Ecological plasticity of spring wheat varieties in the Krasnoyarsk region

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Abstract. The aim of the work was to study the ecological plasticity of soft spring wheat. To achieve this goal the following tasks were defined: to evaluate varieties of soft spring wheat by yield, elements of environmental plasticity and stability, using the principle of ranking varieties, to evaluate their adaptability to environmental conditions. Varieties of soft spring wheat «Altaiskaya 70», «Kanskaya», «Novosibirskaya 15», «Novosibirskaya 29», «Novosibirskaya 31», «Novosibirskaya 41», «Omskaya 32» and «Vavenkov's memory» were the objects of research. The parameters of ecological plasticity and stability (bi, σ) were calculated using the method of S. A. Eberhart and W. A. Russell, the homeostatic index (Hom) was calculated using the formula of V. V. Khangildin, and stability parameters of spring wheat were calculated using the method of E. D. Nettevich. The varieties «Kanskaya», «Omskaya 32», «Altaiskaya 70» realized their yield potential in the conditions of the variety testing area to a greater extent. Comparison of different methods for evaluating varieties for stability and plasticity showed that their resolution was not the same. The most complete information is provided by the use of several methods, while it is more convenient to use the principle of ranking varieties by all parameters and to evaluate them by the sum of points. Under contrasting growing conditions, the varieties showed different adaptive properties in terms of yield. It responded to improvements in growing conditions well and reduced yields in adverse conditions to a lesser extent.

1. Introduction
One of the most important regions of spring wheat cultivation in Russia is Siberia. The steppe and forest-steppe zones of Siberia have great opportunities for the production of high-quality grain with good and excellent baking qualities and high flour strength. Spring wheat occupies up to three-quarters of the sown area for all grain crops. Along with the tasks of increasing productivity, the stability of this indicator is also of great importance. In this direction, it is necessary to introduce the best varieties, to use climate resources in the right direction, and to carry out intensive cultivation technology to influence the grain amount of the best quality [1]. Today the variety acts as a factor without which it is impossible and pointless to use modern developments and ideas in agricultural production. One of the options for solving this problem is targeted breeding to create varieties that can produce sufficiently high yields in different climatic conditions of the year [2]. The combination of maximum responsiveness and stability in one variety remains problematic at the current development stage of the agro-industrial complex. Therefore, it is desirable to select varieties for a certain level of agricultural production technology, forming a pool of appropriate varieties for a certain territory [3].
In recent years (since 2007), more than 20 varieties with high yield potential have been zoned in the Krasnoyarsk territory, however, their introduction into production has not led to a significant increase in yield [4]. At the sites of variety testing for 3-4 years it is possible to assess mainly the potential productivity of varieties, while their resistance to the most important, limiting factors of the environment remains often unclear and unaccounted for. Meanwhile, the yield of any crop is a function not only of the potential productivity, but also of the ecological stability of the variety [5].

In modern conditions adaptive varieties with increased ecological plasticity, which have the ability to use bioclimatic resources more effectively in extensive growing conditions, are of great importance. Zoned varieties should combine high yield, increased ecological plasticity, and have the ability to reduce their productivity to a lesser extent when cultivated under harsh conditions of extensive agrotechnical background, i.e., along with the traditional assessment it is desirable to supplement the characteristics of varieties with their assessment of adaptability level [6].

In connection with the above, the goal was set: to establish the ecological plasticity of soft spring wheat varieties in the southern forest-steppe zone of the Krasnoyarsk territory. To solve it, the following tasks were formulated:

1. To carry out the analysis of ecological plasticity and stability of spring wheat varieties with different techniques.
2. Using the principle of ranking varieties to evaluate their adaptability to environmental conditions in the forest-steppe of the Krasnoyarsk territory.

2. Materials and methods
A group of medium-early varieties «Altayskaya 70», «Kanskaya», «Novosibirskaya 15», «Novosibirskaya 29», «Novosibirskaya 31», «Novosibirskaya 41», «Vavenkov's memory» and «Omskaya 32» was put to the study. The research was carried out according to the generally accepted method of state variety testing [7, 8] on the Krasnoturansk state variety site for 3 years (from 2016 to 2018) in conditions as close as possible to production. The experiment was based on a typical site for the zone, randomized, four times repeated with a seeding rate of 6.0 million germinating grains per ha, the area of the accounting plot was 25 m², the soil was luuvic chernozem. To identify varieties of various types (intensive, semi-intensive, extensive) the test was carried out on several fertility backgrounds (continuous sowing crops and fallow). The crop rotation adopted on the site was three-field: fallow, early spring crops, and continuous sowing crops (csc).

The main and pre-sowing treatment was carried out in accordance with zonal recommendations. Sowing was carried out by the SS-11 seeder in the second decade of May. Sowing times and seeding rates were optimal for the cultivation zone. Harvesting of each variety of spring wheat was carried out in the phase of waxy ripeness in the third decade of September by the method of continuous threshing by a combine Sampo 500.

The parameters of environmental plasticity and stability (bi, σ) were calculated using the method of S. A. Eberhart and W. A. Russell as described by V. A. Zykin [9]. The homeostatic index (Hom) was calculated using the formula of V. V. Khangildin [10]. Parameters of spring wheat stability were calculated using the method of E. D. Nettevich [11]. The coefficient of responsiveness to improvement of growing conditions (Cr) was calculated according to V. A. Zykin (2011) [12].

3. Results and discussion
Wheat yield is determined by the genotypic characteristics of the variety, agrotechnical measures, and soil and climatic conditions. The highest yield is observed when they are optimally combined. In the field there is usually a complex interaction of many factors, and the high productivity of the variety, as a rule, is due to its resistance to a complex of adverse factors. As a result of summarizing the data and processing them using mathematical statistics, the following results were obtained: on average, over three years of research for two previous crops (fallow and continuous sowing crops) the best conditions for forming the yield of medium - early spring wheat were formed for fallow in 2016 (i = 7.2), the least favorable for continuous sowing crops in 2017 (i = - 4.7) (table 1).
On average, it exceeded the standard by 2.7 c/ha. The yield level of spring wheat is determined by a complex set of environmental conditions variability in time and space.

In the group of medium-early varieties «Kanskaya» stood out, which formed a higher yield consistently, both by year and by previous crops. The coefficient of environmental conditions i was calculated as the difference between the average value of the indicator for the study background and its average value for all backgrounds for the entire study period.

**Table 1.** Average yield of spring wheat varieties, c/ha.

| Variety                  | 2016 fallow | 2016 csc | 2017 fallow | 2017 csc | 2018 fallow | 2018 csc | Average |
|--------------------------|-------------|----------|-------------|----------|-------------|----------|---------|
| «Altayskaya 70» (st)     | 25.2        | 17.5     | 15.8        | 13.6     | 20.0        | 18.1     | 18.3    |
| «Kanskaya»               | 28.2        | 22.6     | 18.6        | 15.3     | 21.0        | 20.4     | 21.0    |
| «Novosibirskaya 15»      | 21.1        | 15.6     | 12.5        | 9.2      | 15.4        | 14.9     | 14.8    |
| «Novosibirskaya 29»      | 23.7        | 16.0     | 12.5        | 11.5     | 22.4        | 16.2     | 17.1    |
| «Novosibirskaya 31»      | 25.1        | 18.6     | 14.6        | 11.0     | 15.2        | 12.9     | 16.2    |
| «Novosibirskaya 41»      | 23.5        | 15.8     | 19.8        | 15.9     | 16.7        | 13.9     | 17.6    |
| «Omskaya 32»             | 28.1        | 19.4     | 17.6        | 10.7     | 20.1        | 17.3     | 18.8    |
| «Vavenkov’s memory»      | 19.9        | 14.8     | 13.0        | 12.0     | 11.4        | 7.7      | 13.1    |
| Average                  | 24.3        | 17.5     | 15.5        | 12.4     | 17.8        | 15.2     | 17.1    |
| Coefficient of environmental conditions i | 7.2 | 0.4 | -1.6 | -4.7 | 0.6 | -2.0 | - |
| SSD 5%                   | -           |          |             |          |             |          | 0.7     |

In the studied set of varieties, the average yield ranged from 13.1 c/ha in «Vavenkov’s memory» to 21.0 c/ha in «Kanskaya» (table 1), followed by varieties «Omskaya 32» and «Altayskaya 70» in productivity. The variety «Novosibirskaya 15» also had a low average yield over the years and its previous crops.

**Table 2.** Parameters of ecological plasticity of spring wheat varieties.

| Variety                  | Average yield, Yi | CV, % | IS | Cr | Hom | Plastic, bi | Stability, σ²d |
|--------------------------|-------------------|-------|----|----|-----|-------------|----------------|
| «Altayskaya 70»          | 18.3              | 21.7  | **124.4** | 1.9 | **7.3** | 0.95        | 1.56           |
| «Kanskaya»               | 21.0              | 20.5  | **173.0** | 1.8 | **7.9** | 2.42        | 40.09          |
| «Novosibirskaya 15»      | 14.8              | 26.6  | 65.9 | **2.3** | 4.7 | 1.17        | 2.72           |
| «Novosibirskaya 29»      | 17.1              | 29.6  | 79.1 | 2.1 | 4.7 | 1.27        | 9.73           |
| «Novosibirskaya 31»      | 16.2              | 31.0  | 68.3 | **2.3** | 3.7 | 1.39        | 2.76           |
| «Novosibirskaya 41»      | 17.6              | **19.8** | **126.2** | 1.5 | **11.7** | 0.85        | 7.25           |
| «Omskaya 32»             | 18.8              | 29.8  | 95.9 | **2.6** | 3.6 | 1.62        | 2.70           |
| «Vavenkov's memory»      | 13.1              | 31.0  | 44.8 | 1.7 | 5.3 | 0.89        | 8.07           |

The coefficient of yield variability over time and by previous crops varied in the studied varieties from 19.8 % («Novosibirskaya 41») to 31.0% («Novosibirskaya 31» and «Vavenkov’s memory») (table 2). The varieties «Novosibirskaya 29» and «Omskaya 32» also had high yield variability (about 30%).
According to the indicator of stability (IS), the varieties «Kanskaya» (173.0), «Novosibirskaya 41» (126.2) and standard «Altayskaya 70» (124.4) were distinguished among the analyzed varieties (table 2). The same trend can be seen in the homeostatic index: during the study period it was higher in the variety «Novosibirskaya 41» (11.7), followed by the varieties «Kanskaya» and «Altayskaya 70» (7.9 and 7.3 respectively).

High-intensity varieties «Novosibirskaya 15», «Novosibirskaya 31» and «Omskaya 32» showed the greatest responsiveness (Cr) to environmental improvements.

Analysis of plasticity and stability by the method of S. A. Eberhart and W. A. Russell allowed us to distribute the varieties taken for the study according to these characteristics. The yield of the studied varieties was compared not with the standard, but with the average yield for all the compared varieties.

For three years of testing in the group of studied varieties (table 2) there was a variety of soft spring wheat «Kanskaya», which proved to be both "intensive", i.e. its yield increased sharply with improved cultivation conditions (bi = 2.42), and "extensive" - the yield was always higher than the average value. Varieties «Altayskaya 70» and «Novosibirskaya 41» proved to be "environmentally plastic", i.e. they increased productivity with improved cultivation conditions and reduced it slightly under unfavorable conditions (figure 1). The regression lines of varieties' productivity were constructed based on two deviations points of actual yields from theoretical ones.

![Figure 1. Regression lines for the yield of spring wheat varieties.](image)

Thus, different calculation methods showed slightly different results, so it is advisable to use a rank system when evaluating varieties using different methods (table 3).

The highest score for plasticity and stability was given to the variety «Kanskaya» (6.0 and 8.0 respectively). The most complete information is provided by using several methods, but it is more convenient to use the principle of ranking varieties by all parameters and evaluate them by the sum of
points. According to the sum of points, the best ecological plasticity was shown by the variety «Kanskaya» (table 3).

**Table 3. Rank assessment of ecological plasticity and stability of spring wheat varieties.**

| Variety               | Plasticity indicators | Stability indicators | Sum of points |
|-----------------------|-----------------------|----------------------|---------------|
|                       | bi  | Cr  | Hom | Average rank | σ   | Xi | IS | Average rank |                     |
| «Altaiskaya 70»       | 3   | 4   | 6   | 4.3          | 1   | 3  | 6  | 3.3          | 7.7                 |
| «Kanskaya»            | 8   | 3   | 7   | 6.0          | 8   | 8  | 8  | 8.0          | 14.0                |
| «Novosibirskaya 15»  | 4   | 6   | 4   | 4.7          | 4   | 6  | 2  | 4.0          | 8.7                 |
| «Novosibirskaya 29»  | 5   | 5   | 3   | 4.3          | 7   | 5  | 4  | 5.3          | 9.6                 |
| «Novosibirskaya 31»  | 6   | 7   | 2   | 5.0          | 3   | 2  | 3  | 2.7          | 7.7                 |
| «Novosibirskaya 41»  | 1   | 1   | 8   | 3.3          | 5   | 7  | 7  | 6.3          | 9.6                 |
| «Omskaya 32»         | 1   | 8   | 1   | 3.3          | 2   | 4  | 5  | 3.7          | 7.0                 |
| «Vavenkovmemory»     | 2   | 2   | 5   | 3.0          | 6   | 1  | 1  | 2.7          | 5.7                 |

Comparison of different methods for evaluating genotypes in terms of plasticity and yield stability of spring wheat varieties showed that their resolution was not the same. For example, the article by V. I. Nikitina and D. F. Fedosenko (2020) [13] showed that the stability assessment of crop productivity by the method of N. A. Sobolev [14] established that the spring wheat variety «Kanskaya» was in the group of outsiders. Therefore, the methods proposed by E. D. Nettevich and V. V. Khangildin for local conditions will be the most accurate and objective. If the number of varieties and test conditions vary, the absolute value of environmental indicators of crop productivity will change, but the relative position of varieties will remain.

4. Conclusions

An assessment of the cultivation conditions for the three years of the study for the two previous crops showed that they were most favorable in 2016 for fallow, and the least in 2017 for the continuous sowing crops. Varieties «Kanskaya», «Omskaya 32», «Altaiskaya 70» realized their yield potential in the conditions of the variety site to a greater extent. Comparison of different methods for evaluating varieties for stability and plasticity showed that their resolution was not the same. The most complete information is provided by the use of several methods, while it is more convenient to use the principle of ranking varieties by all parameters and evaluate them by the sum of points. Under contrasting growing conditions, the varieties showed different adaptive properties in terms of yield. According to the sum of points, the best ecological plasticity and stability in this set of varieties was shown by soft spring wheat «Kanskaya». It responds to improvements in growing conditions well and reduces yields in adverse conditions to a lesser extent.

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