The effect of complex fertilizers on the productivity of potato varieties on reclaimed lands in the Central Agricultural District of the Russian Federation

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Abstract. On a reclaimed site in the conditions of the Central Non-Chernozem region of Russia (Tver region), the productivity of potato varieties Sadon and Gala was studied on two backgrounds of mineral nutrition (N_{120}P_{160}K_{180} and N_{120}P_{160}K_{180} + trace elements) with different variants of non-root top dressing (control (without top dressing), Aquarin 12 (2x top dressing), Humate +7 (2x top dressing); Aquarin 12 (1st top dressing) + Humate +7 (2nd top dressing)). As a result, it was revealed that the highest yield and crop quality were obtained from the Sadon variety, which in 2023 formed 32.8 thousand plants/ha, 40.7 t/ha of tubers with a dry matter content of 20.4%. The microelement additive provided a significant increase in yield (1.9 t/ha) only for this variety. Against the background without a trace element additive, the highest tuberous productivity in the Sadon variety was provided by 2-fold use of the preparation Humate+7 (an increase of 6.4 t/ha), in the Gala variety – Aquarin 12 + Humate+7 (an increase of 6.7 t/ha). Against the background of the microelement additive for the Sadon variety, the increase in yield was ensured by the use of all foliar dressings (3.9 - 4.6 t/ha). A strong direct relationship was found between the yield of tubers and the density of plants standing for harvesting and the chlorophyll content index (CCI) (correlation coefficient r = 0.76 – 0.80).

1 Introduction

The Tver region has a significant land fund (8,420 thousand hectares) [1-3]. The area of agricultural land in the Region is 2,612 thousand hectares, including reclaimed land - 256 thousand hectares, of which 109 thousand hectares are used in agricultural production [4].

The development and realization of the potential of reclaimed lands is possible by growing on them such highly productive and economically significant crops as potatoes. Potato cultivation on such lands is possible subject to a scientifically sound choice of varieties and technology [1],[13].

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Potato (*Solanum tuberosum* L.) is one of the most important field crops and is of great importance in human life support. Therefore, it is necessary to improve the technologies of its cultivation, aimed at increasing the productivity and quality of tubers while minimizing environmental damage and economic costs. An important factor in solving this issue is to improve the quality of mineral nutrition with the use of macro- and microelements, as well as growth regulators[13],[17].

At the same time, the use of various complex macro- and microelement fertilizers in cultivation technology used in the processing of tubers or foliar dressing is becoming an increasingly common practice in science and industry[13].

2 Materials and Methods

The purpose of the research is to study the productivity of potato varieties on different backgrounds of mineral nutrition with foliar dressing with complex fertilizers on a reclaimed site in the conditions of the Central Non-Chernozem region of Russia (Tver region).

The research was carried out in 2023 in a two-factor field experiment at the experimental field of the Tver State Agricultural Academy. The soil of the experimental site is sod - medium podzolic, residual carbonate gleiish on the moraine, light loamy in granulometric composition, well cultivated. Prior to the experiment, the soil contained 2.0% organic matter, N alkaline hydrolyzable – 60.2 mg/kg (according to Cornfield), P₂O₅ – 325 mg/kg and K₂O – 93 mg/kg (according to Kirsanov), pHₚₗₐₑ – 4.64, exchange Ca – 2.5 mmol/100 g, exchange Mg – 0.25 mmol/100 g, mobile B – 0.47 mg/kg, mobile S – 7.2 mg/kg. Hydraulic, cultural-technical and chemical reclamation was carried out at this site in 1979 - 1983.

The experiment scheme included the following factors:

Factor A – Variety:
1. Gala;
2. Sadon.

Factor B – Background of mineral nutrition:
1. N₁₂₀ P₁₆₀ K₁₈₀
2. N₁₂₀ P₁₆₀ K₁₈₀ + Microelement fertilizer additive - 800 kg/ha

Factor C – Foliar dressing:
1. Control (without top-dressing)
2. Potato aquarium (2x fold)
3. Humate +7 (2x fold)
4. Potato aquarine (1st) + Humate +7 (2nd)

Total experiment options – 16

4-fold repetition

The dimensions of the plot of the 3rd order: 2.8 m x 5 m; area - 14 m². The area of the plot of the 2nd order is 56 m². The area of the plot of the 1st order is 112 m². The area under the experiment is 896 m².

Research objects:
- potato varieties Sadon and Gala. Medium-early, for table purposes. The peel and flesh are yellow [5].
- complex fertilizers:
  1. Aquarin 12 is a water-soluble mineral fertilizer with chelated trace elements. Composition: N - 12%; P₂O₅ - 12%; K₂O - 35%; MgO - 1%; S - 0.7%; Fe (DTPA) – 0.054%; Zn (EDTA) – 0.014%; Cu (EDTA) – 0.01%; Mn (EDTA) – 0.042%; Mo – 0.004%; B – 0.02%[6];
2. Humate+7 "Healthy Harvest" (10% liquid concentrate) - contains a mixture of potassium and sodium salts of humic acids, as well as trace elements - Cu, Zn, Mn, Mo, Co, Fe [9].

3. Micronutrient fertilizer additive of JSC Buysky Chemical Plant (Composition S - 12%, Ca - 15%, Mg - 6%, Fe - 0.5%; B - 0.2%; Zn, Mn – presence)[10].

Agrotechnics in the experiment is recommended for the Tver region[11]. Planting was carried out with row spacing of 70 cm with a potato planter KS-2MT.

In the experiment, the following were determined: the dates of the onset of potato development phases; the density of standing; crop yield and quality (when considered): the dry matter content in potato tubers[14], the nitrate content using the MIKON-2 kit according to GOST 13496.19-93 [7], the starch content in tubers according to GOST 7194-81[8]; the chlorophyll content index (CCI) - using the chlorophyll content meter CCM-200 plus (Opti-Sciences) (in the flowering phase).

3 Results and Discussion

Phenological observations revealed no differences in the passage of development phases between varieties, backgrounds of mineral nutrition and schemes of foliar fertilization. In 2023, seedlings appeared on the 23rd day after planting (12.06), budding on the 17th day from germination (29.06), flowering on the 11th day from budding (10.07). The growing season of potato (planting and harvesting) was 101 days.

The determination of the chlorophyll index (CCI) in potato leaves during the flowering period showed that the value of the indicator in the Sadon variety was on average 2.7 units higher than in the Gala variety. The difference between the backgrounds of mineral nutrition was 0.4 – 0.9 units, which is lower than LSD$_{0.05}$, therefore, the trace element additive did not have a significant effect on the CCI value (Figure 1).
Fig. 1. Chlorophyll content index (CCI) in potato leaves during the flowering period, units. Note: LSD$^{0.05}$ for the variety is 1.1, LSD$^{0.05}$ for the background is 1.1; LSD$^{0.05}$ for the preparation is 0.8. NPK is the background of mineral nutrition with macro fertilizers; NPK + ME is the background of mineral nutrition with macro fertilizers and the addition of trace element fertilizer.

In the Sadon variety, on both backgrounds of mineral nutrition, the highest value was noted in the variant with two-time use of the preparation Humate+7 (an increase in control of 1.0 - 1.8 units).

In agrocenoses of the Gala variety against the background of 1, the largest increase in the value of the indicator (3.6 – 4.1 units) was provided by both 2-fold use of the preparation Humate+7 and the combined use of the preparations Aquarin 12 and Humate+7. Against the background of the use of a trace element additive, the combined use of Aquarin 12 and Humate+7 preparations also contributed to an increase in the index (by 0.8 units).

Differences in the density of standing for harvesting according to the variants of the experiment were revealed (Table 1).

Higher density of standing (32.8 thousand plants/ha) before harvesting, the Sadon variety was different, which is higher than that of the Gala variety by 5.4 thousand plants/ha or 16.4%.

The use of a trace element additive (background 2) for the Sadon variety reduced the value of the indicator by 2.8 thousand plants/ha, for the Gala variety it did not provide a significant change in its value (the difference was 0.8 t/ha, which is lower than LSD$^{0.05}$ - thousand plants/ha).
The density of standing was affected by foliar dressing. In the Sadon variety, against the background of 1, a significant increase in the indicator value was noted in the variant with the combined use of Aquar in 12 and Humate+7 preparations (by 1.9 thousand plants/ha), against the background of 2 – with 2-fold use of the preparation Humate+7 (per 5.6 thousand plants/ha) and the combined use of Aquar in 12 and Humate+7 preparations (by 3.8 thousand plants/ha).

Table 1. The density of standing plants of potato varieties on different backgrounds of mineral nutrition when using foliar dressing, thousand plants/ha.

<table>
<thead>
<tr>
<th>Background (B)</th>
<th>Preparation (C)</th>
<th>Variety (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sadon</td>
</tr>
<tr>
<td>NPK</td>
<td>Control (water)</td>
<td>34.4</td>
</tr>
<tr>
<td></td>
<td>Aquar in 12 (2x fold)</td>
<td>33.1</td>
</tr>
<tr>
<td></td>
<td>Humate+7 (2x fold)</td>
<td>33.1</td>
</tr>
<tr>
<td></td>
<td>Aquar in 12 + Humate+7</td>
<td>36.3</td>
</tr>
<tr>
<td></td>
<td>Background average</td>
<td>34.2</td>
</tr>
<tr>
<td>NPK + ME</td>
<td>Control (water)</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td>Aquar in 12 (2x fold)</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>Humate+7 (2x fold)</td>
<td>34.4</td>
</tr>
<tr>
<td></td>
<td>Aquar in 12 + Humate+7</td>
<td>32.5</td>
</tr>
<tr>
<td></td>
<td>Background average</td>
<td>31.4</td>
</tr>
<tr>
<td>Average by variety</td>
<td></td>
<td>32.8</td>
</tr>
</tbody>
</table>

LSD<sub>0.05</sub> by A: 2.5  
LSD<sub>0.05</sub> by B: 2.5  
LSD<sub>0.05</sub> by C: 1.8

In the Gala variety, an increase in the density of standing for harvesting from foliar dressing was obtained only against the background without a trace element additive in variants with 2-fold use of the preparation Humate+7 (by 3.1 thousand plants/ha) and the combined use of Aquar in 12 and Humate+7 preparations (per 2.5 thousand plants/ha).

The final indicator of potato productivity is the yield of tubers[14]. The influence of all studied factors on this indicator was revealed (Figure 2).

The variety of domestic selection Sadon had an advantage in yield. Its yield was 40.7 t/ha, which is higher than that of the Gala variety by 11.1 t/ha.

The use of a trace element additive provided a reliable increase only in the Sadon variety (1.9 t/ha), despite a decrease in the density of standing. The difference in backgrounds for the Gala variety was 1.0 t/ha, which is lower than LSD<sub>0.05</sub> (1.9 t/ha).

Against the background of a microelement additive, the greatest tuberous productivity in the Sadon variety was provided by 2-fold use of the preparation Humate+7, in the Gala – Aquar in variety 12 + Humate+7. The difference in the Sadon variety was 6.4 t/ha, in the Gala variety – 6.7 t/ha.
Fig. 2. The yield of tubers of potato varieties on different backgrounds of mineral nutrition when using foliar dressing, t/ha. Note: LSD05 for A – 1.6 t/ha; LSD05 for B – 1.6 t/ha; LSD05 for C – 1.1 t/ha. NPK is the background of mineral nutrition with macro fertilizers; NPK + ME is the background of mineral nutrition with macro fertilizers and the addition of trace element fertilizer.

Against the background of a trace element additive for the Sadon variety, the increase was ensured by the use of all foliar dressing (3.9 - 4.6 t/ha). The difference in productivity between the preparations is within the experiment error, which indicates their equal effectiveness against this background of mineral nutrition.

In the Gala variety, the trace element additive makes the use of all preparations ineffective, which is probably due to the lower genetic potential of the variety. The greatest decrease in yield is typical for the double use of the preparation Humate+7.

Correlation and regression analysis revealed that the yield of tubers is strongly related to the density of plants standing for harvesting and the chlorophyll content index (CCI). Table 2 shows the paired correlation coefficients (r), reliable regression equations, as well as the Fisher and Student criteria.

<table>
<thead>
<tr>
<th>Variables</th>
<th>r</th>
<th>t_{fact} at t_{05}=2.1</th>
<th>F_{fact} at F_{05}=8.7</th>
<th>Regression equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield of tubers, t/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant stand density</td>
<td>0.76</td>
<td>4.37</td>
<td>19.08</td>
<td>Y = 0.001X - 3.3 (1)</td>
</tr>
<tr>
<td>Chlorophyll index</td>
<td>0.80</td>
<td>5.03</td>
<td>25.31</td>
<td>Y = 2.56X - 31.97 (2)</td>
</tr>
</tbody>
</table>

Regression equations (1 and 2) are obtained, the reliability of which is confirmed by the Fisher criterion. In all equations $F_{fact}>F_{05}(8,7)$. 
The study of the biochemical composition of potato tubers is important, since the possibilities of preserving and using raw materials depend on it [13]. The most important feature of potato is the starch content in tubers, since it is the main polysaccharide of this crop [15].

The dry matter content is the main indicator of the finished product quality [12]. Its value was studied in potato tubers of all varieties, depending on the background of mineral nutrition and foliar dressing (Table 3).

Among the studied potato varieties, the Sadon variety was characterized by a higher dry matter content (20.4%), in which this indicator was higher than that of the Gala variety by 2.8%.

The backgrounds of mineral nutrition also influenced the accumulation of dry matter in the studied potato varieties. Thus, for the Sadon variety, this indicator turned out to be 3.5% higher on the first background than on the second.

In the Gala variety, there were no significant differences in the accumulation of dry matter depending on the background of mineral nutrition and amounted to 17.5 and 17.8%, respectively, for the first and second backgrounds.

Foliar dressing had a different effect on the dry matter content in potato tubers of different varieties. The greatest increase in the Sadon variety was obtained from foliar dressing with Aquarin 12 (3.9%), and in the Gala variety, no increase in this indicator was detected.

Table 3. The quality of the harvest of tubers of potato varieties depends on the background of mineral nutrition and the preparations used.

<table>
<thead>
<tr>
<th>Variety (A)</th>
<th>Background (B)</th>
<th>Preparation (C)</th>
<th>Dry matter content, %</th>
<th>Starch content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadon</td>
<td>NPK</td>
<td>Control (water)</td>
<td>20.8</td>
<td>9.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarin 2x</td>
<td>23.0</td>
<td>14.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humate+7 2x</td>
<td>20.9</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarine + Humate+7</td>
<td>23.0</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Background average</td>
<td>21.8</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>NPK + ME</td>
<td>Control (water)</td>
<td>18.1</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarin 2x</td>
<td>19.1</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humate+7 2x</td>
<td>20.1</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarine + Humate+7</td>
<td>18.7</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Background average</td>
<td>18.3</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average by variety</td>
<td>20.4</td>
<td>10.4</td>
</tr>
<tr>
<td>Gala</td>
<td>NPK</td>
<td>Control (water)</td>
<td>19.3</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarin 2x</td>
<td>18.7</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humate+7 2x</td>
<td>16.9</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarine + Humate+7</td>
<td>16.8</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Background average</td>
<td>17.5</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>NPK + ME</td>
<td>Control (water)</td>
<td>19.0</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarin 2x</td>
<td>17.3</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humate+7 2x</td>
<td>19.0</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquarine + Humate+7</td>
<td>15.7</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Background average</td>
<td>17.8</td>
<td>10.9</td>
</tr>
</tbody>
</table>
Average by variety  |  17.6  |  10.1  
LSD<sub>0.05</sub> by A  |  0.9  |  0.6  
LSD<sub>0.05</sub> by B  |  0.9  |  0.6  
LSD<sub>0.05</sub> by C  |  0.6  |  0.4  

* - the differences are insignificant (F<sub>fact.</sub> < F<sub>0.05</sub>)

Starch is a valuable polysaccharide of potato. Its content in tubers determines the direction of their use in production, as well as the possibilities for processing the crop. The starch content in potato tubers varies depending on the variety, which allows the indicator to be used as a varietal feature [12].

In our studies, there were no differences in the indicator value between the varieties (F<sub>fact.</sub> < F<sub>0.05</sub>).

In terms of starch content, the largest increases in the Sadon variety were obtained from foliar dressing with Aquarin 12 (4.5%) on the first background, and in the Gala variety also on the first background from foliar dressing with Humate+7 (5.5%).

### 4 Conclusion

At the site where hydraulic, cultural-technical and chemical reclamation was carried out, the highest density of standing, yield and crop quality was provided by the Sadon variety, which in 2023 formed 32.8 thousand plants/ha, 40.7 t/ha of tubers with a dry matter content of 20.4%. The trace element additive significantly increased the yield only for this variety. Against the background without a trace element additive, the highest tuberous productivity in the Sadon variety was provided by 2-fold use of the preparation Humate+7 (an increase of 6.4 t/ha), in the Gala variety – Aquarin 12 + Humate+7 (an increase of 6.7 t/ha). Against the background of the microelement additive for the Sadon variety, the increase in yield was ensured by the use of all foliar dressings (3.9 - 4.6 t/ha).

A strong direct relationship was found between the yield of tubers and the density of plants standing for harvesting and the chlorophyll content index (CCI) (correlation coefficient r = 0.76 – 0.80).

The improvement in crop quality was noted only against the background without trace element additives. The largest increases in the content of dry matter and starch in the Sadon variety were obtained from foliar dressing with Aquarin 12 (3.9% and 4.5%). In the Gala variety, the greatest increase in starch content was obtained from foliar dressing with Humate+7 (5.5%).

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