Reaction of winter rye on top-dressing to nitrogen fertilization at different level of mobile phosphorus and potassium in the soil

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Abstract. The article presents the results of assessing the effectiveness of methods for fertilizing winter rye with nitrogen, grown on soils with different levels of mobile forms of phosphorus and potassium. The studies were carried out in field experiments located on sod-podzolic heavy loamy soil. It has been established that with an increase in the content of available phosphorus in the soil to a level of more than 250 mg/kg, it leads to a mathematically proven increase in the productivity of winter rye by 1.0 c/ha ($t_{fact.(10.0)} > t_{crit.(2.0)}$) (c - here and below 1 center (c) = 100 kg center). An increase in the amount of mobile potassium in the soil (> 120 mg/kg) contributes to a significant decrease in grain yield by 18.1 c/ha ($t_{fact.(19.9)} > t_{crit.(2.0)}$). The fertilizing carried out contributed to a mathematically proven increase in the productivity of winter rye by 1.0-2.3 c/ha ($t_{fact.(10.7-13.1)} > t_{crit.(2.0)}$). On average, the local method of fertilizing, compared to the spreading method, provided a greater increase in grain yield relative to the control (2.3 c/ha).

1 Introduction

Winter rye is the second most important grain crop after wheat, but unlike it, it is less demanding on growing conditions. Therefore, in areas with insufficiently favorable soil and climatic conditions, rye production is economically profitable. Winter rye plays an important role in the development of the agro-industrial complex of most regions of Russia. Rye is a universal crop, used for the production of bread, alcohol, animal feed, rye malt, starch and other products [1-3]. In 2023, the area under winter rye in the Russian Federation amounted to 831.9 thousand hectares, including in the Perm region - 11.5 thousand hectares. The country's average yield was 21.6 c/ha, the gross grain - 1.2 million tons, in the Perm region, respectively, 14.0 c/ha and 11.9 thousand tons. In recent years, due to a decrease in the area under rye and yield, the gross harvest has decreased by almost 4 times [4-5].

The mineral nutrition conditions of rye are one of the main factors influencing its growth and development [6-10]. Sod-podzolic soils, on which winter rye crops are planted in the Perm region, are characterized by low fertility and, in particular, a low content of mineral nitrogen. Long-term studies have established that the optimal dose of nitrogen

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fertilizing of rye is 30-35 kg N/ha [11-15]. The authors [1, 8-9, 16] have established that the effectiveness of nitrogen fertilizing is determined not only by the doses, but by the timing and methods of their implementation. There is an opinion that when localized, nutrients are more fully used by plants, their losses are significantly reduced, so doses of fertilizers can be reduced by up to 50% compared to broadcast application, i.e. at least double the fertilized area and fertilizer efficiency [15, 17-19]. The question of the optimal method of fertilizing winter rye with different contents of available phosphorus and potassium in soils remains open. Therefore, it is important to link into a single complex the content of mobile forms of phosphorus and potassium in the soil with methods of applying nitrogen fertilizers in order to identify their best combination.

The purpose of the study is to evaluate the effectiveness of methods for fertilizing winter rye with nitrogen grown on soils with different levels of mobile forms of phosphorus and potassium.

2 Materials and methods

The research was carried out in the Perm region on the educational and experimental field of the Perm SATU (57°56′00″ N, 56°14′59″ E) (Figure 1).

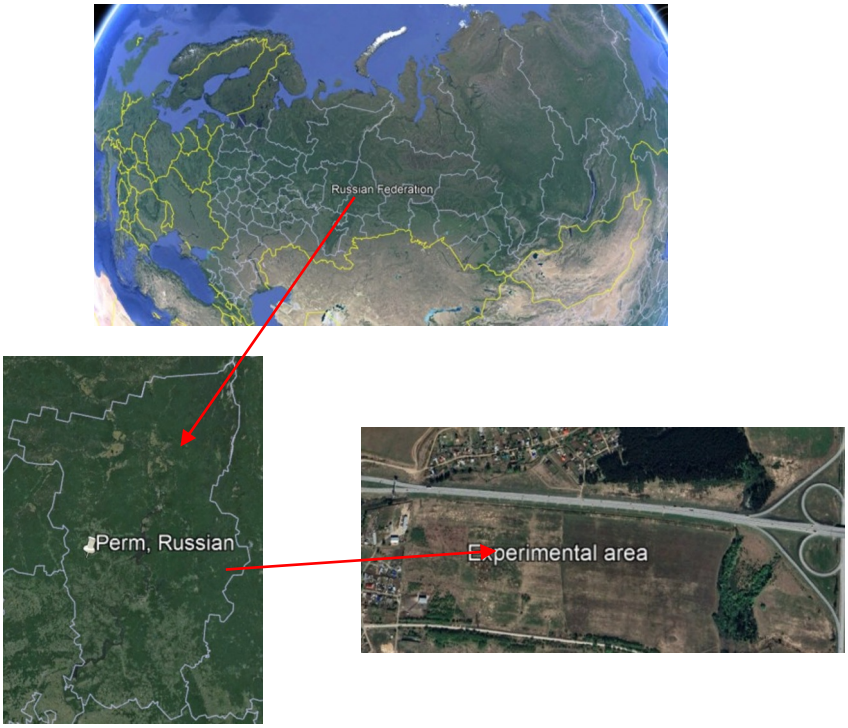


Fig. 1. Location of the experimental field in Perm, Russia.

The soil of the experimental plot is sod-finepodzolic, heavy loamy. Soil samples were taken at the beginning of spring tillering of winter rye (*Secale cereale* L.) from each experimental plot to a depth of 0-20 cm. The soil was dried at a temperature of 22-25 °C to an air-dry state, ground and sifted through a sieve with a diameter of 2 mm. Analysis of soil samples showed: pH_{KCl} (1:2.5, soil: 1N KCl): 5.0-6.0, mineral nitrogen content ($N\text{-}NH_4$ (1:10, soil:2% KCl) + $N\text{-}NO_3$ (1:2.5, soil: 1% $Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$) = 5.9-31.1 mg/kg,

mobile phosphorus and potassium (1:5, soil: 0.2N HCl) respectively 102-605 mg/kg and 41-223 mg/ kg. The levels of phosphorus and potassium in the soil were created artificially by employees of the Department of Agrochemistry on starting establishing a stationary experiment from 1968-1970 application of increased doses of manure and phosphorus-potassium fertilizers according to the developed experimental scheme for agricultural crops in crop rotation. Based on the analysis of the soil selected before fertilizing, we can say that the supply of plants with nitrogen is very low, phosphorus varies from high to very high, and potassium - from low to elevated.

Field experiment with winter rye included the following options: 1. Without fertilizing, 2. Local application of nitrogen fertilizing, 3. Spreading application of nitrogen fertilizing. The experimental design was applied to plots with different levels of available phosphorus (< 250 mg/kg and > 250 mg/kg) and potassium (< 120 mg/kg and > 120 mg/kg) in the soil. Rye was fertilized with ammonium nitrate with a nitrogen content of 34.5-34.6% at a dose of 30 kg N/ha in the spring tillering phase when the soil is physically ripe. Local fertilizing was carried out by cutting fertilizers into the soil with a grain seeder across the crops. The spreading method of applying fertilizer included the surface application of ammonium nitrate with a spreader, followed by incorporation with tooth harrows across the crops. The repeatability of the variants in the experiment is different, due to the content of phosphorus and potassium in the soil (n = 3-17). The placement of plots is randomized in two tiers. The area of the discount area is 80 m^2. The Kirovskaya 89 variety was grown in the experiment. The establishment of the experiments was carried out in two years with different weather conditions. In the first year of research, the summer-autumn part of the growing season lasted longer than usual; with a sharp cold snap and snowfall, the rye, without going through the hardening phase, “went to winter.” Dry and hot weather in the spring-summer period led to accelerated plant development, worsening conditions for ear formation and grain filling. Due to lack of moisture and high temperature, the grain formed puny and small. In the second year of the experiment, germination, growth and development of rye plants during the summer-autumn growing season occurred in dry weather with low temperatures. In the spring-summer period, weather conditions were favorable for the growth and development of rye. Only in August, due to the heat, on some days there was an acceleration of the grain ripening process. The grain yield of winter rye was taken into account using a combine harvester using the continuous method from the entire recording area of the plot at full ripeness of the grain. Mathematical processing of the research results was carried out using Microsoft Excel and STATISTICA 14 programs.

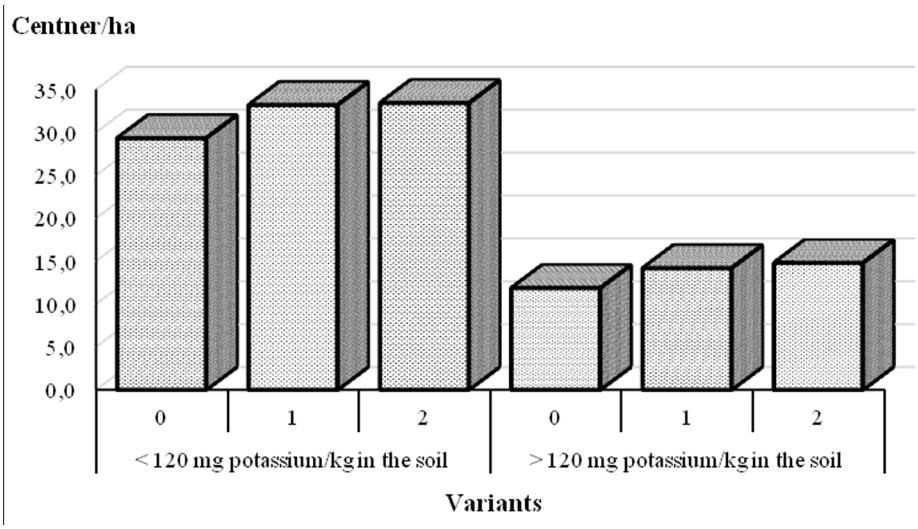
3 Results and Discussion

On soils with a content of available phosphorus less than 250 mg/kg, fertilizing had a positive effect on the yield of winter rye (Figure 2).

The increase relative to the control in the variants with spreading application of fertilizing was: with a potassium level in the soil less than 120 mg/kg 4.1 c/ha (SSD_{05} = 2.0 c/ha), and with a higher level – 2.9 c/ha (SSD_{05} = 1.1 c/ha). In variants with a local method of nitrogen fertilizing, the increase over the control was 3.9 and 2.3 c/ha, respectively. It should be noted that both when the potassium level in the soil is less than 120 mg/kg, and when the potassium level is more than 120 mg/kg, the fertilizing method did not make a significant difference. The difference in feeding methods was: with a potassium level in the soil less than 120 mg/kg 0.2 c/ha, and with a potassium level more than 120 mg/kg 0.6 c/ha, with SSD_{05} 2.0 and 1.1 c/ha, respectively.

On soils with a mobile phosphorus content of more than 250 mg/kg, fertilizing methods had an ambiguous effect on rye yield (Figure 3).

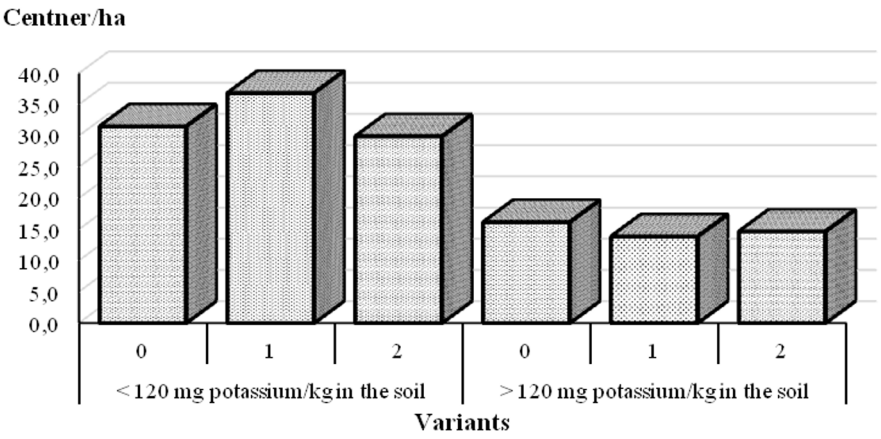
When the level of potassium in the soil was less than 120 mg/kg, the local method of introducing nitrogen provided the maximum mathematically proven increase in grain in the experiment relative to the control, 5.3 c/ha (SSD_{05} = 1.0 c/ha). The spreading feeding method had a negative effect on rye, reducing its yield relative to the control by 1.6 c/ha.



1. Without fertilizing, 2. Local application of nitrogen fertilizing, 3. Spreading application of nitrogen fertilizing

Fig. 2. Productivity of winter rye according to experimental variants with a level of available phosphorus less than 250 mg/kg.

The difference between the methods of applying nitrogen fertilizer to rye was 6.9 c/ha. When the level of potassium in the soil was more than 120 mg/kg, fertilizing led to a mathematically proven decrease in the yield of winter rye relative to the option without fertilizers by 1.5-2.3 c/ha (SSD_{05} = 1.1 c/ha). The tested feeding methods did not have a mathematically proven effect, since the difference in grain yield was 0.8 c/ha.



1. Without fertilizing, 2. Local application of nitrogen fertilizing, 3. Spreading application of nitrogen fertilizing

Fig. 3. Productivity of winter rye according to experimental variants with a level of available phosphorus more than 250 mg/kg.

On soils with a content of mobile phosphorus in the soil of less than 250 mg/kg of soil at different levels of potassium, a mathematically proven very close correlation was established between fertilizing methods and the yield of winter rye, $r = 0.891$ (less than 120 mg K_2O/kg of soil) and 0.948 (more than 120 mg K_2O/kg soil).

With an increase in phosphorus content in the soil (more than 250 mg/kg) with different levels of potassium, a mathematically proven correlation between fertilizing methods and the yield of winter rye has not been established.

4 Conclusion

Based on the conducted research, we can say that on sod-podzolic heavy loamy soils with a content of available phosphorus in the soil of less than 250 mg/kg, for winter rye was the most effective the spreading method of fertilizing with ammonium nitrate at a dose of 30 kg N/ha, the increase to the control was 2.9-4.1 c/ha. With an increase in phosphorus in the soil, local application of fertilizing is more effective; the increase relative to the control was 1.5 c/ha. The effect of potassium on the efficiency of nitrogen fertilization of rye is similar to the effect of changes in variants with phosphorus in the soil. The increase to the control amounted to a potassium level of less than 120 mg/kg with a local method of feeding 4.6 c/ha, with a spreading method – 1.2 c/ha. At a potassium level of more than 120 mg/kg, the local method had no effect on grain yield, and the spreading method provided an increase in grain collection relative to the control by 0.7 c/ha. The low level of fertilizing efficiency is primarily associated with unfavorable growing conditions, in particular weather conditions. In the “responsible” phases of development, there was a lack of moisture, and in some phases, high temperature, which restrained the formation of productive ears, and in the last phases of plant growth and development, led to sterility of pollen and insufficient grain filling (shortening of phases).

References

1. V.A. Maksimov, R.I. Zolotareva, Vestnik of Mari State University. Chapter: Agriculture. Economics, **1**(**13**), 23-29 (2018)
2. R.A. Umarov, B.M. Azizov, Formation of the leaf surface and grain yield of winter rye (Secale L.) with the use of mineral fertilizers in irrigated soils of Uzbekistan. Materials of the IOP Conference Series ‘Earth and Environmental Science’ Tashkent, 012032 (2022) DOI 10.1088/1755-1315/1068/1/012032
3. N.V. Symonenko, O.S. Levchenko, L.M. Holyk, Agriculture and plant sciences theory and practice, **1**(**7**), 107-115 (2023) DOI: 10.54651/agri.2023.01.12
4. Cultivated areas of the Russian Federation in 2023 (spring accounting), Rosstat, thousand hectares, https://zerno.ru/node/23608
5. Gross yields and yields of agricultural crops in the Russian Federation in 2023. Part 1. M.: Federal State Statistics Service (ROSSTAT), 2024, https://rosstat.gov.ru/storage/mediabank/Val1_2023.xlsx
6. V.I. Titova, Agrochemical Herald, **1**, 2-6 (2017)
7. V.V. Lapa, N.N. Ivakhnenko, A.A. Gracheva, S.M. Shumak, Soil Science and Agrochemistry, **1**(**56**), 105-121 (2016)
8. I.V. Lyskova, Agricultural Science Euro-North-East, **6**(**61**), 35-40 (2017) DOI: 10.30766/2072-9081.2017.61.6.35-40

9. T.V. Shaykova, M.V. Dyatlova, E.S. Volkova, Fodder Production, **6**, 8-12 (2023) DOI: 10.25685/KRM.2023.6.2023.009
10. D. Allen, D.S. Tegesov, V.V. Vvedensky, M. Barry, Journal of Agriculture and Environment, **1**(**41**), (2024) DOI: 10.23649/JAE.2024.41.19
11. N.M. Mudrykh, V.R. Yamaltdinova, D.G. Shishkov, The responsiveness of winter rye to the application of mineral fertilizers in a long-term stationary experiment Materials of the All-Russian Scientific and Practical Conference 'Agrotechnology of the xxi century: development strategy, technology and innovation' Perm, 86-90 (2021)
12. V.F. Tsupak, L.A. Sinyakov, F.G. Gusintsev, Field crops of the Non-Chernozem zone (Kolos, Leningrad, 1980)
13. N.Kh. Dudina, E.A. Panova, M.P. Petukhov, Agrochemistry and fertilizer system (Agropromizdat, Moscow, 1991)
14. V.V. Kidin, Features of nutrition and fertilizers of agricultural crops (RSAU named after K.A. Timiryazeva, Moscow, 2009)
15. L.A. Mikhailova, T.A. Korotkikh, Features of nutrition and fertilizers of the main agricultural crops on the soils of the Predural'ya (PSAA, Perm, 2012)
16. V.P. Murygin, V.A. Popov, S.L. Eliseev, Journal Perm Agrarian Bulletin, **2**(**18**), 43-47 (2017)
17. Yu.P. Zhukov, System of application of fertilizers in non-Black Earth farms (Moscow worker, Moscow, 1983)
18. I.R. Wildflush, Agricultural Chemistry, **10**, 132-144 (1996)
19. A.K. Tyulyush, P.Sh. Li, Yi.S. Quanyi, Bulletin of TuvSU. Natural Science and argricultural sciences, **3**(**49**), 66-75 (2019) DOI: 10.24411/2077-5326-2019-10013