lower i.e. 43.3%.
3. According to the long-term experiment research, one can conclude that the average value of activated soil nitrogen in brown forest soil is 4.5 kg N/ha for added 10 kg N/ha of fertilizer nitrogen.
4. The total and easily hydrolyzed nitrogen methods that were used in the proposed model i.e. in the calculation (spring dressing) that proved reliable, the differences between the quantity of fertilizer nitrogen that should be used according to the proposed model and the actually applied fertilizer quantities in the long-term experiment are minimal and range within 1.34-5.63 kg N/ha.

5. In the easily hydrolyzed nitrogen method used in the proposed calculation for determining quantities of nitrogen fertilizer required for the whole vegetation period of wheat, the differences between the nitrogen quantities that should be applied in sowing and for spring dressing, according to the proposed method and actually applied quantities, are also minimal and range within 0.4-18.95 kg N/ha limits. These results completely confirm the accuracy i.e. the value of the proposed method as well as reliability of the proposed methods for determining soil nitrogen availability.

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# ODREDJIVANJE POTREBNIH KOLIČINA DJUBRIVA ZA PŠENICU

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Cilj ovog istraživanja je bio da se na osnovu utvrdjene pouzdanosti za ocenu pristupačnosti azota zemljišta (ukupni i lakohidrolizujući azot) primeni i proveri predloženi model za utvrdjivanje količine azota djubriva koju treba uneti u zemljište za planirani prinos.

Istraživanja su obavljena na gajnjači koja se koristi u okviru stacionarnog ogleda sa odredjenim sistemom djubrenja i plodoredom već 30 godina.

Za odredjivanje potrebnih količina djubriva za pšenicu, primenjen je model obračuna za koji je potrebno utvrditi: pouzdanu metodu za ocenu pristupačanosti zemljišnog azota, na osnovu koje se odredjuje koeficijent iskorišćenja azota iz zemljišta, zatim koeficijent iskorišćavanja azota iz djubriva i vrednost aktiviranog azota zemljišta za unetu količinu azota djubriva.

Korišćena vrednost koeficijenta iskorišćavanja azota iz djubriva za uslove koji vladaju u gajnjači je bio 50%, pri obračunu za prihranu pšenice i 43,3% za obračun potrebnih količina djubriva za ceo vegetacioni period.

Na osnovu obavljenih istraživanja može se zaključiti da je prosečna vrednost aktiviranog azota zemljišta bila 4,5 kgN/ha na dodatih 10 kgN/ha azota djubriva.

Za metode ukupnog i lakohidrolizujućeg azota, koje su korišćene za predloženi model, odnosno obračun (prihrana) i za koje je utvrdjena pouzdanost, razlike izmedju količina azota djubriva koje treba primeniti po predloženom modelu i stvarno primenjenih količina djubriva na stacionarnom ogleda su minimalne i bile su u granicama od 1,34-5,63 kgN/ha.

Za metodu lakohidrolizujućeg azota, koja je korišćena za predloženi obračun potrebnih količina azota djubriva za ceo vegetacioni period za pšenicu, razlike izmedju količine azota djubriva koje treba primeniti pri setvi i za prihranu, po predloženom modelu i stvarno primenjenih količina su takodje bile minimalne i to u granicama od 0,4-18,95 kgN/ha.

Ovi rezultati u potpunosti potvrdjuju tačnost, odnosno vrednost predloženog modela, ali i pouzdanost navedenih metoda za ocenu pristupačnosti azota zemljišta.

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