Evaluation of spring durum wheat varieties by yield, structure and grain quality

A G Lozhkin¹*, P N Malchikov², A E Makushev¹, O A Vasiliev¹, L G Shashkarov¹ and N N Pushkarenko¹

¹Faculty of biotechnology and agronomy, Chuvash State Agricultural Academy, 29 K. Marx Street, Cheboksary, 428003, Russia
²Selection of durum wheat Laboratory, Samara Research Institute of Agriculture, 41 K. Marx Street, Bezenchuk, Samara region, 446254, Russia
*E-mail: lozhkin_tmvl@mail.ru

Abstract. The article presents three-year data on the productivity of spring durum wheat varieties in the European continental climate, in order to select the most promising of them and determine the possibilities of breeding and technological adaptation in the region. The experiment involved five varieties of spring durum wheat as B 200, B 205, B 209, B Niva, and Luch 25 taken from Russian Middle Volga regions. Indicators of the best productive bushiness were noted in varieties B Niva and B 209. It was found that the number and weight of seeds in the ear, depending on the variety, varied proportionally to the length of the ear. The best indicators of the structure of the crop were established in varieties B 209 and B Niva. The weight of 1000 seeds was 42.32 to 53.3 g for different varieties of durum wheat. Taking into account the biological yield, the advantage of the variety B Niva over the control variant was revealed. The best formation of grain gluten was observed in agroclimatic conditions in 2015 and 2016: for three years the best indicators of gluten was on average 30.4 % and 29.95%, respectively, for varieties B Niva and B 200.

1. Introduction
Durum wheat is the only raw material for the manufacture of pasta of the highest quality, characterized by high strength, amber-yellow color, low digestibility, slight loss of substances during cooking, pleasant taste and nutritional value. Durum wheat on the globe ranks second after a soft wheat in areas of cultivation. Its share in the total area of wheat sowing in the world is about 10 %. Its largest areas are concentrated in Portugal, Spain, Italy, where it is grown for the production of high-quality pasta [1], since high yield of flour is possible only due to the dense, hard glassy and large endosperm. Scientists believe that there is a direct link between the bulk mass of grain and the yield of flour. The weight of 1000 grains is less important, while the links between vitreousness and gluten and protein content are more important. The correlation coefficient between bulk weight, weight of 1000 grains, grain vitreousness and yield of flour (semolina) is 0.86-0.76 and 0.5 units. The most suitable wheat is that with a protein content of 13.5-14 % [1]

Grain yield is determined by the yield index [2]. Scientists believe that under normal growing conditions, the yield index reaches 50% and it decreases to 35% in dry years. Reducing the size of the stems contributes to an increase in the yield index and therefore the main task is the selection of short-stemmed forms of durum wheat plants. The experiment was carried out in semi-arid conditions in North
Africa with six varieties of durum wheat (Triticum durum Desf.) of different origin, including two local varieties. Two local varieties (Guem Goum Erham and Hedba 3) have very high straw growth, low yield index, large mass index of 1000 grains and are resistant to drought. Morphological characteristics of Algerian durum wheat varieties were used in breeding with other introduced varieties Ardente, Akalu, Nefer and Excalibur. These lines were imported from France and all contain the dwarfism gene from the Akamoji variety of Chinese origin, have a short growing season, have a very short straw, a large amount of grain in the ear, a high yield and a high yield index in favorable years. A complete diallel crossing between six varieties was carried out at the Experimental station of the technical Institute of cereals in Hemis Miliana, Algeria [2].

Promising genetic improvement of durum wheat plants using molecular genetics techniques are considered in [3]. The use of molecular markers is now becoming an important tool for plant improvement and opens up new prospects for the breeder. The authors used RAPD markers to identify the genotype of varieties in order to further select the necessary alleles [3].

In Russia, durum wheat is produced mainly in the conditions of the middle Volga and South Ural regions in the amount of 650,000 – 700,000 tons on the area of more than 0.5 million hectares. Imports of pasta (mainly from Italy) annually exceed 100 thousand tons. The demand of the Russian market for high-quality pasta is estimated at 750,000 – 800,000 tons, in high-quality wheat cereals at 100,000 tons, which is equivalent to 1.5 million tons of durum wheat [4]. Taking into account the prospects for the development of export potential and import substitution, the volume of production of durum wheat in Russia should be at least 2,000,000 – 2,500,000 tons annually. In this regard, it is advisable to assess the possibility of expanding the area of cultivation of this culture in the world as a whole, and also in Russia. In our research, we study the possibility of expanding the geography of cultivation of spring durum wheat on the example of the Northern Volga regions. At the same time, the increase in gross grain harvest should occur not only by increasing the area of culture, but also by raising yields.

The of this work is to determine the influence of bioclimatic potential of the region, which is atypical for cultivation of durum wheat, on the productivity of spring durum wheat varieties of different morphotypes.

2. Materials and methods

Research on the productivity of varieties of spring durum wheat was conducted in the Student Scientific and Production Center of the Chuvash State Agricultural Academy in 2015-2017 on medium-loamy dark gray forest soil. The experiments involved five varieties of spring durum wheat: Bezenchuk 200 (B 200-control), Bezenchuk 205 (B 205), Bezenchuk 209 (B 209), Bezenchuk Niva (B Niva), and Luch 25. The first four varieties were bred in the Samara Research Institute (Russia), the Luch 25 – in the Institute of Agriculture of the South-East (Russia). Seeds of all varieties had the category of elite. Varieties B 200, B 205 and B 209 belong to the variety gordeiform, B Niva and Luch 25-leucurum. According to the duration of the period "shoots-earing" they are arranged in order of increasing the period as follows: B 205, Luch 25, B 200, B Niva, and B 209. Variety B 209 carries a strong plant height reduction gene RhtB1b and belongs to the stunted morphotype. All other varieties do not have strong genes that control the height of plants, its value depends on the duration of vegetation and environmental conditions during the growth of internodes and their number.

The studies were carried out by the type of microfield experiments in six-fold repetition with randomized placement of plots. The size of one plot was 4 m², and the area of all plots with protective strips was 400 m². Soil preparation for sowing grain crops included: autumn plowing to a depth of 22±3 cm, spring harrowing to a depth of 4-5 cm, pre-sowing cultivation to a depth of 12±3 cm. Before sowing, soil samples were selected from plots for agrochemical analysis and sent to the test laboratory of the Chuvash State Agricultural Academy (Russia). Agrochemical analysis of soils was carried out in accordance with ISO 14235:1998. Sowing was carried out at the beginning of May by the SS-11 "Alpha" breeding seeder to a depth of 4±2 cm at a soil temperature of 10±2 °C. The seeding rate was calculated based on the standard of 5,000,000 pieces of germinating seeds per 1 ha.
Weather conditions in 2015 were generally favorable for the growth and development of spring durum wheat plants. The second decade of May was characterized by moderately warm weather with frequent precipitation. Their sum exceeded two long-term norms. The average monthly temperature was 3.8 degrees above the long-term. In June, against the background of elevated temperatures, there was a shortage of precipitation. The formation of the ear took place in conditions of insufficient moisture supply. In July, the weather was kept cool for this season with frequent and heavy rains. Waxy ripeness of grain is noted in mid-August. In general, during the active vegetation period (May-August), the average air temperature exceeded the long-term index by 1.8°C and amounted to 18.2°C, the amount of precipitation was 249 mm or 115% of the long-term norm.

Sowing of spring durum wheat in 2016 was performed in late April-early May. This year, the growth and development of field crops came in conditions of lack of moisture on the background of high temperature during the growing season. The least amount of precipitation was observed in the first two months of vegetation: in May – 17%, in June – 45% of the long-term monthly norm. In July they fell 88%, in August – 80% of the long-term amounts. Productive moisture reserves in the soil continued to be low. Rains in September fell for 22 days, with precipitation of more than 51 mm for 9 days. In total, for the month the amount of precipitation was 134 mm, 290% of the long-term norm. In this regard, harvesting in 2016 was completed only in October. In general, during the period of active vegetation of plants (May – August), the average air temperature was 19.6°C, exceeding the long-term by 3.2°C. Precipitation fell 134.3 mm, 54% of the long-term norm.

In 2017, sowing was carried out in the second decade of May. The growth and development of durum wheat plants at the beginning of the growing season (May, June) took place in conditions of excess moisture on the background of low temperatures. The second half of the growing season (July-August) on the temperature regime and precipitation differed little from the average annual norms. The ripening period (the third decade of August) coincided with heavy rainfall, accompanied by strong winds, which caused lodging of crops. In General, during the growing season of durum wheat (May-August), the average daily temperature (15.8°C) was lower than the average annual values by 0.6°C. These circumstances and the relatively late sowing period led to an elongation of the growing season and late harvesting.

The onset of the phases of plant development was established by eye. For the beginning of the phase, the day when at least 10% of plants entered this phase was taken; for the full onset of the phase, when it spread to at least 75% of plants. In some cases, for greater accuracy, the ocular assessment was replaced by counting plants. For structural analysis of the crop at each repetition, 10 samples of 25 plants with a root system were taken. Then from the combined sheaf (separate repetition) was taken without a choice of 25 plants and proceeded to the appropriate calculations and measurements of all plants, then to determine the average for the variants of the experiment. The height of the plants was determined using a measuring ruler from the root neck to the top of the main spike. Total and productive bushiness was determined by counting the average number of common and spike-bearing shoots on one plant. Also in our studies we determined the number of internodes of durum wheat stem on which the strength of the stem depends. The productivity of the main ear was determined by counting the number of grains and their mass. The mass of 1000 seeds was determined to characterize the fullness and size of the seeds. The crop was evaluated by a trial sheaf, which were selected before harvesting. Mathematical processing of the obtained data was carried out by the method of dispersion analysis. Laboratory analyses of grain gluten, protein and gluten deformation index (GDI) were carried out according to ISO 21415-2:2015.

3. Research results
The soil of experimental plot light-grey forest medium-loamy soils on forest loam, has a capacity of plough layer of 25 cm, the capacity of the subsurface horizon A1B – 13 cm. Researcher Korshunova L V (2007) established that the greatest influence on the yield of spring wheat having the content in the soil mobile phosphorus, the value of the exchange acidity and humus content [5]. The content of humus in the arable layer of light gray forest soils of the experimental field varies from 2.30 to 2.55%, mobile phosphorus according to Kirsanov –146…155 mg/kg (high content), exchange potassium –
115…119 mg/kg (average content), pH of exchange acidity – 5.72…6.00 (close to neutral). The amount of absorbed bases varies from 12.5 to 16.0 mg/100 g of soil; hydrolytic acidity – 1.20-1.75 mg/100 g.

The results of biometric analysis of spring durum wheat plants (Table 1) noted that the number of plants per 1 m² ranged from 314 to 370 units/m². At the same time, the greatest preservation of plants for harvesting was noted in varieties Luch 25 and B Niva.

Table 1. Biometric indicators of varieties of spring durum wheat on average for 2015–2017.

| Varieties | A number of plants before harvesting, pcs/m² | Height of plants, cm | Bushiness | Number of internodes, pcs |
|-----------|---------------------------------------------|----------------------|-----------|--------------------------|
| B 200     | 349                                         | 76.6                 | 2.0       | 1.9                      | 3.8          |
| B 205     | 314                                         | 104.8                | 2.1       | 2.1                      | 3.8          |
| B 209     | 343                                         | 74.6                 | 2.4       | 2.3                      | 3.5          |
| B Niva    | 357                                         | 93.2                 | 2.4       | 2.3                      | 3.5          |
| Luch 25   | 370                                         | 94.4                 | 2.0       | 1.7                      | 3.6          |
| NSR 05    | 8.9                                         | 6.5                  | 0.3       | 0.3                      | 0.4          |

The height of plants in varieties ranged from 74.6 to 104.8 cm. the tallest varieties were reliably observed in varieties B 205 and low-growing-B 209 (Table 1).

Variety B 209 carries a strong plant height reduction gene RhtB1b and belongs to the stunted morphotype. However, not always high altitude is an advantage, low-growing plants are usually more resistant to lodging [6]. In our studies, the number of internodes in varieties on average for three years varied within 3.5...3.8 units, but the difference in the variants cannot be considered reliable, because the changes were within the error of field experience. It has been shown that the indicators of general and productive bushiness varied within 2.0...2.4 and 1.7...2.3, respectively. The best results of general and productive bushiness were noted for B Niva and B 209, 2.4 and 2.3, particularly. Good tillering energy allowed these varieties to form a greater number of productive stems, grade B 209…788 pcs/m² and B Niva – 821 pcs/m². In the control variant, 663 productive stems per 1 m² were formed. The weakest tillering was observed in the variety Luch 25, where the index of productive bushiness was 1.7 and the number of productive stems – 629 pcs/m².

Analysis of crop structure is an important method of assessing the development of cultivated plants, it allows to establish patterns of crop formation and to trace its dependence on the variety of environmental factors [7]. The results of the analysis of the yield structure on average for the studied years are given in Table 2.

Table 2. Yield structure and yield of spring durum wheat varieties on average for 2015 – 2017.

| Varieties | Ear length, cm | The number of grains in the main spike, pcs | Weight of grains in the main ear, g | Weight of 1000 seeds, g | Yield, t/ha |
|-----------|----------------|--------------------------------------------|----------------------------------|------------------------|------------|
| B 200     | 4.6            | 20.2                                       | 0.9                              | 48.1                   | 2.63       |
| B 205     | 3.4            | 16.8                                       | 0.7                              | 42.3                   | 1.96       |
| B 209     | 4.4            | 21.8                                       | 1.0                              | 46.7                   | 2.96       |
| B Niva    | 5.1            | 22.9                                       | 1.1                              | 52.4                   | 3.41       |
| Luch 25   | 5.0            | 18.6                                       | 1.0                              | 53.3                   | 2.98       |
| NSR 05    | 0.7            | 1.4                                        | 0.2                              | 3.5                    | 4.7        |

It follows from them that the number and weight of seeds in the ear, depending on the variety, changed in proportion to the length of the ear. The length of the ear of durum wheat in the variants ranged from 3.85 to 5.1 cm. Also, in our studies, we determined the productivity of the main ear by counting the number of grains and their weight. The best indicators of the yield structure compared to
control reliably observed in grade B field, where the length of the ear were respectively 5.1 cm, number of seeds per spike, 22.9 per PCs, weight of seeds per spike was 1.1 g. the Lowest annual rates were observed in grade B 205, the length of the spike is 3.4 cm, number of seeds per spike 16.8 pcs, and seed weight – 0.7 g.

It was also found that the yield of durum wheat grain is influenced primarily by the number of productive stems, the weight of the ear and the number of grains in the ear which are largely dependent on weather conditions [8]. As a result of their research, they identified various features of the development of interphase periods in varieties of hard spring wheat, depending on their biological characteristics. As for varieties, the most significant indicators were recorded in the variety Kharkovskaya 41, the least-in the variety Giselle [8].

The weight of 1000 seeds is determined to characterize the full weight and size of the seeds. Large, heavy seeds, having a larger supply of nutrients, in the field when germinating give powerful shoots, which later develop well and provide a higher yield. In the studied 2015, the weather was more favorable for the cultivation of durum wheat than the conditions of 2016 and 2017, characterized by drought in 2016 and an abundance of precipitation at low temperatures during the growing season of 2017. For example, this indicator for varieties in 2015 ranged from 45 to 60 g, in 2016 from 41 to 53 g and in 2017-from 38 to 46 g, respectively. As a result, in the agro-climatic conditions of 2015, durum wheat plants formed a more complete grain with the best mass index of 1000 seeds. The weight of 1000 seeds was an average of 42.3 to 53.3 g in three years. Grade B Niva and Luch 25 significantly exceeded the control and other options for this indicator. B 205 was inferior to all other varieties in terms of weight of 1000 seeds, which averaged 42.3 g for three atypical agro-climatic years. The analysis of the average yield data for the years of research revealed that, on average, for three years, the highest biological yield was reliably formed by grade B Niva - 3.4 t/ha. The lowest yield index of 1.9 t/ha was formed by grade B 205 compared to the control variant (Table 2).

The nutritional value of spring durum wheat varieties on average for three years is presented in Table 3. The best formation of grain gluten was observed in agroclimatic conditions in 2015 and 2016, on average for three years the best indicators of gluten 30.4 % -29.95 %, respectively, formed varieties B Niva and B 200. The protein content in the grain in our studies directly depends on the amount of gluten, where the largest number is also determined by the varieties B Niva and B 200.

| Varieties | Gluten,% | GDI   | Protein, % |
|-----------|---------|-------|------------|
| B 200     | 29.9    | 65.0  | 16.9       |
| B 205     | 21.4    | 41.2  | 14.3       |
| B 209     | 13.6    | not determined | 11.3 |
| B Niva    | 30.4    | 62.7  | 17.0       |
| Luch 25   | 25.7    | 53.0  | 16.2       |
| NSR 05    | 3.4     | 4.5   | 0.7        |

In terms of measuring the gluten deformation index (GDI), the best value of the CDI is 60-70 units obtained in the grain varieties of durum wheat B Niva and B 200 (Table 3).

4. Conclusion
Thus, according to the results of studies, it can be concluded that the conditions of the temperate continental climate of the Northern Volga region in general correspond to the biological requirements of durum wheat of different morphotypes. Field experiments were conducted over three atypical climatic years allowed us to establish that the formation of productivity of spring durum wheat is influenced by the number of productive stems per unit area, the weight of the ear and the number of grains in the ear, which largely depend on weather conditions.

From the studied five varieties (B 200, B 205, B 209, B Niva, and Luch) B Niva has been identified as a promising one, since it formed the highest yield of 3.41 t/ha and had the best indicators of grain
quality: gluten and protein content was 30% and 17%, respectively. We recommend this variety for cultivation and selection works, as the most adapted variety not only in the Northern Volga region, but also in the temperate climatic zone of Europe.

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