Characteristics of the adaptive properties of winter soft wheat varieties in the conditions of the Middle Volga region

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Abstract. The paper deals with the obtained results of examining the adaptive properties of winter wheat varieties cultivated in the seventh (Middle Volga) region of the Russian Federation. The following varieties were taken as the object of the current research: Bezenchukskaya 380, Nemchinovskaya 57, Scepter, Moskovskaya 56, Fotinya, Claudia 2. This research was carried out with the aim to improve the efficiency of grain production. The chosen varieties had been studying at six levels of mineral nutrition over three years. The indicators obtained by years of research (without fertilization), characterizing the attitude of genotypes to the conditions prevailing during the growing season of crops, were considered as the influence of unregulated environmental factors. The indicators obtained during the application of fertilizers were assessed as controlled environmental factors. The adaptive properties of winter wheat varieties were assessed by indicators characterizing potential adaptability or potential productivity, resistance to stress and the intensity of reaction to favorable environmental conditions. Taking into consideration the adaptive properties of the winter wheat varieties, it was found that they are mainly potentially productive forms, but varieties differ significantly in stress resistance and reaction to favorable environmental conditions. As a result of a comprehensive assessment, conclusions were made about the advisability of using a particular variety in technologies with different levels of cultivation intensity. Firstly, the varieties such as Bezenchukskaya 380, Fotinya and Claudia 2 should be used in technologies of moderate intensity. Secondly, it would be more efficient to cultivate the varieties Nemchinovskaya 57 and Scepter using intensive technologies. Thirdly, the variety Moskovskaya 56 could be cultivated with applying both moderate and high-intensity technologies.

1. Introduction

In variety testing of winter wheat, as a rule, the main criteria for evaluating varieties is the amount of yield increase in relation to the variety adopted as the standard. However, the results of such an assessment are insufficient; they would largely depend on the level of the realized productivity of the standard. At the same time, it is difficult to predict how varieties would grow in changing environmental conditions, which is important for making the right decision on efficiency of their future application in agricultural production. Modern varieties have high yield potential. At the same time, their cultivation under production conditions does not always provide the expected yield [1, 2, 3]. This situation is due to insufficient information on the growing of varieties in unregulated environmental conditions and their reactions to technological methods [4, 5]. Therefore, the
assessment of the adaptive properties of varieties and the selection of ones with a high realization of potential productivity is an important reserve for further increasing grain production.

2. Object, conditions and methods of research
The object of the current research was the following varieties of winter wheat, released in the seventh (Middle Volga) region: Bezenchukskaya 380, Nemchinovskaya 57, Scepter, Moskovskaya 56, Fotinya, Claudia 2. The varieties had been evaluating at six levels of mineral nutrition for three years. The weather conditions for the years of research were characterized by the hydrothermal humidity factor (HHF): 2016-2017 - favorable; 2017-2018 - not favorable enough; 2018 - 2019 is unfavorable. To assess the adaptive properties, the following indicators were used: adaptive ability (Yi) calculated by the method of L.A. Zhivotkov [6] with coauthors; stress resistance (Ymin-Ymax) according to the equations of Rosielle A.A., Hamblin J.[7]; intensity of the variety, the reaction of the genotype to a favorable background (I) according to the formula of A.P. Golovochenko [8].

3. Results
One of the indicators characterizing the responsiveness of varieties to the prevailing environmental conditions is the coefficient of adaptability. If the coefficient exceeds 1, it is considered that the variety is potentially adaptive or potentially highly productive. For analysis of the productive and adaptive potential of winter wheat varieties used the data on yield obtained in experiments dispersed in time (at one plot over a number of years) on six contrasting contents of mineral nutrition. When calculating the coefficient of adaptability, the authors proceeded from the fact that all varieties under the prevailing conditions of a particular year experience the same influence of the environment, but the reaction of genotypes to the environment manifests itself in different ways. Therefore, all changes in the reaction, positive and negative, accumulate in the average index, which expresses general variety reaction. Deviation from the general variety reaction rate of a single variety characterizes its adaptability, and since the variety shows this property for a number of years, the average indicator reflects the potential of its productivity. The assessment of the adaptability coefficient without fertilizers shows the ratio of varieties to unregulated environmental conditions, but in the case with the use of fertilizers - to regulated environmental conditions (Table 1).

Table 1. The adaptability coefficient of winter wheat varieties on contrasting growing conditions.

| Variety               | Conditions                     | Yi       |
|-----------------------|-------------------------------|----------|
| Bezenchukskaya 380    | without fertilization         | 1.00     |
|                       | N16P16K16 during sowing + N68  | 0.99     |
| Nemchinovskaya 57     |                               | 1.01     |
|                       | for fertilizing               | 0.95     |
| Scepter               |                               | 1.01     |
|                       |                               | 1.01     |
| Moskovskaya 56        |                               | 0.98     |
|                       |                               | 1.06     |
| Fotinya               |                               | 1.04     |
|                       |                               | 0.96     |
| Claudia 2             |                               | 1.02     |
|                       |                               | 1.00     |

Evaluating the obtained indicators of the coefficient, it could be seen that all varieties were characterized by high potential productivity under conditions without fertilization. Changing the nutritional conditions of crops to more favorable ones showed that the Scepter varieties were characterized by stable high productivity (Yi = 1.01) and Claudia 2 (Yi = 1.00 - 1.02). The variety Moskovskaya 56 fully realizes the productivity potential at a higher nutritional level (Yi = 1.06). The varieties Bezenchukskaya 380, Nemchinovskaya 57 and Fotinya, insignificantly, but reduce the level of realization of potential productivity and adaptability with an increase in the level of nutrition (Yi = 0.99; 0.95; 0.96, relatively). Perhaps, this happens as a result of a change in the dominant influence of factors on the genotype of varieties. The influence of weather conditions on the amount of these varieties yield is more efficient in comparison with the plant nutrition factor.
Another important indicator characterizing the adaptability of varieties is stress resistance. This indicator is the difference between the yields (Y_{\text{min}} - Y_{\text{max}}) in alternative conditions, which have a negative characteristic, which influence the level of varieties resistance to stressful growing conditions. It points out that the stress resistance of the variety is higher with a smaller difference between the conditions, therefore, the range of its adaptive capabilities is wider. In the current research, contrasting levels of crop mineral nutrition were used as an alternative controlled environment. The minimum yields were obtained in 2018-2019, the growing season of winter wheat was characterized as unfavorable for sowing and growing of crops. The maximum yields were obtained in 2016-2017, the weather conditions were favorable for sowing and growing of winter wheat. The significant difference in yields over the years of this research represents alternative uncontrolled environmental conditions. The adaptive capacity of varieties could vary and depend on the level of mineral nutrition (controlled environmental conditions). This is due to the fact that without fertilization, the genotype reacts only to the factor of the year (uncontrolled environmental conditions); when fertilizers are applied, the genotype reacts to the factor of the year and the factor of changes in crop nutrition. Thus, it would be efficient to evaluate the stress resistance of varieties for each nutritional conditions apart (Table 2).

Table 2. Level resistance of winter wheat varieties to stressful conditions.

| Variety                  | Without fertilization | Variety level (grade) | N_{16}P_{16}K_{16} during sowing + N_{68} for fertilizing | Variety level (grade) |
|--------------------------|-----------------------|-----------------------|----------------------------------------------------------|-----------------------|
| Bezenchukskaya 380       | -1.3                  | 1                     | -3.5                                                     | 2                     |
| Nemchinovskaya 57        | -3.4                  | 6                     | -4.2                                                     | 5                     |
| Scepter                  | -3.3                  | 5                     | -4.7                                                     | 6                     |
| Moskovskaya 56           | -2.4                  | 2                     | -4.1                                                     | 4                     |
| Fotinya                  | -2.8                  | 4                     | -2.8                                                     | 1                     |
| Claudia 2                | -2.6                  | 3                     | -3.6                                                     | 3                     |

The given data gives information about the changes in environmental conditions cause different adaptive capabilities of varieties. Thus, under conditions without fertilization, the genotype shows a reaction only to the factor of the year, the variety Bezenchukskaya 380 was characterized by high stress resistance (Y_{\text{min}}-Y_{\text{max}} = -1.3). The stress resistance of the following varieties was lower: Moskovskaya 56, Claudia 2 and Fotinha (Y_{\text{min}}-Y_{\text{max}} = -2.4; -2.6; -2.8 respectively); the varieties Scepter and Nemchinovskaya 57 (Y_{\text{min}}-Y_{\text{max}} = -3.3; -3.4 respectively). The assessment of the resistance level of varieties to stressful conditions with applying fertilization showed that the ranking of this indicator is changing. The results obtained indicate that cultivation techniques (in a specific plot, the crop nutrition regime), taking into account the genotype, could increase or decrease the stress resistance. For instance, comparing the ranking of varieties under different conditions, it could be seen that the application of mineral fertilizers significantly increases stress resistance in the Fotinya variety (grade 1). The variety Bezenchukskaya 380 slightly reduces the stress resistance (grade 2). The Claudia 2 variety is characterized by the preservation of adaptive capabilities at different levels of mineral nutrition (grade 3). The Moskovskaya 56 variety shows a decrease in the stress resistance (grade 4). The varieties Nemchinovskaya 57 and Scepter (grade 5 and grade 6) retain the low stress resistance and do not depend on the nutritional conditions.

Currently, when choosing a variety, it is required take into account not only the stable productivity of the variety, but also its intensity. Since many agricultural enterprises are focused on carrying out agrotechnical technologies that increase the intensity of farming. It should be taken into consideration that biologically different varieties realize their potential yield in different ways. Intensive farming requires intensive type varieties capable of responding quickly to efficient growing conditions. In this case, the reaction is understood both to positive unregulated factors of vegetation conditions (for example, precipitation, favorable temperature conditions), and to regulated factors (fertilization, use of...
chemicals for plant protection). For this aim, in order to establish the reaction of varieties to favorable unregulated factors, the growing conditions had been analyzing during the years of the current research. Thus, it was found that the growing season in 2016-2017 was characterized as an optimal environment - the medium index was 5.2. The growing conditions in 2018-2019 represented a limiting environment - the environment index was 2.5. Having determined the difference in yield between contrasting conditions for each specific variety and having established its relation to the environment index, we obtained an indicator of the intensity of the variety or its reaction to favorable weather conditions. In order to determine the reaction of varieties to controlled favorable environmental factors, six levels of mineral nutrition were analyzed at which the varieties were growing. It was determined that all varieties formed the highest yield on the option of N_{16}P_{16}K_{16} for sowing + N_{68} for fertilizing. The lowest yield of the varieties was in the case without fertilizers. The optimal and limiting conditions at the established environmental index made it possible to evaluate varieties for the reaction of the genotype to favorable conditions (intensity level). The cultivation without fertilization characterizes the reaction of varieties to favorable unregulated environmental conditions. Indeed, the conditions where applied fertilizers characterize the response of the varieties to favorable controlled environmental conditions (Table 3).

| Variety          | Without fertilization | Variety level (grade) | N_{16}P_{16}K_{16} during sowing + N_{68} for fertilizing | Variety level (grade) |
|------------------|-----------------------|-----------------------|-------------------------------------------------------------|-----------------------|
| Bezenchukskaya 380 | 33.0                  | 6                     | 70.0                                                         | 5                     |
| Nemchinovskaya 57  | 87.2                  | 1                     | 84.0                                                         | 2                     |
| Scepter          | 84.6                  | 2                     | 94.1                                                         | 1                     |
| Moskovskaya 56    | 61.5                  | 5                     | 82.3                                                         | 3                     |
| Fotinya          | 72.0                  | 3                     | 56.0                                                         | 6                     |
| Claudia 2         | 66.7                  | 4                     | 72.3                                                         | 4                     |

Analyzing the intensity level of winter wheat varieties according to the reaction to favorable unregulated environmental conditions, i.e. on optimal weather conditions during the period of crop sowing and growing, it could be noted that varieties are characterized by a significant reaction - Nemchinovskaya 57 and Scepter (I = 87.2; 84.6, respectively). The lower reaction to the environmental conditions were in the varieties Fotinya and Claudia 2 (I = 72.0; 66.7, relatively). The varieties Moskovskaya 56 and Bezenchukskaya 380 (I = 61.5; 33.0, respectively) had lower indicators of reaction to the improvement of unregulated conditions. An assessment of the varieties reaction to favorable regulated environmental conditions, in this case to the optimal nutritional level, showed that the varieties Scepter and Nemchinovskaya 57 had a significant reaction to the improvement of regulated environmental factors (I = 94.1; 84.0, relatively). The reaction is lower in the Moskovskaya 56 variety (I = 82.3), but significantly higher than in the Claudia 2, Bezenchukskaya 380 and Fotinya varieties (I = 72.3; 70.0; 56.0).

4. Conclusions
As a result of the current research, it was revealed that the examined varieties of winter wheat, under the special soil and climatic conditions of the Middle Volga region, are characterized by a different complex of adaptive properties. Thus, the variety Bezenchukskaya 380 has high potential productivity and adaptability, it is characterized by high adaptive capabilities, which are based on stable stress resistance. At the same time, this variety is characterized by low responsiveness to favorable environmental conditions. Based on the information given in the article, it could be assumed that the variety Bezenchukskaya 380 could be successfully used for cultivation with applying technologies of moderate intensity. The varieties Nemchinovskaya 57 and Scepter are characterized by high potential productivity. However, these varieties are characterized by consistently low stress resistance, which
significantly limits the adaptive capacity. A distinctive feature of these varieties is high intensity, they significantly react to favorable environmental conditions. Thus it could be used for growing the varieties Nemchinovskaya 57 and Scepter in the frame of the intensive technologies. The variety Moskovskaya 56 has high potential productivity, characterized by moderate stress resistance and unstable reaction to favorable environmental conditions. This variety could be cultivated using both moderate and high intensity technologies. The variety Fotinya is characterized by high potential productivity, unstable stress resistance and significant reaction to improved growing conditions. It would be favorable to cultivate the Fotinha variety using technologies of moderate intensity. High potential productivity and adaptability are characteristic of the variety Claudia 2. The variety is characterized by a stable average level of stress resistance and stable, but low reaction to favorable environmental conditions. The Claudia 2 variety is more intended for cultivation by technologies of moderate intensity.

References
[1] Waseem M, Mumtaz S, Hameed M, Ashraf M and Ahmad I 2021 Adaptive traits for drought tolerance in red-grained wheat (Triticum aestivum L.) landraces Arid Land Research and Management 35(4) 414–445
[2] Makarova T, Samofalova N, Ilichkina N, Popov A and Kostylenko O 2020 Adaptability parameters of the winter durum wheat varieties of various ecology in the Rostov region E3S Web of Conferences 175, 01014
[3] Mohammadi R, Sadeghzadeh B, Ahmadi M M and Amri A 2020 Biological interpretation of genotype × environment interaction in rainfed durum wheat Cereal Research Communications 48(4) 547–54
[4] Guo J, Li C, Zhao J, Zhou M and Hao C 2020 Ecological genomics of Chinese wheat improvement: implications in breeding for adaptation BMC Plant Biology 20 (1) 494
[5] Rustamov Kh N, Akparov Z I, Abbasov M A 2020 Adaptive potential of durum wheat varieties of Azerbaijan Transactions on Applied Botany, Genetics and Breeding 181 (4) 22–28
[6] Zhivotkov L A, Morozova Z A and Sekatueva L I 1994 Methodology for identifying the potential productivity and adaptability of varieties and breeding forms of winter wheat according to the indicator "Productivity" Selection and seed production 2 3–6
[7] Rosielle A A and Hamblin J 1981 Theoretical aspects of selection for yield in stress and nonstress environments Crop science 21 (6) 943–46
[8] Golovochenko A P 2001 Features of adaptive breeding of spring soft wheat in the forest-steppe zone of the Middle Volga region (Samara) p 380