Varietal specificity of the reaction of winter rye to background changes of mineral nutrition

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Abstract. The study of the genetic characteristics of the reaction of plants to changes in environmental conditions makes it possible to more effectively use the achievements of breeding. In the conditions of the open forest-steppe of the Krasnoyarsk Territory in 2019 - 2020, a study of the yield of winter rye was carried out on a site with a low nitrogen content against two backgrounds: without fertilizers (control) and with fertilization. The object of the research is the varieties included in the State Register for the East Siberian region Yeniseyka (standard), Sinilga, Krasnoyarskaya universal and the Arga variety undergoing state testing. In the dry 2019 year, the average yield in the control variant was 27.5 centner/ha, the increase from fertilization was 8.2 centner/ha. In conditions of excessive moisture in 2020, it was respectively - 32.7 centner/ha and 13.6 centner/ha. The response of varieties to background changes of mineral nutrition was different. The most responsive to fertilization was the Arga variety, the most stable was the Sinilga variety. Krasnoyarskaya universal and Arga surpassed Yeniseyka and Sinilga in average yield by 2.3-2.7 centners/ha and were more resistant to lodging. Arga had an advantage in productivity with a sufficient supply of nutrients, the Krasnoyarsk universal was characterized by greater stability and less response to agrotechnical background changes.

1. Introduction
Winter rye is a crop with high adaptive properties and important agrotechnical value. Rye grain contains a wide range of nutrients and is used in the bakery, malt, starch, alcohol and feed industries. In recent decades, in the Russian Federation, there has been a sharp decline in the acreage under this crop, which leads to a shortage of valuable raw materials and negatively affects the structure of crop rotations [1].

The solution to this problem is possible both by improving selection and seed production, and by introducing advanced cultivation technologies.

Compared to other cereals, rye has the most developed root system, which absorbs water and nutrients very efficiently, extracting them even from complex, hardly soluble compounds. This explains the relatively low requirements of rye to soils and reduced sensitivity to the reaction of the soil solution.

At the same time, due to this feature, rye is highly responsive to agrotechnical methods, especially to fertilization [2]. Researches [3,4,5,6] found that the use of mineral fertilizers increases the yield of winter rye by 40-60%. The authors note the genetic dependence of this reaction. Therefore, the factor "genotype x environment", which reflects the potential of the variety's plasticity and ecological stability, requires constant attention. Varietal agrotechnics, controlling modification variability, takes into account the specificity of the reaction of different varieties to the action of environmental factors, including the application of fertilizers [7]. This makes it possible to distinguish both genotypes that effectively "pay"
for fertilization with the harvest, and those that have the ability to use a high content of nutrients in the soil and, at the same time, not greatly reduce the yield in case of their shortage.

Knowledge of the genetic characteristics of plants' responsiveness to improving the background of mineral nutrition allows us to develop an agrotechnical program that ensures the effective use of each variety in specific conditions and recommends it for cultivation using one technology or another (low-cost, intensive, etc.). This not only unites the achievements of breeding and agricultural technology into a single whole, but also enhances their joint action.

The aim of the research is to study the variability of the yield of winter rye varieties on different backgrounds of mineral nutrition.

2. Research methodology
The researches were carried out in 2019-2020 on the experimental fields of the Krasnoyarsk Research Institute of Agriculture in the open forest-steppe zone. The soil of the site is characterized by a low nitrogen content (4.6-6.3 mg / 100 g), an increased phosphorus content (20.6-25.0 mg / 100 g), and a high potassium content (14.0-14.9 mg / 100 g) - according to Chirikov. The predecessor is pure fallow. The researches were carried out against two backgrounds: without fertilizers (control) and fertilized (autumn application of a dose of N30P30K30 and spring application of nitrogen at a dose of 30 kg of active substance). The objects of the study were winter rye varieties included in the State Register for the East Siberian region: Yeniseyka (standard), Sinilga, Krasnoyarskaya universal, and variety Arga which is undergoing state testing. Sowing was by SSFK-7 sower. The seeding rate is 5 million germinating grains per hectare. Repetition is 4 times. Sowing time is August 28. Accounting area is 10 m². Optimal harvesting with the Hege-125 harvester. Phenological observations and counts - according to the methodology of the State Commission for Variety Testing of Agricultural Crops. The experimental data were statistically processed according to B.A. Dospekhov using the SNEDEKOP computer program. Stability factor S.F. was calculated as the ratio of the value of a trait in a highly productive environment to the value of a trait in a low-productivity environment [8].

Overwintering during the years of the research took place in favorable conditions. The growing seasons in terms of temperature conditions are close to the average long-term indicators. According to the water regime, 2019 was characterized by a moisture deficit; in 2020, precipitation fell 1.5 times more than the norm.

3. Research results
The change in the background of mineral nutrition did not affect the winter hardiness of winter rye plants; in all variants of the experiment, this indicator was 5 points.

In 2019, in the control variant, the average yield of varieties was 27.5 c / ha, with fertilization - 35.7 c / ha (Table 1). The response of cultivars to changes in the background of mineral nutrition was different. For the Yeniseyka standard, the increase on the fertilized background compared to the background without fertilizers was 8.4 c / ha, for the Krasnoyarskaya Universal variety - 8.6 c / ha (figure 1).

![Figure 1. Ear, grain, appearance of the variety "Krasnoyarskaya universal".](image-url)
The Sinilga variety reacted least of all to fertilization (an increase is 6.5 c/ha). On average, according to the experience, the increase in yield from fertilization was 8.2 c/ha. In both variants of the experiment, the highest yield was observed in the Arga variety (background without fertilizers - 29.5 c/ha, excess over the Yenisey standard of 3.5 c/ha, fertilized background - 38.9 c/ha, excess over the standard of 4.5 c/ha). The most responsive to fertilization was the Arga variety (an increase of 9.4 c/ha) (Fig. 2).

In a wetter 2020, a higher yield of varieties was noted: in the control variant, on average, according to the experiment, it was 32.7 c/ha, against a fertilized background - 46.3 c/ha. At the same time, the effect of fertilizers on yield and differences in the response of varieties were more significant. For the standard variety Yeniseyka, fertilization increased the yield by 13.7 c/ha, for the Krasnoyarskaya universalnaya variety - by 12.5 c/ha, for the Sinilga variety - by 11.0 c/ha, for the Arga variety - by 17.2 c/ha. The highest yield was noted in the control variant in the Krasnoyarskaya Universal - 35.7 c/ha, the excess over the standard - 3.9 c/ha, against the fertilized background - in the Arga variety - 48.3 c/ha, the excess - 2.8 c/ha.

Table 1. Productivity of winter rye varieties depending on the background of mineral nutrition, c/ha. 2019-2020.

| Agrochemical background | Variety          | Least Significant Difference (LSD)₀⁵ |
|-------------------------|------------------|-------------------------------------|
|                         | Yeniseyka standard | Sinilga    | Krasnoyarskaya universal | Arga | Average By experience |
| 2019 without fertilizers (control) | 26.0 | 27.3 | 27.2 | 29.5 | 27.5 | on the factor A*2.4 on the factor B*1.5 |
| Na₂PO₄K₃₀ +N₃₀          | 34.4 | 33.8 | 35.8 | 38.9 | 35.7 |
| Increase to control 2020 год without fertilizers (control) | 8.4 | 6.5 | 8.6 | 9.4 | 8.2 |
|                         | 31.8 | 32.3 | 35.7 | 31.1 | 32.7 | on the factor A*2.4 on the factor B*1.7 |
On average, over two years, the highest yield was formed by the Krasnoyarskaya universal variety in the control variant (31.4 c / ha), in the N₃₀P₃₀K₃₀ + N₃₀ variant - the Arga variety (43.6 c / ha). The greatest increase from fertilization was noted in the Arga variety (13.3 c / ha), the smallest - in the Sinilga variety (8.7 c / ha). Yeniseyka and Krasnoyarskaya universal occupied an intermediate position - 11.0 c / ha and 10.6 c / ha, respectively.

According to all variants of the experiment, Krasnoyarskaya universal and Arga had an advantage in yield.

Stability factor S.F. shows the level of phenotypic resistance of a particular sample. The higher this indicator, the less stable the variety. Variety Sinilga (1.29) was characterized by the smallest S.F., by the largest - cultivar Arga (1.44). For Yeniseyka this indicator was 1.38, for Krasnoyarskaya Universal - 1.34.

The peculiarities of the growing season in 2020 (heavy rainfall) made it possible to assess the varieties for lodging resistance. The plant height is the main feature that determines the resistance to lodging. The application of fertilizers increased the plant height by 5-13 cm. Sinilga was the tallest variety. The plant height in it was 125 cm in the control variant and 130 cm on a fertilized background; in varieties Yeniseyka - 117 and 130, Krasnoyarskaya universal - 112 and 117, Arga - 105 and 115 cm, respectively. The use of fertilizers reduced the resistance to lodging in the Yeniseyka variety from 4.5 to 4.1 points, Sinilga - from 4.2 to 3.9 points, Krasnoyarskaya universal - from 5.0 to 4.8 points. The Arga variety was characterized by the highest lodging resistance - 5.0 points regardless of the background (Table 2).

Table 2. Plant height and lodging resistance of winter rye varieties depending on the background of mineral nutrition in 2020.
4. Conclusion
On the site with a low nitrogen content in the soil (4.6-6.3 mg / 100 g NO-NO₃ according to Kirsanov), the application of mineral fertilizers at a dose of N₃₀P₃₀K₃₀ in the fall + N₃₀. In the spring the yield of winter rye varieties was increased on average by experience by 36%. The most responsive to fertilization was the Arga variety (increase from fertilization - 44%). The Krasnoyarskaya Universal and Arga varieties were superior to the Yeniseyka and Sinilga varieties in terms of the average yield and resistance to lodging. Arga had an advantage in productivity with a sufficient supply of nutrients, Krasnoyarsk universal was characterized by greater stability and less response to changes in the agrotechnical background.

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