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# Study of Drought Resistance of New Varieties of Spring Barley Based on Photosynthetic Potential and Leaf Diagnostics "Ecotest 2020" in Arid Conditions of the Lower Volga Region

Guzenko A. Yu.[1], A.V. Guzenko[1], V.L. Sapunkov[1]

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## ABSTRACT

**Background:** Due to the changing climatic conditions in the Southern Federal District over the past thirty years, the yield of spring barley has fallen sharply due to the sharp hot and extreme temperatures. In 2023, based on early research and a summary of meteorological forecast data in the Volgograd region, an experiment was launched on the basis of the Federal Scientific Center of Agroecology of the Russian Academy of Sciences in Kamyshinsky district to test spring barley varieties: Medicum 139, Medicum 200, Kamyshinsky 23, Dmitrievsky 5 and Novonikolaevsky. These varieties were selected as the most stress-and drought-resistant in terms of their breeding characteristics.

**Methods:** The technology of cultivating varieties of spring barley in field experiments was according to B.A. Dospekhov and the methodology of the state variety testing of agricultural crops.

**Result:** When studying the products of spring barley varieties, variety tests were conducted in arid conditions of the Southern Federal District. The study of the potential of spring barley varieties in experimental plots according to PP and NPP made it possible to assess the productivity of crops in the "germination-tillering" phase. The results of leaf diagnostics, further research in the Kamyshinsky district allowed us to identify the most heat- and drought-resistant varieties despite extreme weather conditions.

**Key words:** Chlorophyll in leaves, Dry matter, EcoTest 2020, Leaf diagnostics, Photosynthetic potential, Spring barley.

## INTRODUCTION

Barley is primarily a cereal grain crop grown in rabi season and widely used for food, fodder and in beer industry. Dual purpose barley provides quality fodder as well as grain (Singh *et al*., 2017). Globally, it ranks fourth in cereal production after maize, wheat and rice and is included in the list of the priority crops in the Agriculture Master Plan of the State of Kuwait (Al-Ghzawi, 2019; Azarenko, 2003; Seminchenko, 2021).

Most regions of the Russian Federation are located in areas of risky farming. This important factor is overlaid by annual climatic anomalies, which vary significantly in different regions: from early spring droughts with fires to frosts in June, from 3-4-year droughts to 2-3-month precipitation rates falling in 1-2 days (Dontsova, 2016; Klem, 2019; Sheudzhen, 2014).

Spring barley is a popular crop in the Lower Volga region. Grain is mainly used as concentrated livestock feed and raw materials for the cereal industry. In the Volgograd region, the area of crops of this plant in 2021-2022 reached 305.7 thousand hectares (Aristarkhov, 2014; Bendada Hocine, 2020; Isaichev, 2013). The widespread use of barley is explained by the fact that it is less demanding to the growing conditions. The yield of spring barley in the Volgograd region remains low and averages 1.21-1.37 t/ha, which requires the creation of varieties more adapted to local conditions. Until recently, spring barley varieties were grown in the region, created outside its borders and insufficiently adapted to the arid climatic conditions of the Lower Volga region. One of the ways to solve this problem is selection (Zelenev, 2022). The sharply continental climate of the Lower Volga region with its characteristic periodic droughts places increased demands on cultivated varieties. The influence of genotypes is also significant for grain yield and thousand-eater mass, for chlorophyll content. High productivity and crop quality can only be obtained with a favorable combination of all plant development factors. During the growth and development

[1]Federal State Budgetary Scientific Institution "Federal Scientific Center of Agroecology, Complex Melioration and Protective Afforestation of the Russian Academy of Sciences" (Federal Research Center of Agroecology of the Russian Academy of Sciences), Russia.

**Corresponding Author:** Guzenko A. Yu., Federal State Budgetary Scientific Institution "Federal Scientific Center of Agroecology, Complex Melioration and Protective Afforestation of the Russian Academy of Sciences" (Federal Research Center of Agroecology of the Russian Academy of Sciences), Russia.
Email: guzenko-ay@vfanc.ru

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of plants in severely arid conditions, the intensity of photosynthesis and photosynthetic activity of barley certainly changes (Labidi, 2022; Nushtaeva, 2021). The photosynthetic activity of plants in crops includes a number of important indicators: the size of the photosynthetic apparatus, the speed of its development, the duration and intensity of leaf activity and the net productivity of photosynthesis. Indicators of leaf area, duration of their work and accumulation of dry biomass determine the productivity of photosynthetic activity of crops. Leaf area is one of the important indicators characterizing the photosynthetic activity of plants depending on the movement of nutritional elements in the plant (Isaichev, 2013; Astafurova, 2011). Based on the literature data, we set the following objectives of this study.

**Purpose**

To study the productive potential and sustainability of new varieties of spring barley, taking into account modern technologies and agro-climatic features of the experimental site of the Southern Federal District.

**Novelty**

For the first time, new varieties of spring barley of various genetic characteristics are being studied in the soil and climatic conditions of the Southern Federal District.

## MATERIALS AND METHODS

The technology of cultivating varieties of spring barley in field experiments was according to B.A. Dospekhov and the methodology of the state variety testing of agricultural crops (Dospekhov, 2011). The leaf surface area, the net photosynthesis productivity (NPP) according to Nichiporovich (Nichiporovich, 1966) and the structure of the crop were studied on the base Federal Research Center of Agroecology of the Russian Academy of Sciences in 2022 and 2023 years.

Leaf diagnostics was carried out using the device "EcoTest 2020" according to the methodology of A.S. Pleshkov and B.A. Yagodin.

Pre-sowing cultivation of the fallow field was carried out on 04.10.2022 and 04.18.2023. Sowing was carried out on 04.12.2022 and 04.21.2023. The norm is 3.5-4.0 million germinating seeds per 1 ha. The depth of seeding is 3-4 cm.

The seeder is CC -11 (Alpha). The objects of research were 5 varieties of spring barley (Table 1).

The leaf surface area, the net photosynthesis productivity (NPP) according to Nichiporovich (Nichiporovich, 1966) and the structure of the crop were studied.

10 green leaves were randomly selected from each sample, weighed and the area was determined by linear measurements of length (L) and greatest width (W).

The area of the measured leaves (S) was calculated using the formula:

$$S = Lav \times Wav \times 0.7 \times n$$

Where

n- The number of measured leaves.

The dry mass was determined by drying the collected material to a constant weight at 800°C in a drying cabinet, cooled in a desiccator and weighed to the third decimal place on an analytical scale. The photosynthetic activity of spring wheat plants in crops was determined in accordance with the methodological guidelines (Kretovich, 1972).

Visual and chemical diagnostics were carried out using the method of functional diagnostics of plant nutrition, first proposed by domestic scientists Pleshkov A.S. and Yagodin B.A. The Eco test 2020 device with a certain wavelength with the background of this climate was used (Fig 1).

The calculation, with wavelength measurement, for the nutrition elements of each variety was carried out in the phase of plant development-tillering. The measurements were carried out against the background of chloroplast movement before the sample was illuminated with a lamp and after illumination from the control measurements "K2-K3-K4-K5", ensuring the movement of chloroplasts in solution with an incandescent lamp with a time interval of 45 seconds (Fig 1).

Mathematical data processing was performed using correlation and regression analysis methods along the trend line, using the Excel 7.0 software package.

## RESULTS AND DISCUSSION

Conducting research on the experimental site of the Volgograd region of the Southern Federal District allowed us to identify the most heat- and drought-resistant varieties, despite the extreme conditions of soil leaching along the slope steepness, as well as due to heavy rains (Kostin, 2018; Sukhova, 2019).

**Table 1:** Spring barley varieties tested in 2022-2023.

| Name of the variety | Brief description | Origin |
|---|---|---|
| Kamyshinsky 23 | High productivity, resistance to lodging | "Federal Scientific Center of Agroecology, |
| Medicum 139 | Tall, precocious, coarse-grained | Integrated Land Reclamation and Protective |
| Medicum 200 | Drought-resistant, increased bushiness | Afforestation of the Russian Academy of |
| Dmitrievsky 5 | In terms of heat and drought resistance, | bushiness, Sciences", Volgograd |
| | lodging resistance, brittleness of the ear and stem, | |
| | it is at the level of the standard variety Kamyshinsky 23 | |
| Novonikolaevsky | Large grains, increased bushiness | |

The soil relief at this experimental site consisted of large fractions of granulometric composition and a humus-depleted fertile layer of 0-10 cm -1.2%. In this regard, field germination was 15 days after sowing, on average 46 to-52 plants/m$^2$. Consequently, this number of plants from the seeding rate of 3.5 million pcs/m$^2$ was due to the factor of an initially critical lack of nutrition at the experimental site (Perekrestov, 2019).

Considering that the research was conducted with an emphasis on the genetic data of spring barley varieties and on resistance to extreme hot and arid conditions in the spring and summer period of the Volgograd region, studies were conducted on the photosynthetic potential and activity of chloroplasts in barley nutrition elements.

The temperature regime and amount of precipitation in March 2022 (179 mm) made it possible to obtain full shoots two weeks after sowing. At the end of May 2022, heavy rainfall occurred. Unfavorable conditions associated with high temperatures in the first ten days of June 2022, observed during the booting phase, slightly slowed down the development processes of spring barley plants, however, from the second ten days of June (before the start of the flowering phase), short-term precipitation fell, which allowed spring barley plants to form full-fledged grain. In March 2023, positive dynamics of daytime temperatures were established, but negative ones were observed at night, with an average monthly temperature of 2.30 C. In March, 147 mm of precipitation fell in the form of rain and snow, this replenished the moisture supply in the upper layers of the soil. In April, there was a gradual increase in air temperatures, but at night, recurrent night frosts were recorded. The average temperature for April was +8.40 C and 62.6 mm of precipitation fell. The climatic conditions of the experimental site in the first ten days of May for sowing spring barley were favorable in terms of temperature, but later extreme temperature changes were observed due to prolonged rainfalls. The average monthly air temperature is 15.10 C. During this period, 51.4 mm of precipitation fell. In June the weather was clear and hot. In the first ten days there were heavy rains, totaling 58 mm. The maximum air temperature reached +32.00 C. In July the heat increased to +380 C and there was little precipitation-14.5 mm. Heavy rainfall for 2022-2023. had a positive effect on the development of productive tillering, root mass and shoot mass of each variety of spring Barley (Guzenko, 2022).

In the process of research site have shown that already at the early stages of ontogenesis, different varieties of spring barley have differences in the size of the leaf apparatus, depending on the characteristics of each variety.

The Kamyshinsky variety 23 with a result of 581.5% had the best indicators in terms of the volume of leaf surfaces in the phase period "tillering-earing", however, Dmitrievsky 5 also showed itself with a slight difference, the difference was 35-to 48 thousand m$^2$ day/ha (Table 2).

**Table 2:** Photosynthetic potential of spring barley crops in the Kamyshinsky district of the Volgograd region (thousand m$^2$ day/ha), average for 2022-2023.

| Name of the variety | The interphase period | | |
|---|---|---|---|
| | Tillering-exit into the tube | Exit into the tube-earing | Tillering-earing |
| Medicum 139 | 173.3 | 279.4 | 452.7 |
| Medicum 200 | 186.3 | 287.3 | 473.6 |
| Kamyshinsky 23 | 219.6 | 361.9 | 581.5 |
| Novonikolaevsky | 201.3 | 317.3 | 518.6 |
| Dmitrievsky 5 | 191.9 | 294.3 | 532.2 |
| HCP05 | 9.72 | 15.402 | 127.93 |

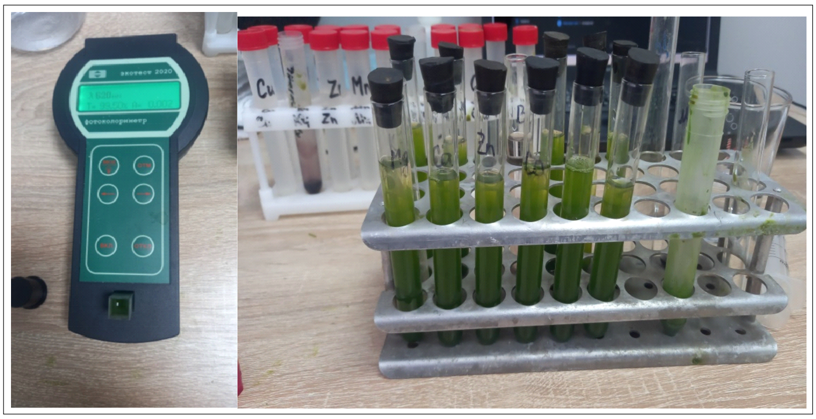

**Fig 1:** Test tubes with prepared chloroplast suspension for measuring the movement of chloroplasts by plant nutrition elements in spring barley varieties.

A concomitant indicator of PP is, as previously indicated, the purest photosynthetic productivity, which is noted on the Kamyshinsky variety 23. Also, from spring barley, there was a slight decrease in NPP from the leading variety, Dmitrievsky 5 - by 0.23 g/m$^2$ (Table 3).

Further studies have shown that the active accumulation of absolute dry matter occurs in the “exit into the tube” phase and amounts to the maximum amount in Kamyshinsky 23 varieties - 480 g/m$^2$ (Table 4).

The analysis of chloroplast isolation and optical density measurements in this area between the varieties was also carried out and showed a weightless difference in the lack of elements in plants.

During the development of barley in the “tillering-booting” phase, the movement of chloroplasts in plant leaves and the supply of plant nutrients was studied using a mobile laboratory to carry out functional diagnostics using the express “Ecotest 2020” method.

The purpose of the invention is to rank the level of nutritional elements required by the plant - the “response” of the wavelength of chloroplasts to the studied nutrients of spring barley varieties. Using dispersion quantitative analysis of each diagnosed element, the significance and amount of nutrient reserves during the movement of chloroplasts are assessed (Dolgopolova, 2019). The value (percentage) of the response is determined by the difference in the photochemical activity of the chloroplast suspension when diagnosing nutrients in the finished chloroplast suspension. This method made it possible to adjust the need for plant nutrients responsible for drought resistance of spring barley varieties: phosphorus, potassium, nitrogen, zinc, copper and others. For analysis, we used 3-4 leaves (from the top) of adult plants in the tillering phase (April 29, 2022 and May 6, 2023).

The study of the movement of chloroplasts by nutrition elements in the varieties of the Federal Research Center of Agroecology of the Russian Academy of Sciences showed that a high percentage of deviation from the control measurement “K2 - K3 - K4 - K4 - K5” was in Medicum 139 and Medicum 200 within ± 9-to 14%. The smallest deviation in the range of 4–5% for all food elements was in the grades Kamyshinsky 23 and Dmitrievsky 5 - on average 3-5% (Fig 2).

Based on the data obtained on the content of nutrients in extreme soil and climatic conditions with a small supply of humus, the following varieties proved to be the most stable: Kamyshinsky 23, Novonikolaevsky and Dmitrievsky 5 (Fig 2).

Summing up the leaf diagnostics, further research at the experimental site in the Kamyshinsky district allowed us to identify the most heat- and drought-resistant varieties, despite extreme conditions and soil relief consisting of large fractions of granulometric composition and depleted with humus, these are: Kamyshinsky 23 and Dmitrievsky 5 (Table 5).

The productive stem growth by varieties was on average in the range of 147-152 pcs/m$^2$, but the most progressive number of stems was calculated by varieties: Kamyshinsky 23-178 pcs/m$^2$ (Table 5). Other varieties had a lower productive stem from the two previous varieties by an average of 8-12% (Table 5). Based on the data obtained on the content of nutrients in extreme soil and climatic conditions with a small supply of humus.

**Table 3:** Net photosynthesis productivity of spring barley in the Volgograd region of the Southern Federal District, g/m$^2$, average for 2022-2023.

| Name of the variety | The interphase period | | |
|---|---|---|---|
| | Tillering-exit into the tube | Exit into the tube-earing | Tillering-earing |
| Medicum 139 | 0.01 | 0.08 | 0.09 |
| Medicum 200 | 0.02 | 0.08 | 0.1 |
| Kamyshinsky 23 | 0.11 | 0.17 | 0.28 |
| Novonikolaevsky | 0.07 | 0.15 | 0.19 |
| Dmitrievsky 5 | 0.05 | 0.14 | 0.23 |
| HCP05 | 0.002 | 0.013 | 0.008 |

**Table 4:** Dynamics of dry matter accumulation in spring barley crops in the Volgograd region of the Southern Federal District, g/m$^2$, average for 2022-2023.

| Name of the variety | The interphase period | | |
|---|---|---|---|
| | Tillering-exit into the tube | Exit into the tube-earing | Tillering-earing |
| Medicum 139 | 89 | 247 | 336 |
| Medicum 200 | 94 | 276 | 370 |
| Kamyshinsky 23 | 136 | 344 | 480 |
| Novonikolaevsky | 102 | 294 | 396 |
| Dmitrievsky 5 | 110 | 337 | 456 |
| HCP05 | 5,31 | 14,98 | 20,38 |

As in the previous above-mentioned indicators, the leading varieties in yield are Kamyshinsky 23 (1.23 t/ha) and Dmitrievsky 5 (0.93 t/ha). The lowest values were obtained from Medicum 139-0.65 t/ha (Table 6).

Based on the verification of spring barley in the tillering phase for the potential of chloroplast activity in plant leaves (3-4 leaves), a trend model of cultivated varieties in the soil-climatic zone of chestnut soils with a humus content of 1.2% (Variable-X) was developed. The actual yield (Variable-Y) was taken as the main indicator of the potential of spring barley varieties. The reliability of the obtained trend line equations is confirmed by the approximation value ($R^2$), or the so-called coefficient of determination, which shows the degree of compliance of the trend model with the initial data. When conducting an approximation analysis, Kamyshinsky 23 varieties ($R^2$=0.63) obey the polynomial equation (Table 7),

**Table 5:** Yield structure of spring barley varieties in the Volgograd region of the Southern Federal District, average for 2022-2023.

| Name of the variety | Stem height, cm | Ear length, cm | Number of grains per ear, pcs | Productive stem, pcs/m$^2$ |
|---|---|---|---|---|
| Medicum 139 | 46 | 6.7 | 16 | 152 |
| Medicum 200 | 56 | 6.5 | 15 | 146 |
| Kamyshinsky 23 | 47 | 6.8 | 17 | 178 |
| Novonikolaevsky | 46 | 7.1 | 16 | 145 |
| Dmitrievsky 5 | 47 | 6.5 | 16 | 161 |
| HCP05 | 2.42 | 0.34 | 0,8 | 7,82 |

**Table 6:** Yield structure of spring barley varieties in the Volgograd region of the Southern Federal District, t/ha, average for 2022-2023.

| Name of the variety | Weight of 1000 seeds, g | Biological yield, t/ha | Actual yield, t/ha |
|---|---|---|---|
| Medicum 139 | 18.7 | 0.92 | 0.65 |
| Medicum 200 | 24.3 | 1.52 | 0.84 |
| Kamyshinsky 23 | 25.1 | 1.61 | 1.23 |
| Dmitrievsky 5 | 19.7 | 1.19 | 0.93 |
| Novonikolaevsky | 20.3 | 1.04 | 0.91 |
| HCP05 | 1.08 | 0.06 | 0.05 |

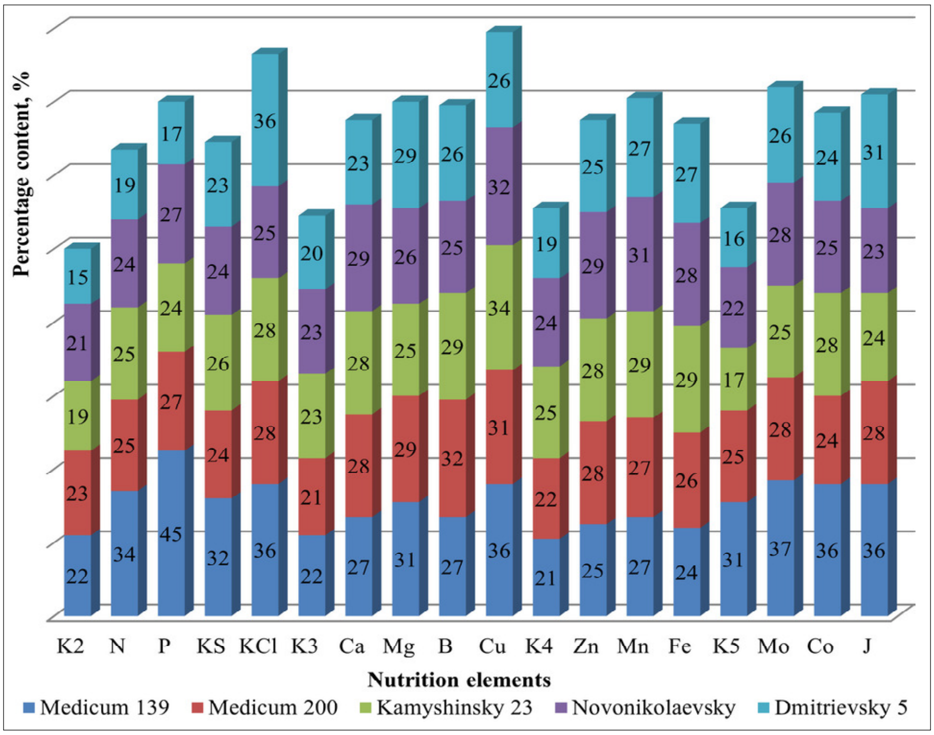


**Fig 2:** Leaf diagnostics of varieties of the Federal Research Center of Agroecology of the Russian Academy of Sciences in the 3-4 leaf phase at the experimental site of the Volgograd region of the Southern Federal District, average for 2022-2023.

**Table 7:** Trend model of spring barley varieties for the progressiveness of photosynthetic potential in the Volgograd region, Southern Federal District, 2022-2023.

| Name of the variety | R2 | The equation of the trend line | |
|---|---|---|---|
| | | The equation | Name |
| Medicum 139 | 0.13 | y = 2,51991n(x)+22,29 | Logarithmic |
| Medicum 200 | 0.46 | y = 0,4489x+21235 | Linear |
| Kamyshinsky 23 | 0.63 | $y = 0,02x^4+0,0721x^3+0,8351x^2+2,6842x+162$ | Polynomial |
| Novonikolaevsky | 0.61 | y = 0,0005x4-0,0117x3+0,0005x2+1,45x+20,985 | Polynomial |
| Dmitrievsky 5 | 0.74 | $y = 23,322e^{0202x}$ | Exponential |

which shows the instability of the movement of chloroplasts in plant leaves, the stability of further development of barley in the phases of vegetation, which can lead to average yield stability of this variety (Table 7).

Based on data on other varieties, such as: Dmitrievsky 5 ($R^2$ = 0.74) and belongs to the exponential form of the equation - $y = 23,322e^{0202x}$ (Table 7), which shows an increase in the movement of chloroplasts due to the nutrients contained in spring barley plants. It shows the presence of high activity of the green matter of spring barley plants due to the genetic characteristics of the variety and resistance to this area of the climatic zone.

This has also been demonstrated in a variety of substrates (hydroponics, growing pots and limestone soil). those old varieties of Scottish barley (Bere barley), which are better at absorbing and accumulating Mn, are better able to maintain the state of the photosynthetic apparatus compared to modern elite lines (Schmidt *et al*., 2019). Given that increasing the efficiency of photosynthesis is now considered a key strategy for increasing yield (Parry *et al*., 2013; Long *et al*., 2015), the effectiveness of microelements on other $CO_2$ indicators is also determined by the application of various root and foliar fertilizers, but genetic resistance in our studies showed a huge role in the drought resistance of plants to high hot temperatures.

## CONCLUSION

As a result of research at the experimental site in arid conditions, despite the soil with critically low humus horizon values, the data obtained made it possible to identify potential new varieties of spring barley that have genetic resistance to hot and arid. These varieties, such as Kamyshinsky 23, Dmitrievsky 5, can be used in the future in the same climatic zone as the Southern Federal District.

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**Conflict of interest**

All authors declared that there is no conflict of interest.

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