Agroecological potential of winter soft wheat varieties for Middle Volga region conditions

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Abstract. Ecological plasticity and stability in productivity of seven varieties of winter soft wheat were studied in 2020-2021. As a result of the study it was found that on average for 2 years the most productive varieties were Grom, Sura va and Biryuza with yields of 60.5, 48.5 and 46.5 dt/ha, respectively. Moisture and protein content in all the varieties studied were within the optimum limits. The environment index showed that growing conditions were worse in 2021 ($I_1 = -12.8$) than in 2020 ($I_1 = 12.9$). The varieties Grom, Biryuza and Krastal were the most plastic ($bi = 1.3; 1.53; 1.41$, respectively). These varieties should be cultivated according to intensive technology. The yields of these varieties on improved growing conditions are high. The value of the linear regression coefficient for the variety Povolzhskaya Niva is practically zero ($bi = 0.01$). This variety does not respond to changes in growing conditions. In varieties Skipetr, Doneko and Surava the linear regression coefficient approached 1. These varieties respond to improved growing conditions. The calculation of the ecological plasticity index showed that the varieties Grom, Surava and Biryuza are also ecologically plastic. The Povolzhskaya Niva and Doneco varieties were found to be the most stable. Their standard deviation ($\sigma_d^2$) was 0.004. In the other varieties it was between 0.01 and 0.8. The most unstable variety was Krastal. The standard deviation ($\sigma_d^2$) was 1.1.

1. Introduction

In recent years, weather conditions have changed dramatically over the years and even during the growing season of crops. This leads to yield losses or quality deterioration. Therefore, there is a need to develop varieties that combine high economic value traits with ecological stability and plasticity.

The variety must provide a maximum yield increase at a minimum cost. This is only possible if the varieties are adapted to the stresses of the environment. Using the information on adaptive capacity, it is possible to determine the optimal agro-ecological zoning of the variety, and, given its responsiveness to the improvement of growing conditions, to create it [1].

Winter wheat is the most valuable and productive crop. Its grain contains a large amount of gluten proteins and other valuable substances, so it is widely used for food purposes: in baking, confectionary industry, for production of groats, pasta. Therefore, increasing the yield of this crop is always relevant [2, 3].

But modern varieties must be not only high-yielding, giving high quality products, but also resistant to adverse environmental factors. Only the high adaptability of the variety to agro-ecological resources of the environment (due to homeostaticity of its genotype) can ensure the stability of yield in different environmental conditions [4].
Therefore, the aim of the work was to determine the agroecological potential (ecological plasticity and environmental stability) of winter soft wheat varieties, in the conditions of Penza region, which will determine the potential of their development under specific conditions.

2. Methods and Materials
The research was conducted under the conditions of OOO (LLC) Cherkizovo-Cropgrowing in 2020-2021. The soil of the experimental plot was medium-humus medium-powered heavy loamy leached chernozem (black soil). Humus content in the arable layer was 6.5%; N-120 mg/kg, P-90 mg/kg, K-160 mg/kg. The pH of the soil solution was 5.0-5.5. The object of the research were varieties of winter soft wheat. A total of 7 varieties. Winter wheat was preceded by naked fallow. Seed rate - 5.5 million of germinated grains per hectare. The area of the plot was 25 m², repeated four times, the placement of plots systematic. The object of the research - a set of winter wheat varieties. The cultivation technology of winter wheat was the one generally accepted for Penza region.

During the growth and development of winter wheat plants, phenological observations were made and the following phases of vegetation were noted: sowing, sprouting, tillering, renewal of vegetation, shooting, earing, blossoming, full ripeness. The beginning of a phase was noted when 10% of the plants of the plot entered this phase, and the full onset of the phase - when such plants were at least 75%. All observations were made according to the methodology of the State Variety Testing Commission [5]. The yield structure, weight of 1000 seeds were determined according to generally accepted methods. Humidity was determined during the economic ripeness with a moisture meter.

The following agronomic techniques were used on the experimental plot.
1. Fallow disking, after the forecrop, up to 8 cm, 3rd decade of May.
2. Deep loosening - 25-28 cm, 2nd decade of June.
3. Cultivation - 8-12 cm, 1st decade of July.
4. Cultivation - up to 8 cm, 3rd decade of July.
5. Pre-cultivation - up to 8 cm, 3rd decade of August, immediately before sowing.

To determine the parameters of ecological plasticity and ecological stability most authors use the method of Eberhart and Russell [6]. We used this method modified by Zykin V.A. et al. [7].

The index of ecological plasticity was determined according to the method proposed by A.A. Gryaznov [8].

Ecological plasticity is characterised by the linear regression coefficient $b_i$, which is calculated according to the formula:

$$b_i = \frac{\sum Y_{ij}I_j}{\sum I_j^2},$$

where $\sum Y_{ij}$ – the sum of the product of the yield of a particular variety in a particular year by the corresponding value of the environmental index; $\sum I_j^2$ - the sum of the squares of the environmental conditions indices [6].

The environmental conditions indices are determined according to the formula:

$$I_j = \frac{\sum Y_{ij}}{n} - \frac{\sum \sum Y_{ij}}{v \times n},$$

where $\sum Y_{ij}$ – the sum of the yields of all varieties in one year; $\sum \sum Y_{ij}$ – the sum of the yields from all variants of the experiment; $v$ – the number of varieties; $n$ – the number of years.

The environmental stability is determined by dispersion $\sigma_{ij}^2$:

$$\sigma_{ij}^2 = \frac{\sum \sigma_{ij}^2}{(n-2)},$$

where $\sum \sigma_{ij}^2$ - the sum of the squares of the deviations of the actual yield from the theoretical yield; $n$ – the number of items. The theoretical yields for the varieties were determined using the formula:

$$Y_{ij} = x_i + b_i I_j,$$

where $x_i$ – the average yields over the years of the experiment; $b_i I_j$ – the product of the varietal regression coefficient by the environmental conditions index [6].
The ecological plasticity index was determined using the formula:

$$\text{EPI} = \frac{\text{VY}}{\text{AYE}},$$

where, EPI – the ecological plasticity index, VY - variety yield, AYE - total average yield in the experiment [8].

3. Results

The main way to increase agricultural production is to increase yields. Table 1 shows the average yield and quality of winter soft wheat varieties.

Table 1. Yield and quality of winter soft wheat varieties, average.

| Variety           | Yield, dt/ha | Humidity during harvesting, % | Protein, % |
|-------------------|--------------|-------------------------------|------------|
| Povolzhskaya Niva | 39.0         | 11.5                          | 15.5       |
| Grom              | 60.5         | 14.5                          | 13.5       |
| Skipetr           | 45.5         | 13.5                          | 14.5       |
| Doneko            | 41.0         | 12.5                          | 14.0       |
| Surava            | 48.5         | 11.0                          | 13.5       |
| Biryuza           | 46.5         | 12.5                          | 14.5       |
| Krastal           | 44.0         | 13.5                          | 13.5       |
| average           | 46.4         | 11.1                          | 14.1       |

The analysis of the experimental data showed that the average yield of winter soft wheat varieties in the experiment ranged from 39.0 to 60.5 dt/ha in two years. The average yield of all the varieties was 46.4 dt/ha. The average yield was higher in the varieties Grom (60.5 dt/ha), Surava (48.5 dt/ha) and Biryuza (46.5 dt/ha). The most productive variety was Grom, with a yield of 14.1 dt/ha higher than the overall average yield. The other varieties formed a yield below the overall average by 0.9-7.4 dt/ha. The lowest yield was observed for the variety Povolzhskaya Niva and amounted to 39 dt/ha.

Moisture is the most important indicator of grain quality. For the main grain crops, the basic moisture content varies from 13.5 to 15 %. During the harvesting period of winter soft wheat varieties, the moisture content was between 11.0 and 14.5 %, i.e. optimal.

Protein content is the amount of protein expressed as a percentage. It should be between 11-17 %. A higher protein content than 17-19 per cent and a lower protein content of less than 11 per cent would impair the quality of the bread. The protein content of winter soft wheat varieties was within the optimum range (13.5-15.5 %).

The high potential yield of plants can be realized only if it is "protected" by resistance to the action of abiotic and biotic stresses. Moreover, the worse the soil, climatic and weather conditions are, the higher is the role of ecological stability of plants in the implementation of their potential yield [9].

The role of variety as a biological system that ensures the stabilization of yield at a high level is especially important in a variety of soil-climatic and economic conditions of agricultural production [10]. The main comprehensive indicator of the adaptability of selected genotypes is the level of their yield in different environmental conditions [11]. Zykin V.A. et al. under the concept of "ecological plasticity" mean the ability of the variety to produce consistently high yields under different growing conditions. Ecological stability is the ability of the variety to maintain its structure and functions in the process of exposure to internal and external environmental factors [12]. To calculate the linear regression coefficient (ecological plasticity) it is necessary to determine the indices of environmental conditions. The set of indices characterizes the variability of the conditions in which the varieties were grown in a given experiment. The best conditions for growth and development of genotypes are formed under positive values of environmental conditions, the worst under negative conditions [13].

The results show that the most favourable conditions for the development of winter wheat plants were formed in 2020 (Table 2). The index of environmental conditions is 12.9. Less favourable conditions were in 2021. The index of environmental conditions had a negative value - -12.9.
Table 2. Ecological plasticity of winter soft wheat varieties.

| Variety          | Yield, dt/ha | Yi | bi  |
|------------------|--------------|----|-----|
| Povolzhskaya Niva| 39.0         | 78 | 0.01|
| Grom             | 77.0         | 121| 1.3 |
| Skipetr          | 58.0         | 88 | 0.98|
| Doneko           | 52.0         | 82 | 0.86|
| Surava           | 61.0         | 97 | 0.99|
| Biryuza          | 66.0         | 93 | 1.53|
| Krastal          | 62.0         | 88 | 1.41|
| ∑Yj              | 415          | 650| 46.4|

The varieties had a linear regression coefficient (bi) between 0.01 and 1.53. The higher the value of the linear regression coefficient, the more demanding the varieties to the conditions of cultivation and agricultural technology. The varieties Grom, Biryuza and Krastal are characterized by the greatest plasticity (bi - 1.3; 1.53; 1.41, respectively).

These varieties should be cultivated according to intensive technology. The response of these varieties to improved growing conditions is high. The value of the linear regression coefficient of the variety Povolzhskaya Niva is practically equal to zero (bi = 0.01).

This variety does not respond to changes in growing conditions. In varieties Skipetr, Doneko and Surava the linear regression coefficient approached 1. These varieties will respond to improved growing conditions.

To determine the stability of the genotype it is necessary to know the theoretical yield of varieties, i.e. the yield that is formed under favourable conditions. Thus, the theoretical yield in 2020 was higher than in 2021 for all studied winter wheat varieties and was in the range of 39.1 - 77.3 dt/ha. The highest theoretical yield in 2020 was calculated for the variety Grom (77.3 dt/ha). The same trend was observed in 2021 (Table 3).

Table 3. Calculated theoretical yield of winter soft wheat varieties, dt/ha.

| Variety          | Average yield per year |
|------------------|------------------------|
|                  | 2020                   | 2021                   |
| Povolzhskaya Niva| 39.1                   | 38.9                   |
| Grom             | 77.3                   | 43.9                   |
| Skipetr          | 56.6                   | 31.5                   |
| Doneko           | 52.1                   | 29.9                   |
| Surava           | 61.3                   | 35.8                   |
| Biryuza          | 66.2                   | 26.9                   |
| Krastal          | 62.2                   | 28.3                   |

The calculations of ecological stability are presented in Table 4.

Table 4. Ecological stability of winter soft wheat varieties.

| Variety          | Yield deviation σij, dt/ha | ∑σij² | σd² |
|------------------|-----------------------------|-------|-----|
|                  | 2020r.                      | 2021r.|
| Povolzhskaya Niva| -0.1                        | 0.1   | 0.02| 0.004|
| Grom             | -0.3                        | 0.1   | 0.1 | 0.02|
| Skipetr          | 1.4                         | 1.5   | 4.21| 0.8 |
| Doneko           | -0.1                        | 0.1   | 0.02| 0.004|
| Surava           | -0.3                        | 0.2   | 0.13| 0.03|
| Biryuza          | -0.2                        | 0.1   | 0.05| 0.01|
| Krastal          | -0.2                        | -2.3  | 5.33| 1.1 |
Ecological stability was determined by the standard deviation ($\sigma^2$). The lower this indicator, the more stable the variety is. The Povolzhskaya Niva and Doneko varieties were found to be the most stable. Their standard deviation ($\sigma^2$) was 0.004. In other varieties it was in the range of 0.01 - 0.8. The most unstable variety was Krastal. The standard deviation ($\sigma^2$) was 1.1.

A.A. Gryaznov proposed to evaluate the plasticity of the variety according to the index of ecological plasticity [4]. The index of ecological plasticity makes it possible to rank varieties according to their ecological plasticity, inhibiting the influence of monoculture. It is determined within variety groups (Table 5).

| Variety        | Yield, dt/ha | Average $X_v$, dt/ha | EPI  |
|----------------|--------------|----------------------|------|
|                | 2020 | 2021 |                |             |
| Povolzhskaya Niva | 39.0 | 39.0 | 39.0 | 0.84 |
| Grom           | 77.0 | 44.0 | 60.5 | 1.30 |
| Skipetr        | 58.0 | 33.0 | 45.5 | 0.98 |
| Doneko         | 52.0 | 30.0 | 41.0 | 0.88 |
| Surava         | 61.0 | 36.0 | 48.5 | 1.04 |
| Biryuza        | 66.0 | 27.0 | 46.5 | 1.00 |
| Krastal        | 62.0 | 26.0 | 44.0 | 0.95 |
| Average $X_p$  | 59.2 | 33.6 | 46.4 |      |

As shown in Table 5, the ecological plasticity index varies from 0.84 to 1.3. If the ecological plasticity index is $>1$, then the variety or hybrid is considered to be plastic, if $<1$, then there is a closer relationship with growing conditions.

The analysis of the experimental data showed that the varieties of winter soft wheat Grom, Surava and Biryuza are ecologically plastic. The index of ecological plasticity is 1.3; 1.04 and 1.00, respectively. The other varieties require more attention during cultivation.

4. Conclusion.
The most interesting varieties of winter soft wheat are Grom, Biryuza and Krastal, which are characterized by the greatest plasticity (bi - 1.3; 1.53; 1.41, respectively.). These varieties should be cultivated according to intensive technology. The yields of these varieties on improved growing conditions are high. These varieties can be recommended for cultivation in the conditions of Penza region.

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