Agrochemical Principles of Targetting Winter Wheat Yield on Leached Chernozem of the Stavropol Elevation

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Winter wheat is one of the most common major food crops in the world. Wheat grain value is determined by high content of protein, fat, and carbohydrates. Cultivation of winter wheat is beneficial, as the resulting product has a low cost. Winter wheat is a high-yield crop (second only to rice). The average yield of the winter wheat in the Russian Federation is 30 t/ha, while in the advanced farms it reaches to 50-60 t/ha. The highest yield in the Russian Federation was obtained in the Krasnodar Territory, amounting for 103.6 kg/ha, whereas worldwide, in Canada - 170 kg/ha. Protein content greatly depends on soil and climatic conditions. In wheat and other crops, protein content increases in the regions from north to south and from east to west. Aridity of air, solar radiation, high concentrations of nitrogen in the soil, and the level of agricultural technology affect the quality of the grain. The Department of Agricultural Chemistry and Plant Physiology of the Federal State Budgetary Educational Institution of Higher Professional Education (FSBI HPO) “Stavropol State Agrarian University” carried out studies in the 2010-2014 on leached chernozem of the Stavropol elevation. The conducted studies aimed at targeting of winter wheat (Zustrich cultivar) yield in the zone of moderate humidity based on the optimization of fertilizer application. The article presents the four-year data on the effect of fertilization rates on the dynamics of labile phosphorus and exchangeable potassium in the soil layer of 0-20 cm, as well as on the yield and quality of winter wheat (Zustrich cultivar), cultivated on leached chernozem in the zone of erratic moistening of the Stavropol Territory. According to the results based on three years data, at the expected harvest of 6.0 t/ha, the reliability of the yield targeting on leached chernozem of Stavropol elevation, when applying N126P80K72, was 99% according to the calculation method suggested by V. Ageev (Esaulko & Ustimenko, 2014).

Key words: Weather conditions, Mineral fertilizers, Leached chernozem, Winter wheat, yield targeting.

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Winter wheat is the main grain crops in the Stavropol Territory. Every year it is planted on an area of 1.2-1.3 million ha. In 90-ies of the XX century and the beginning of the XXI century, grain yield in the Territory reached to 24-30 t/ha from the entire area, whereas in some years it was even higher, amounting to 32-34 t/ha (Gerasimov et al., 2014).

The total crop acreage of wheat in the Stavropol Territory in 2013 amounted to 1717.5 thousand hectares. In relation to 2012, the acreage decreased by 9%, while compared to 2010, when the area of planted land was maximal, amounting to 1730.7 thousand hectares, crop acreage decreased by 10% (Berezhnoy et al., 2014; Gerasimov et al., 2014).
Yield of winter wheat in 2013 was 31.5 kg/ha. This is by 29.0% more than in 2012. The average yield of wheat in 2011 was 39.5 kg/ha. This is substantially higher than the yield index in 2012 (43%), though the yield in 2010 is somewhat less than in 2011 by 13% (Gerasimov et al., 2014; Trukhachev et al., 2014).

In the Stavropol Territory there are sharp fluctuations in the yield of winter wheat, despite the stable crop acreage. Therefore, our task is to optimize the nutrition of winter wheat to improve its yield and quality.

Among the agronomic practices aimed at increasing crop yields and improving the quality of crop production, paramount importance has optimization of mineral nutrition on the basis of rational use of fertilizers, taking into account bioclimatic potential of the area (zone), peculiarities of the plants and market conditions (Esaulko & Gorbatko, 2012; Sadras & Lemaire, 2014). A balanced nutrition of plants by macro-and micronutrients controls many metabolic processes and plays a key role in the formation of the crop and its chemical composition. All nutrients in plants operate vital functions. Their content determines the productivity of crops; lack of nutrients will certainly affect the productivity and product quality (Massoudifar et al., 2014; Zhao et al., 2014; Kunrath et al., 2015; Grahmann et al., 2013).

The most important task of domestic agriculture under the contemporary conditions is increasing of its productivity. Currently, the provisions that agricultural chemicals are the material basis of soil fertility, as well as the wealth and power of the state, are increasingly supported by long-term scientific research (‘íp et al., 2013). Today’s agronomy is knowledge of the system consisting of soil, plant, and the active layer of the atmosphere. On the other hand, it is a set of agro-technology methods, implemented at different time frames under specific soil and climatic conditions to insure high yields (Basha et al., 2013; Deeks et al., 2013). A set of science-based agro-technology methods related to natural and economic parameters contributes to achieving the goal, i.e. obtaining high crop productivity and sustainable crop production with simultaneous reproduction of soil fertility and environmental friendliness of agricultural products (Montemurro&Maiorana, 2013; Yuan et al., 2014). The problem of providing the population with foodstuff and feeding is solved mainly through further increase of the arable land productivity. This is facilitated by the specific field of agricultural science (Wang et al., 2014; Pandiaraj et al., 2015). Yield targeting means development of a set of interrelated activities, whose timely and quality performance provides achievement of the targeted level of crop yields of given quality while improving soil fertility and meeting the requirements of environmental protection (Esaulko & Ustimenko, 2014; Lü et al., 2013).

Methodology
Field research was carried out at the agricultural experiment station of the Stavropol State Agrarian University. Studies were conducted in the 2010-2014. The research object was winter wheat (midripening Zustrich cultivar with ripeness period of 273-282 days), medium growth and having high standing ability. This cultivar is of steppe ecotype and has high ecological plasticity, drought hardness and frost tolerance. In terms of quality it belongs to the strong wheat (content of the protein ranges from 12.0 to 13.5%, fibrin from 27 to 28%) (Esaulko & Ustimenko, 2014).

Soil of the test area was represented by low humic, heavy loamy, deep leached chernozem having a pretty solid structure density of 1.15-1.31 g/cm³. The exchange capacity of the arable layer was 40 mg. eq. per 100 g of soil. The reaction of soil solution averaged to 6.7, which is close to neutral pH. The soil is characterized by medium content of humus (5.1-5.6%), the average content of labile phosphorus (22 mg/kg of soil), and high content of exchangeable potassium (240-260 mg/kg soil). The total average multiyear precipitation in the area of the conducted experiments is 623 mm, and the average annual temperature is 9.2°C. Based on the main agro-climatic indicators, we can conclude that the weather conditions of the agricultural experiment station are favorable for cultivating and producing sustainable yields of winter wheat.

The ammophos, ammonium nitrate, and potassium chloride were used as mineral fertilizers. The fertilizers were applied before seeding during the basic soil processing. Pea was the preceding crop. Arrangement of plots was carried out using randomized block design replication method with 3-fold replications. The plot was 12 m wide and 80 m
The formulas for the calculation of mineral fertilizer rates for expected yield of winter wheat

Calculation of mineral fertilizer rates for expected yield of winter wheat equal to 4.0, 5.0 and 6.0 t/ha was carried out by two methods. In accordance with the first approach, developed by V. Ageev, the rates of phosphate and potash fertilizers were calculated as follows:

$$R = \frac{Y - Y_{P_{2}O_{5}}}{K_{s}} \times 100,$$

where:
- \(R\) – rate of \(P_{2}O_{5}\) and \(K_{2}O\), kg/ha;
- \(Y\) – \(P_{2}O_{5}\) and \(K_{2}O\) removal with the expected grain yield, kg/ha;
- \(K_{s}\) – utilization coefficient of phosphorus and potassium from the soil versus removal with the expected grain yield (0.47-0.66 for phosphorus and 0.58-0.70 for potassium with due consideration of labile forms of phosphorus and potassium content in the soils and targeted yield);
- \(K_{f}\) – the utilization coefficient of phosphorus and potassium from fertilizer (40 and 70%, respectively).

Rates of nitrogen fertilizers were calculated by the modified formula:

$$R = \frac{Y_{(N)} - Y_{(P_{2}O_{5})}K_{c}(P_{2}O_{5})K_{f}}{K_{f}} \times 100,$$

where:
- \(R\) – the removal (N) ratio of the expected grain yield to the \(P_{2}O_{5}\) of the targeted grain yield;
- \(K_{c}\) – compensation factor of nutrients removal due to fertilizers (0.49-0.52 for nitrogen, 1.10-1.36 for phosphorus, and 0.30-0.43 for potassium depending on the expected level of productivity).

According to the second method, developed by the scientists of Stavropol Science Research Institute of Agriculture (SSRIA) and the “Stavropol” Agrochemical Center (SACC), rates of fertilizers were calculated using the formula:

$$R = CTK_{c},$$

where:
- \(C\) – the expected grain yield, hundred weight/ha;
- \(Y\) – removal of \(N\), \(P_{2}O_{5}\), and \(K_{2}O\) per one hundred weight of expected grain yield;
- \(K_{c}\) – compensation factor of nutrients removal due to fertilizers (0.49-0.52 for nitrogen, 1.10-1.36 for phosphorus, and 0.30-0.43 for potassium depending on the expected level of productivity).

In addition, a control option was included (without fertilizer) and an option with average recommended fertilizing rates for the given soil-climatic zones. Potassium chloride was applied when plowing, amorphous was applied when sown, while ammonium nitrate was applied during early spring nutrition.

**RESULTS**

Weather conditions during the research years were characterized by irregular precipitation, inferior to multiyear rate by 43-89 mm (Table 1).

The most favorable agro-meteorological conditions for the formation of culture crop were in the 2010-2011. The amount of precipitation during the crops growing season (580 mm) was inferior to mean annual precipitation by 7%, though uniform distribution of rainfall contributed to the optimum moisture availability of crops and the highest yield of winter wheat. The average annual temperature of 10.6 °C was by 1.4°C higher than the multiyear values.

**Table 1.** Distribution of precipitation during the study according to the data of the Stavropol meteorological station, mm

<table>
<thead>
<tr>
<th>Years</th>
<th>Total precipitation</th>
<th>Total annual precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VIII</td>
<td>IX</td>
</tr>
<tr>
<td>2010-2011</td>
<td>5</td>
<td>67</td>
</tr>
<tr>
<td>2011-2012</td>
<td>28</td>
<td>39</td>
</tr>
<tr>
<td>2012-2013</td>
<td>75</td>
<td>11</td>
</tr>
<tr>
<td>2013-2014</td>
<td>57</td>
<td>111</td>
</tr>
<tr>
<td>Multiyear average</td>
<td>54</td>
<td>43</td>
</tr>
</tbody>
</table>
Weather conditions in 2011-2012 were extremely unfavorable for the crop formation. The uneven distribution of precipitation in the spring and summer seasons had an adverse effect on the winter wheat crop formation. The amount of precipitation in 2011-2012 was less than the mean multiyear precipitation by 27%. Rainfall in 2012-2013 was worse than the mean multiyear precipitation by 15%. Overall, in 2013-2014 the total amount of precipitation was 705 mm that exceeded the average annual rates by 13%. However, rainfall distribution during the crops growing season was uneven, and a shortage of precipitation was observed against the background of high air temperatures and atmospheric drought (Fuhrer et al., 2014). At that, the elevated temperature regime was noted throughout the whole crops growing season. The average annual temperature has exceeded the mean multiyear temperature by 0.3°C.

Effect of optimizing the application of mineral fertilizers rates on the dynamics of the labile phosphorus content and exchangeable potassium in the 0-20 cm layer of leached chernozem.

We found that the highest content of labile phosphorus and exchangeable potassium according to V. Ageev calculation method was noted in all the tested options during the booting stage on labile phosphorus and before seeding stage on the exchangeable potassium; this value was reduced with the increase in vegetative mass till the stage of full ripeness (Tables 2 and 3).

Not all tested options exceeded control rates in terms of the labile phosphorus content in the soil. Thus, the labile phosphorus content in the soil at the options with the recommended fertilization rates and \( N_{105} \cdot P_{60} \cdot K_{60} \) was insignificantly lower than controls during all the studied vegetation stages. Other studied fertilizer rates increased during the growing season the content of labile phosphorus in the soil layer of 0-20 cm. At that, the difference with the control was 4.7-6.9 mg/kg before seeds; 4.0-5.6 mg/kg in the tillering stage; 2.2-4.4 mg/kg in the ear stage, and 2.9-5.1 mg/kg in a stage of full ripeness. In this case, a significant increase of labile phosphorus relative to control was noted in all the options with the recommended fertilization rate and \( N_{126} \cdot P_{80} \cdot K_{72} \).

The highest content of labile phosphorus in the soil during all the stages of plant development was noted when applying \( N_{126} \cdot P_{80} \cdot K_{72} \).

Table 2. Effect of the optimized mineral fertilizers application on the dynamics of the labile phosphorus content (mg/kg) in the 0-20 cm layer of leached chernozem, 2010-2014

<table>
<thead>
<tr>
<th>Calculation method</th>
<th>Before seeding</th>
<th>Tillering</th>
<th>Earing</th>
<th>Full ripeness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>24.3</td>
<td>25.4</td>
<td>22.0</td>
<td>20.2</td>
</tr>
<tr>
<td>Recommended N₆₀P₆₀K₃₀</td>
<td>29.0</td>
<td>29.4</td>
<td>24.2</td>
<td>23.1</td>
</tr>
<tr>
<td>*N₆₀P₃₄K₃₄</td>
<td>26.7</td>
<td>27.3</td>
<td>22.9</td>
<td>21.0</td>
</tr>
<tr>
<td>*N₁₀₅P₆₀K₆₀</td>
<td>28.0</td>
<td>27.9</td>
<td>24.1</td>
<td>22.7</td>
</tr>
<tr>
<td>*N₁₂₆P₈₀K₇₂</td>
<td>31.2</td>
<td>31.0</td>
<td>26.4</td>
<td>25.3</td>
</tr>
</tbody>
</table>

*Calculation method according to V.Ageev

Table 3. Effect of the optimized mineral fertilizers application on the dynamics of the exchangeable potassium content (mg/kg) in the 0-20 cm layer of leached chernozem, 2010-2014

<table>
<thead>
<tr>
<th>Calculation method</th>
<th>Before seeding</th>
<th>Tillering</th>
<th>Earing</th>
<th>Full ripeness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>241</td>
<td>232</td>
<td>218</td>
<td>216</td>
</tr>
<tr>
<td>Recommended N₆₀P₆₀K₃₀</td>
<td>253</td>
<td>244</td>
<td>228</td>
<td>231</td>
</tr>
<tr>
<td>*N₆₀P₃₄K₃₄</td>
<td>253</td>
<td>238</td>
<td>221</td>
<td>203</td>
</tr>
<tr>
<td>*N₁₀₅P₆₀K₆₀</td>
<td>257</td>
<td>250</td>
<td>232</td>
<td>220</td>
</tr>
<tr>
<td>*N₁₂₆P₈₀K₇₂</td>
<td>262</td>
<td>254</td>
<td>240</td>
<td>237</td>
</tr>
</tbody>
</table>

*Calculation method according to V.Ageev
During the vegetation not all fertilized options exceeded on average the control in terms of the labile exchangeable potassium content in the soil (Zörb et al., 2014). Thus, the content of exchangeable potassium in the soil at the option with N_{60}P_{34}K_{34} was insignificantly lower than controls in all the studied vegetation stages. At that, the substantial increase in exchangeable potassium against the control was mentioned for all the options with N_{126}P_{80}K_{72}: 262, 254, 240 and 237 mg/kg of soil, and the difference compared with the control amounted to 21 and 22 mg/kg of soil.

**Effect of different mineral fertilizers rates on the structure of the winter wheat crop**

From the data presented in Table 4 it is obvious that the tested fertilizer rates, as compared to control, reliably increased wheat yield structure parameters (Miao et al., 2015), such as the length of the spike (increased by 0.7-3 cm), the number of grains per spike (increased by 2-7 pc.), the weight of thousand grains (increased by 1.2-3.5 g), and the mass per spike (increased by 0.01-0.09 g).

It should be noted that all studied fertilizer rates had reliable effect on the number of plants per 1 m², as the difference relative to the control was 44-148 pcs. Thus, the number of plants and the density of productive haulm were priority in the formation of the crop in the option with expected yield of 6.0 t/ha at estimated fertilizer system based on application of N_{126}P_{80}K_{72} and N_{110}P_{82}K_{51}; higher values were shown by structural indicators of spike and the mass of thousand grains.

**Effect of different mineral fertilizers rates on the yield of winter wheat in the temperate humid zone of the Stavropol Territory**

The data presented in Table 5 show that all studied fertilizer rates reliably increased the yield of winter wheat (He et al., 2013); the difference relative to control was 1.03-2.9 t/ha in 2010-2011, 0.97-2.28 t/ha in 2011-2012, 0.69-3.17 t/ha in 2012-2013, and 0.66-2.69 t/ha in 2013-2014.

When optimizing mineral nutrition for expected yield of winter wheat at the level of 4.0 t/ha, we revealed that all studied computational methods for determining fertilizers rates showed a fairly high accuracy in targeting of crop yields, while deviations from 3 to 7% were negligible. When applying N_{60}P_{44}K_{24} (4.85 t/ha), the calculations performed by the second method showed culture productivity, which was higher
than that calculated by V. Ageev method by 18%.

Similar results were observed when targeting the yield of 5.0 t/ha. Both calculation methods provided a negligible deviation from the targeted productivity towards decrease by -2.0 and -2.5%.

When applying fertilizers for targeted productivity level of 6.0 t/ha, the rate calculated by V. Ageev method exceeded that calculated by the method, suggested by SSRIA and SACC, by 4.8%. In turn, applying N_{60}P_{34}K_{30} resulted in significant deviation from the targeted productivity level by 11%. In contrast, when applying N_{126}P_{80}K_{72}, calculated by the method of SSRIA and SACC, the deviation was within the experimental error.

Regardless of the calculation method, we were unable to obtain the targeted level of winter wheat yield equal to 6.0 t/ha. Nevertheless, the greatest targeting effect was produced in 2012-2013, when all options provided reliable increase in crop yield (deviation was +4% and +13%, respectively).

Thus, in the course of the research conducted, all studied fertilizer rates significantly increased the yield of winter wheat as compared with the controls. Comparison of the concerned methods of estimated fertilizer rates with regard to targeted yields of 4.0 and 6.0 t/ha showed that there were no significant differences in the yield of winter wheat.

### Table 5. Winter wheat yield in temperate humid zone of Stavropol Territory for 2010-2014, based on the optimization of mineral nutrition rates

<table>
<thead>
<tr>
<th>Fertilizer Calculation Targeted Yield, t/ha</th>
<th>Average Yield, t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.12</td>
</tr>
<tr>
<td>N_{60}P_{40}K_{30} Recommended</td>
<td>4.3</td>
</tr>
<tr>
<td>N_{60}P_{34}K_{34} 1*</td>
<td>4.15</td>
</tr>
<tr>
<td>N_{60}P_{44}K_{24} 2*</td>
<td>4.39</td>
</tr>
<tr>
<td>N_{60}P_{60}K_{40} 1*</td>
<td>4.63</td>
</tr>
<tr>
<td>N_{60}P_{40}K_{40} 2*</td>
<td>5.17</td>
</tr>
<tr>
<td>N_{126}P_{80}K_{72} 1*</td>
<td>6.02</td>
</tr>
<tr>
<td>N_{110}P_{82}K_{51} 2*</td>
<td>5.8</td>
</tr>
<tr>
<td>HCP05</td>
<td>0.27</td>
</tr>
<tr>
<td>Sx, %</td>
<td>3.6</td>
</tr>
</tbody>
</table>

* 1-Calculation method by V. Ageev.
* 2-Calculation method by the scientists of SSRIA and SACC.

### Table 6. Effect of mineral fertilizers rates on grain quality of winter wheat

<table>
<thead>
<tr>
<th>Expected Yield, t/ha</th>
<th>Calculation method</th>
<th>Fertilizer rates</th>
<th>Fibrin content, %</th>
<th>Hardness, %</th>
<th>Fibrin strain</th>
<th>Grain class</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Control</td>
<td>0</td>
<td>17.1</td>
<td>38.0</td>
<td>80</td>
<td>V</td>
<td>9.19</td>
</tr>
<tr>
<td>4.0</td>
<td>Recommended</td>
<td>N_{60}P_{40}K_{30}</td>
<td>19.5</td>
<td>40.0</td>
<td>73</td>
<td>IV</td>
<td>11.34</td>
</tr>
<tr>
<td>2*</td>
<td></td>
<td>N_{60}P_{44}K_{24}</td>
<td>24.7</td>
<td>45.0</td>
<td>75</td>
<td>IV</td>
<td>11.00</td>
</tr>
<tr>
<td>5.0</td>
<td>1*</td>
<td>N_{105}P_{60}K_{40}</td>
<td>25.8</td>
<td>49.0</td>
<td>72</td>
<td>IV</td>
<td>11.51</td>
</tr>
<tr>
<td>2*</td>
<td></td>
<td>N_{90}P_{67}K_{40}</td>
<td>26.5</td>
<td>48.0</td>
<td>73</td>
<td>IV</td>
<td>11.12</td>
</tr>
<tr>
<td>6.0</td>
<td>1*</td>
<td>N_{105}P_{60}K_{40}</td>
<td>27.0</td>
<td>65.0</td>
<td>75</td>
<td>III</td>
<td>12.48</td>
</tr>
<tr>
<td>2*</td>
<td></td>
<td>N_{110}P_{82}K_{51}</td>
<td>26.7</td>
<td>55.0</td>
<td>73</td>
<td>III</td>
<td>12.71</td>
</tr>
</tbody>
</table>

* 1-Calculation method by V. Ageev.
* 2-Calculation method by the scientists of SSRIA and SACC.
On the average, over four years of studies, both calculation methods of fertilizer rates provided targeted wheat yield at the level of 4 t/ha when applying N60P34K34 and N68P44K24. Targeted yield at the levels of 5.0 and 6.0 t/ha were not reached, though the greater targeting reliability of 99% was obtained when applying the fertilizer rate of N126P80K72 for targeted yield of 6.0 t/ha using V. Ageev calculation method.

**Effect of various mineral fertilizers rates on grain quality of winter wheat in the temperate humid zone of the Stavropol Territory**

As is obvious from Table 6, grain hardness index in various options ranged from 38.0 to 65.0%, whereas for the milling industry minimal grain hardness index of winter wheat should not be below 40% (He et al., 2013). Expected yield levels of 4.0 and 5.0 t/ha, as well as the recommended fertilizer rate, provided grain of Class IV, while control parameter corresponded to class V. Nothing but the expected productivity levels of 6.0 t/ha provided grain of class III. On the average, over four years all the studied fertilizer rates increased fibrin content by 2.4-9.9% as compared with the control. At that, in the options with the expected yield of 5.0 and 6.0 t/ha V. Ageev method provided higher fibrin content. The application of all the studied rates of mineral fertilizers also contributed to the production of high quality fibrin: readings of fibrin strain meter showed 72-80 un. All studied fertilizer rates increased protein content as compared to the control. The maximum protein content, regardless of calculation method was observed in the options with the expected yield of 6 t/ha.

**DISCUSSION**

While conducting research on winter wheat crops, we have found a close relationship between the change in content of labile forms of nitrogen in the soil, as well as mineral fertilizers forms and rates applied depending on the agrometeorological conditions. Mineral nitrogen content in soil is dependent on the precipitation amount and distribution during the culture’s growing season. The higher amount of precipitation, higher the content of mineral nitrogen in soil.

When optimizing mineral nutrition for the expected level of winter wheat yield of 4.0 t/ha, we found that all studied calculation methods for determining fertilizers rates showed a fairly high accuracy in yield targeting, while deviations from 3 to 7% were negligible. Higher levels of culture productivity was noted when applying N68P44K24 (4.85 t/ha), calculated by the second method, which was by 18% higher than the rates calculated by V. Ageev method.

Yield targeting at the level of 5.0 t/ha showed similar results. Both calculation methods provided a negligible deviation from the expected productivity towards the decrease by -2.0 and -2.5%.

**CONCLUSION**

Not all fertilized options on average were superior to control in terms of the labile phosphorus content in the soil during the vegetation. Thus, the content of labile phosphorus in the soil at the recommended system of fertilizers and application of N105P60K60 was insignificantly lower than controls in all the studied vegetation stages. Other studied fertilizer rates during the growing season increased the content of labile phosphorus in the soil layer of 0-20 cm. The difference with the control was 4.7-6.9 mg/kg before seeds; 4.0-5.6 mg/kg in the tillering stage; 2.2-4.4 mg/kg in the ear stage and 2.9-5.1 mg/kg in a stage of full ripeness. At that, a significant increase of labile phosphorus relative to control was noted in all the options with the recommended system of fertilizers and N126P80K72.

The highest content of labile phosphorus in all stages of plant development was noted when applying N126P80K72 – 31.2, 31.0, 26.4, 25.3 mg/kg soil.

During the vegetation not all fertilized options exceeded on average the control in terms of the content of the labile exchangeable potassium in the soil. Thus, the content of exchangeable potassium in the soil at the option with N60P34K34 was insignificantly lower than controls in all the studied vegetation stage. At that, the substantial increase in exchangeable potassium against the control was mentioned for all the options with N126P80K72: 262, 254, 240 and 237 mg/kg of soil, and the differences as compared with the controls were 21 and 22 mg/kg of soil, respectively.

All studied fertilizer rates had reliable effect in terms of the number of plants per 1 m², as
the difference relative to the control was 44-148 pcs. Thus, the number of plants and the density of productive haulm had priority in the formation of the crop when targeting yield of 6.0 t/ha at estimated fertilizer system with application of N\textsubscript{126}P\textsubscript{80}K\textsubscript{72} and N\textsubscript{110}P\textsubscript{82}K\textsubscript{51}; higher values were shown by structural indicators of spike and the mass of thousand grains. When applying fertilizers for targeted productivity level of 6.0 t/ha, the rate calculated by V.Ageev method exceeded the rate calculated by the method, recommended by SSRIA and SACC, by 4.8%. In turn, when applying N\textsubscript{126}P\textsubscript{80}K\textsubscript{72}, we observed a significant deviation by 11% from the targeted level of productivity. In contrast, when applying N\textsubscript{110}P\textsubscript{82}K\textsubscript{51} calculated by the method of SSRIA and SACC, the deviation was within the experimental error. Regardless of the calculation method we were unable to obtain the targeted level of winter wheat yield of 6.0 t/ha. Nevertheless, the greatest targeting effect was produced in 2012-2013, when all options provided reliable increase in crop yield (deviation was +4% and +13%, respectively).

Grain hardness index in various options ranged from 38.0 to 65.0%, whereas for the milling industry minimal grain hardness index of winter wheat should not be below 40% (He et al., 2013). Expected yield levels of 4.0 and 5.0 t/ha, as well as the recommended fertilizer rate, provided a grain of Class IV, while control parameter corresponded to class V. Nothing but the expected productivity levels of 6.0 t/ha provided the grain of class III. All studied fertilizer rates increased protein content as compared to the control. The maximum protein content, regardless of calculation method was observed in the options with the expected yield of 6 t/ha.

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**REFERENCES**

5. Esaulko, A. N. & Gorbokato, L.S., The biologization of fertilizer is the way of development of sustainable agriculture. Sustainable agriculture and rural development in terms of the republic of Serbia strategic coals realization within the Danube region – preservation of rural values, 2012; 180-196.
fertilization in conservation agriculture. Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 2013; 8: 1-19


