THE EFFICIENCY OF USING NITROGEN FERTILIZERS IN WHEAT CROP

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Abstract. Nitrogen has its undeniable role in increasing crop productivity and quality. However, used improperly, it can cause serious environmental damage. Increasing the efficiency of the use of chemical nitrogen fertilizers (NUE) is a goal of the future, necessary for a sustainable and competitive agriculture. The wheat crop studied is part of a long-term experiment, established in Lovrin in 1967. The experimental factors studied are: factor A - nitrogen, with the following graduations: N0, N30, N60, N90 and N120 and factor B - phosphorus, with the following graduations: P0, P40, P80, P120 and P160. From the combination of the two studied factors results 25 experimental variants, placed in the field according to the method of subdivided plots, in four repetitions. Chemical fertilizers with phosphorus - 46% superphosphate - were administered to the wheat crop in autumn and were incorporated under the basic plowing. Nitrogen fertilizers - 33.5% ammonium nitrate - were applied in fractions: 40% of the dose at start of vegetation, in the spring and 60% at straw elongation. The wheat culture is part of a three-year crop rotation - soybeans-wheat-corn. Following in rotation after soybeans, no nitrogen fertilizers were applied at the establishment of the crop. The variety studied is the Ciprian variety, created at SCDA Lovrin. For the evaluation of NUE, Plant N Uptake, Nitrogen Use Efficiency and Partial Factor Productivity were analyzed in this paper. In the climatic conditions of the two experimental years, a distinctly significant positive correlation is established between the nitrogen dose administered and production, the value of the correlation coefficient being 0.56 **. Between the nitrogen dose, the protein content and the amount of protein per ha the correlation coefficient is very significant, with the following values of the correlation coefficients: r = 0.96 *** (for protein) and r = 0.90 *** (for N uptake). Nitrogen use efficiency correlates negatively, very significantly, with the administered dose - r = -0.87 ***. This study also reveals the importance of phosphorus in the absorption and accumulation of nitrogen in wheat caryopsis. The amount of nitrogen accumulated increases with increasing dose of phosphorus, up to 80 kg ha-1, with the gradual reduction of the amount accumulated to high values of phosphorus administered (120 kg ha-1 and 160 kg ha-1, respectively).

Keywords: winter wheat, nitrogen, N uptake, Nitrogen Use Efficiency.

INTRODUCTION

The use of nitrogen fertilizers globally has reached 100 billion kg annually, more than half of this amount being used for the production of cereals (wheat, rice, corn, etc.) (LADHA, 2016). Intensive agriculture in recent decades has led to growth 7 times of the amount of nitrogen used in agriculture. However, the various practices applied to crop management cause significant losses of nitrogen, with repercussions on the environment (water and air). More than 50% of the administered nitrogen is not recovered by plants (LASSALETTA, 2014). The largest losses occur through leaching and cause eutrophication of freshwaters (LONDON, 2005) and marine waters (BEMAN, 2005). Also, nitrogen oxide emissions severely affect the ozone layer in the stratosphere (RAMOS, 1996; STULEN, 1998).

With all its the negative effects on the biosphere, nitrogen fertilizers remain the basic source of agricultural production - quantitative and qualitative, to meet the food needs of both humans and animals.

The challenge of the future is to provide food resources for a growing population and at the same time preserve the quality of the environment. The development of agricultural strategies that include the selection of resistant and less demanding genotypes towards nitrogen nutrition is a desideratum of the future (DELMER, 2005).

It is well known that nitrogen significantly influences the growth and development of plants. Knowledge of the physiological mechanisms that contribute to the absorption and use of nitrogen are particularly important to increase the efficiency of use of this chemical element.

Nitrogen use efficiency (NUE) is defined as the amount of nitrogen in total nitrogen applied to a crop that is absorbed and recovered by plants.

In order to evaluate as accurately as possible the response of crops to fertilization, a series of indices are used and described in the literature (NOVOA, 1981; CASSMAN, 2002). In agronomic studies, the highlighting of these indices is generally based on the production obtained and on the total amount of nitrogen absorbed from the soil (DOBERMANN, 2005).
Among the mentioned indices, Plant N Uptake, Nitrogen Use Efficiency and Partial Factor Productivity will be analyzed in this paper.

For their calculation the formulas suggested by Dobermann, Moll and Hiremath will be used:

Nitrogen use efficiency was calculated with the formula suggested by Moll:

\[
\text{NUE} (\%) = \frac{(N_f - N_c)}{N_{\text{supply}}} 
\]

in which:
- \(N_f\) — total nitrogen of fertilized crop;
- \(N_c\) — total nitrogen of control variant (unfertilized);
- \(N_{\text{supply}}\) — rate of N fertilizer applied.

For N uptake the formula suggested by Hiremath was used:

\[
\text{Plant N uptake (kg N/ha)} = \frac{N_{\text{total}} (\text{kg N/kg yield}) \times \text{GY (kg/ha)}}{100} 
\]

in which:
- \(\text{GY (kg/ha)}\) — wheat grain yield.

The formula suggested by Dobermann was used to determine the partial productivity factor. This factor has been used extensively over time and indicates the ratio between the amount of nutrient that is used and the amount of nutrient that is administered to crops.

\[
\text{PFP (kg grain/kg N)} = \frac{\text{GY}}{N_{\text{supply}}} 
\]

in which:
- \(\text{GY (kg/ha)}\) — grain yield;
- \(N_{\text{supply}}\) — rate of N fertilizer applied.

Numerous specialized works show that, while its production and quality increase with increasing dose of nitrogen, the efficiency of its use decreases with increasing dose. This is because nitrogen uptake is conditioned by certain factors that are limited or inhibited by high doses.

**MATERIAL AND METHODS**

The experiment was set up at the Agricultural Research and Development Station Lovrin, on a typical chernozem, poorly glazed, slightly alkalized, with a pH -6.7, poorly supplied with nitrogen and medium supplied with phosphorus and potassium.

The studied culture is part of a long-term experience with fertilizers, established in Lovrin in 1967. The experimental factors studied are: factor A - nitrogen, with the following grades: N0, N30, N60, N90 and N120 and factor B - phosphorus, with the following grades: P0, P40, P80, P120 and P160. From the combination of the two studied factors results 25 experimental variants, placed in the field according to the method of subdivided plots, in four repetitions.

Chemical fertilizers with phosphorus - 46% superphosphate - were administered to the wheat crop in autumn and were incorporated under the basic plowing. Nitrogen fertilizers - 33.5% ammonium nitrate - were applied in fractions: 40% of the dose at start of vegetation, in the spring and 60% at straw elongation. The wheat culture is part of a three-year crop rotation - soybeans-wheat-corn. Following in rotation after soybeans, no nitrogen fertilizers were applied at the establishment of the crop.

The variety studied is the Ciprian variety, created at ARDS Lovrin.

The protein content of wheat was determined using the Perten apparatus, in the wheat breeding laboratory at ARDS Lovrin.

The data obtained were statistically interpreted according to the method of analysis of variance (ANOVA).

**RESULTS AND DISCUSSIONS**

The pedological and atmospheric drought installed in the last years in the western part of Romania, especially in the spring months, determined a poor recovery of nitrogen fertilizers administered to crops, which was highlighted in the poor production and quality of the crop.

In this study is presented the contribution of technological factors, both unilaterally and combined on the analyzed parameters.

Table 1 shows the production obtained between 2019-2020. There is a limitation on the increase of production at high doses of nitrogen, starting up with dose of 90 kg ha-1. The level of production in the analyzed period varies between 3905 - 4997 kg ha-1.

The unilateral application of nitrogen registers, compared to the unfertilized control variant, statistically significant and distinctly significant production increases. The highest value of production is obtained in the fertilized...
variant with 60 kg ha⁻¹, with 926.3 kg more than in the control variant, a statistically significant value for the probability of transgression of 1%.

Unilaterally applied phosphorus brings small production increases, not statistically assured.

The highest yields are highlighted by the combined application of the two types of fertilizers, with the highest value recorded in the N₉₀P₆₀ variant, with a distinctly significant increase compared to the control, of 1091.7 kg.

**The agrophysical influence of winter wheat yield**

<table>
<thead>
<tr>
<th>Factor A</th>
<th>Factor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>b₁-P₀</td>
<td>b₂-P₄₀</td>
</tr>
<tr>
<td>Yield</td>
<td>Difference</td>
</tr>
<tr>
<td>a₁ – N₀</td>
<td>3905</td>
</tr>
<tr>
<td>a₂ – N₃₀</td>
<td>4373</td>
</tr>
<tr>
<td>a₃ – N₆₀</td>
<td>4831</td>
</tr>
<tr>
<td>a₄ – N₉₀</td>
<td>4571</td>
</tr>
<tr>
<td>a₅ – N₁₂₀</td>
<td>4594</td>
</tr>
</tbody>
</table>

DL 5% = 651 DL 1% = 886 DL 0.1% = 1195

Table 2 shows the protein content, determined after harvesting the culture, in the laboratory, using the Perten NIR Infrared device.

**The protein content**

<table>
<thead>
<tr>
<th>Factor A</th>
<th>Factor B</th>
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<tbody>
<tr>
<td>b₁-P₀</td>
<td>b₂-P₄₀</td>
</tr>
<tr>
<td>a₁ – N₀</td>
<td>9.73</td>
</tr>
<tr>
<td>a₂ – N₃₀</td>
<td>12.70</td>
</tr>
<tr>
<td>a₃ – N₆₀</td>
<td>13.00</td>
</tr>
<tr>
<td>a₄ – N₉₀</td>
<td>14.43</td>
</tr>
<tr>
<td>a₅ – N₁₂₀</td>
<td>14.57</td>
</tr>
</tbody>
</table>

DL 5% = 0.77 DL 1% = 1.05 DL 0.1% = 1.41

The amplitude of the protein content in the experiment is 5.77%. The predominant influence on the protein content was the nitrogen fertilization. The contribution of phosphorus fertilization was almost insignificant. Consequently, the application of nitrogen is one of the decisive technological measures for achieving a desirable protein content.

The highest value of the protein percentage is highlighted by the combined application of the two types of fertilizers, with differences from the unfertilized control statistically assured very significant, for the probability of transgression of 0.1%.

Nitrogen uptake, calculated as the product of the amount of nitrogen / kg of grain and the yield per hectare, is shown in Table 3. Previously, the contribution of phosphorus to obtaining higher wheat yields was also revealed. Expressing the protein content in kg / ha we witness a notable indirect contribution of phosphorus to the increase in protein production per hectare.

Analyzing Table 3 shows the importance of phosphorus in the absorption and accumulation of nitrogen in wheat caryopsis. The amount of accumulated nitrogen increases with the increase of the dose of phosphorus, up to the value of 80 kg ha⁻¹, with the gradual reduction of the amount accumulated at high values of phosphorus administered (120 kg ha⁻¹ and 160 kg ha⁻¹ respectively).

**Nitrogen uptake**

<table>
<thead>
<tr>
<th>Factor A</th>
<th>Factor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>b₁-P₀</td>
<td>b₂-P₄₀</td>
</tr>
<tr>
<td>a₁ – N₀</td>
<td>67.52</td>
</tr>
<tr>
<td>a₂ – N₃₀</td>
<td>94.25</td>
</tr>
<tr>
<td>a₃ – N₆₀</td>
<td>109.64</td>
</tr>
<tr>
<td>a₄ – N₉₀</td>
<td>117.65</td>
</tr>
<tr>
<td>a₅ – N₁₂₀</td>
<td>114.93</td>
</tr>
</tbody>
</table>

DL 5% = 15.76 DL 1% = 21.75 DL 0.1% = 30.12

Nitrogen use efficiency, a factor of practical importance for each farm, with repercussions on both crop productivity and quality, and on the environment, is shown in Table 4. NUE records interesting values under the influence of experimental factors. As revealed in many other specialized works, with increasing doses of nitrogen decreases the efficiency of its use. Thus, in the climatic conditions of the two years analyzed, there is a
decrease of NUE, from 70.3%, value recorded when applying the dose of 30 kg / ha, to 38.53% - when applying the maximum dose (120 kg / ha).

Figure 1 shows the simple correlation between the amount of nitrogen administered to the crop and the indicators studied in this experiment.

Thus, in the climatic conditions of the two experimental years, a distinctly significant positive correlation is established between the administered nitrogen dose and production, the value of the correlation coefficient being 0.56 **. Between the nitrogen dose, the protein content and the amount of protein per ha the correlation is very significant, with the following values of the correlation coefficients: $r = 0.96 ***$ (for protein) and $r = 0.90 ***$ (for N uptake). Nitrogen efficiency correlates negatively, very significantly, with the administered dose - $r = -0.87 ***$.
In Figure 2, the eigenvalues for all principal components, obtained by applying the ACP method, are plotted in a sequence of principal factors (principal components). The number of factors is chosen where the levels of the graph show a linear decreasing pattern. The figure above illustrates the existence of variance in the experimental data in proportion of 68.95% in relation to PC1 and proportion of 20.46% in relation to PC2.

CONCLUSIONS

The climatic conditions of the two years of experimentation were very atypical for the western part of Romania, characterized by severe pedological and atmospheric drought in the spring months and temperatures that exceeded the multiannual average by up to + 6 °C in April. Under these conditions, the efficiency of chemical fertilizers with nitrogen, administered in spring, was very low.

Nitrogen has its undeniable role in increasing crop productivity and quality. The efficiency of its use by plants depends on a number of factors. This paper presents the influence of nitrogen and phosphorus doses administered to wheat crop on NUE.

With increasing doses of nitrogen decreases the efficiency of its use. Thus, in the climatic conditions of the two years analyzed, there is a decrease of NUE, from 70.3%, value recorded when applying the dose of 30 kg / ha, to 38.53% - when applying the maximum dose (120 kg / ha) . There is an increase in NUE in the combined administration of the two types of fertilizers, phosphorus being an indisputable support for the absorption and accumulation of nitrogen in plants.

BIBLIOGRAPHY