Experimental verification of cluster analysis to identify valuable breeding samples of spring wheat

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Abstract. The article provides experimental data on the study of breeding material of spring wheat, spelt and lines of interspecific hybrids. On the basis of structural and cluster analyzes, the morphological similarity of the new breeding lines of interspecific hybrids (Triticum durum × Triticum dicoccum) with spring durum wheat varieties and their significant difference from the Runo spelt variety were revealed. Cluster analysis by indicators of structural analysis in 2018-2019 of varieties, breeding lines and interspecific hybrids made it possible to form 7 clusters. Cluster No. 1 deserves attention, in which the high-yielding variety Triada and the hybrid Hordeiform 1461-15, obtained as a result of interspecific hybridization, are grouped (Triticum durum × Triticum dicoccum). The short-stemmed (76 cm) line leukurum 1560-18, allocated in a separate cluster, has a well-grained ear, the most resistant to lodging. Cluster analysis of grain quality made it possible to identify varieties and lines that ensure the collection of protein above the standard varieties of soft wheat Daria, Granny. A new valuable source material with a complex of positive traits for breeding for high productivity was revealed (varieties Triada, Donskaya elegy, hybrid Hordeiform 1461-15). Yield of the Triada variety in 2020 was 5.3 t/ha, of the Donskaya elegy 4.36 t/ha, of interspecific hybrid No. 1461-15 - 4.27 t/ha with LSD₀₅ = 0.4 t/ha, which is significantly higher indicators of other varieties and lines.

1. Introduction

Durum wheat is the main raw material for the pasta and cereal industries, and ranks second after soft wheat in terms of sown areas. It is less plastic and less in demand, the area of distribution of durum wheat is much smaller. In recent years, imports of pasta have increased, the bulk of which is high-quality Italian products. At the same time, the process of import substitution should not lead to a decrease in the average quality level of pasta and cereals on the Russian food market. The contribution of selection here can be significant [1].

Grain quality of spring durum wheat varieties, among other factors, is determined by the adaptability to specific agro-ecological conditions. In the Oryol Region, the yield properties and grain quality of durum spring wheat varieties are poorly studied, and the grain of soft wheat varieties often does not meet the requirements of the processing industry [2]. Spring durum wheat (Triticum durum Desf.) and spelt wheat (Triticum dicoccum (Schrank.) Schuebl.) are genetically high protein species with a protein content in grain up to 20% or more [3]. In the process of breeding durum wheat, a breeding material was created that is not inferior to filmy spelt (var. Runo) in nutritional value, taste, smell and consistency of porridge and surpasses it in carotenoid content, color, resistance to germination on the root. The obtained selection lines of groats purpose are distinguished by high yields (4-5 t/ha), broad rate of
response to environmental conditions, adaptability to drought and responsiveness to favorable conditions [4].

The aim of the work was comparative studies of yield, elements of its structure, biological characteristics of the best varieties of spring wheat (Triticum durum) and interspecific hybrids (Triticum durum x Triticum dicoccum) in the conditions of central Russia.

2. Materials and methods

The object of the study was: breeding lines of spring durum wheat, varieties of spring soft wheat, varieties obtained as a result of interspecific hybridization Triticum durum x Triticum dicoccum at FSBSI "Samara Research Institute of Agriculture named after N.M. Tulaykov". Standards: spring durum wheat variety Donskaya elegy and spelt Runo variety.

Experimental crops were placed in the crop rotation fields of the selection center of the FNTs ZBK ("Federal Scientific Center of Legumes and Groat Crops"). Predecessor – fallow. Soils - dark gray forest, medium loamy, medium cultivated. The arable layer has a medium acid reaction of the soil solution, an average humus content, an increased content of mobile phosphorus for this type of soil, and an average content of exchangeable potassium. According to the main physical and chemical indicators, these soils are typical for this natural and economic zone.

In competitive and ecological variety testing, the total area of the plot is 16.5 sq.m. The accounting area of the plot is 15 sq.m. The placement of the plots in the experiment was randomized, the repetition was 4 times. The seeding rate is 4.5-5 million germinating grains per hectare. Phenological observations, accounting for disease damage, assessment of phenotypic variability of quantitative traits were carried out according to generally accepted and widely tested methods in scientific institutions. Sampling for the analysis of plants according to the elements of the yield structure was carried out as the cultivars matured. For structural analysis, 25 plants with roots were selected from each plot. The analysis of the structure of the yield included the determination of productive bushiness (pcs.), dry plant weight (g); the number of grains from the main spike and from the lateral branches (pieces); grain masses from the main spike and lateral branches (g); the number of grains from plants (pcs.); weight of grains per plant (g); weight of 1000 grains (g). Dispersion and cluster analysis of the results was carried out. Cluster analysis was carried out by the method of determining the Euclidean distance between clusters with combining according to the rule of the unweighted centroid method (UPGMC) with normalization of the initial data.

3. Results and discussion

Against the background of homogeneous technological conditions during the research period in 2018-2020, weather conditions had a significant impact on the yield of durum wheat and interspecific hybrids. At the same time, the influence of variants (varieties) on the total variance was significant - 67%. The average yield of the best durum wheat cultivars ranged from 4.9 to 6.4 t/ha for the new Triada cultivar and the line of interspecific hybrids 1461-15. They and the line of durum wheat leukurum 2024-23 in the competitive variety testing significantly exceeded the yield standard Donskaya Elegy. The annual yield of the best breeding lines of interspecific hybrids was significantly higher than the productivity of the Runo spelt variety, but slightly lower in comparison with the best durum wheat varieties and the standard. However, their cereal advantages open up prospects for breeding work. [5]. Significant differences in yield were established between them. On average, over 2 years, the highest yield (more than 5.5 t/ha) is characteristic of the Hordeiform line No. 1461-15 (No. 682d-7 x k-1949 Triticum dicoccum). Hordeiform line No.1899-15 (In memory of Chekhovich x k-12946 Triticum dicoccum) had maximum (5.57 t/ha) in 2019. The best breeding lines of interspecific hybrids, which can be considered a naked spelt by a complex of traits, were the least susceptible to abiotic stressors and had a high resistance to lodging (Table 1).
Table 1. Yield of spring durum wheat varieties, t/ha.

| Variant          | Yield, t/ha | Analysis result, 2019. | Dispersion | Standard deviation | Error | Accuracy % |
|------------------|-------------|------------------------|------------|--------------------|-------|------------|
|                  | 2018        | 2019                  |            |                    |       |            |
| Donskaya Elegy   | 5.22        | 5.47                  | 0.40       | 0.63               | 0.32  | 5.78       |
| Triada           | 4.78        | 6.40                  | 0.24       | 0.49               | 0.25  | 3.86       |
| 2024-23(348)     | 5.47        | 6.12                  | 0.01       | 0.11               | 0.06  | 0.94       |
| 1927Д-4 (308)    | 4.67        | 5.73                  | 0.20       | 0.45               | 0.22  | 3.90       |
| 1941-17 (320)    | 4.67        | 4.93                  | 0.11       | 0.33               | 0.17  | 3.37       |
| B.Orl-1*         | 4.25        | 5.20                  | 0.27       | 0.52               | 0.26  | 5.03       |
| 1898-6*          | 4.31        | 5.40                  | 0.01       | 0.09               | 0.05  | 0.87       |
| 1899-15 (281) *  | 4.80        | 5.57                  | 0.40       | 0.63               | 0.32  | 5.70       |
| 1899-12 (278) *  | 4.13        | 5.72                  | 0.00       | 0.06               | 0.03  | 0.54       |
| 2001-4 (356)*    | 4.00        | 5.58                  | 0.04       | 0.20               | 0.10  | 1.80       |
| 1461-15*         | 5.25        | 6.42                  | 0.01       | 0.11               | 0.06  | 0.87       |
| 1299-ДЗ3(75)*    | 4.53        | 5.20                  | 0.12       | 0.35               | 0.18  | 3.38       |
| 1300-4(329)*     | 4.00        | 5.03                  | 0.24       | 0.49               | 0.25  | 4.88       |
| 1795-Д7(313)*    | 4.14        | 5.05                  | 1.25       | 1.12               | 0.56  | 11.04      |
| Spelt Runo       | 3.8         | 4.03                  | 0.10       | 0.31               | 0.15  | 3.83       |
| By experience    | 4.39        | 5.57                  | 0.49       | 0.70               | 0.08  | 1.44       |
| **LSD**          | **0.37**    | **0.59**              | **0.07**   | **0.12**           | **0.03** | **1.44** |

* - interspecific hybrids Triticum durum\times Triticum dicoccum.

Based on the indicators of the structural analysis of plants, taking into account the yield, a cluster analysis was carried out by the method of determining the Euclidean distance. These traits characterize the phenotypic variability of the studied varieties and reflect the relationship of interspecific hybrids with varieties and breeding lines of durum wheat and spelt. Spelt variety Runo (Triticum dicoccum), line Leukurum 1560-18, lodging resistant, having a short-stemmed Anser-10 variety in its genealogy, the line Hordeiform 1918, obtained on the basis of the large-grain Marina variety, formed separate clusters. They are the most distant from other samples in terms of morphological characteristics.

Cluster analysis of varieties, breeding lines and interspecific hybrids in 2018 made it possible to form 7 clusters. Cluster No. 1 deserves attention, in which the high-yielding Triada variety, included in the State Register of the Russian Federation in the Central Black Earth Region since 2020, and the new Hordeiform 1461-15 line, obtained as a result of interspecific hybridization, are grouped. Clusters No. 2, No. 3, No. 4 are represented by separate morphologically heterogeneous genotypes. Clusters No. 5 and No. 6 included new varieties of spring durum wheat. Cluster 7 includes the Donskaya Elegy standard and varieties and lines of Samara selection, including those obtained as a result of distant hybridization (Table 2).
Table 2. Formed durum spring wheat clusters.

| Cluster no. | Cluster varieties and lines |
|-------------|----------------------------|
| 1           | 2) Triada, 4) 1927D-4, 5) 1941-17, 8) 1899-15, 11) 1461-15, 12) 1299-D-13 |
| 2           | 15) Spelt Runo |
| 3           | 17) 1560-18 |
| 4           | 19) 1918 |
| 5           | 23) 2034, 24) 2042 |
| 6           | 22) 2006, 25) 2126 |
| 7           | 1) Donskaya Elegy, 3) 2024-23 6) B.Orl-1, 7) 1898-6, 9) 1899-12 10) 2001-4, 13) 1300-4, 14) 1795-D7, 16)1890-17, 18)1938-5, 20)1941-69, 21) 1941-470, 26) 2219 |

Cluster No.1 is important for selection. The best yield line Hordeiform1461-15, combined into cluster No. 1 with the Triada variety and new breeding lines, has the longest (loose) ear, high ear productivity and a high yield level (5.64 t/ha). Short-stemmed (76 cm) line 1560-18, allocated in a separate cluster No. 3, has a well-grained ear, the most resistant to lodging. Clusters No. 4, No. 5 and No. 6 group coarse-grained samples similar in morphological parameters, but significantly different in yield under the conditions of the Oryol region (Table 3).

Table 3. Characteristics of clusters by elements of the structure of the yield and yield.

| Cluster No. | Height, cm | Bushiness, pcs. | Ear length, cm | Number of grains per spike, pcs. | Weight of grain per spike, pcs. | Weight of 1000 grains, g | Yield, t/ha |
|-------------|------------|----------------|----------------|----------------------------------|---------------------------------|--------------------------|-------------|
| 1           | 105.17     | 2.50           | 7.12           | 37.50                            | 2.18                            | 58.55                    | 5.64        |
| 2           | 100.00     | 2.30           | 4.30           | 44.00                            | 1.85                            | 41.90                    | 4.03        |
| 3           | 76.00      | 2.00           | 7.30           | 43.00                            | 2.50                            | 58.10                    | 5.40        |
| 4           | 105.00     | 3.50           | 6.20           | 33.00                            | 2.26                            | 68.70                    | 5.00        |
| 5           | 98.00      | 2.30           | 6.75           | 30.00                            | 2.17                            | 63.90                    | 4.97        |
| 6           | 100.00     | 2.62           | 6.85           | 33.00                            | 2.12                            | 64.30                    | 5.40        |
| 7           | 108.54     | 2.57           | 6.20           | 33.15                            | 1.86                            | 56.01                    | 5.18        |

As a result of the structural analysis of plants in 2019, taking into account the yield on the basis of the Euclidean distance, calculated according to the traits characterizing the phenotypic variability of the studied varieties, the relationship of interspecific hybrids with varieties and breeding lines of durum wheat was established. Interspecific hybrids include 1461-15 (№682d7(Triticum durum) x k-1949(Triticum dicoccum), 1898-6 (In memory of Chekhovich (Triticum durum) x k-9934 (Triticum dicoccum).

Breeding lines for cereals have been improved in the breeding process relative to spelt (var. Runo) in terms of carotenoid pigment content and falling number. They also have a glassy grain. In order to increase the protein and gluten content in the breeding process and to improve the quality of products, the physical and biochemical parameters of grain associated with plant ontogeny require detailed and comprehensive consideration. Cluster analysis of varieties, breeding lines and interspecific hybrids in terms of grain quality made it possible to form 6 clusters. Cluster 3 deserves attention, in which the high-yielding Triada variety, recommended since 2020 for cultivation in the Oryol region, and the new line 1461-15, obtained as a result of interspecific hybridization, are grouped. Clusters No. 1, No. 2 are represented by varieties of soft wheat, which have proven themselves well in the Central Black Earth Region. Cluster 4 included high-tech accessions: new varieties Triada, Zolotaya, Benchuk-Orlovskaya 1 and breeding lines, as well as a multilinear composition based on interspecific hybrid lines. Clusters No. 4, No. 5, include varieties and lines of spring durum wheat and interspecific hybrids. Cluster No. 6 is represented by the Runo variety of filmy spelt (Table 4).
Factors associated with high protein and gluten content are important for breeding durum wheat for grain quality. Most of the varieties and lines presented in cluster No. 3 have high values of the indica-ted indicators, are inferior in yield only to the Arabella variety of wheat, which has formed cluster No. 2, but ensure protein collection at the level of the specified variety, exceeding the standard varieties of Daria, Granni (cluster No. 1). Cluster No. 4 combines samples of spring durum wheat, the best in terms of biochemical quality indicators of grain grown in the conditions of the Oryol region in 2018-2019, but significantly inferior in yield. Cluster No. 5 is represented by large-grain new lines with a high grain quality index (Table 5).

### Table 4. Formed clusters of spring wheat by grain quality.

| Cluster No. | Cluster varieties and lines |
|-------------|----------------------------|
| 1           | 1) Daria, 2) Granni        |
| 2           | 3) Arabella                |
| 3           | 7) Triada, 8) 2024-23, 9) 1927D-4 12) 1898-6, 13) 1899-15 14) 1899-12, 11) Bezenchuk-Orlovskaya 1, 16) 1461-D15 |
| 4           | 6) Donskaya Elegy, 10) 1941-17 15) 2001-4 18) 1300-4 |
| 5           | 17) 1299-D-13 19) 1795-D7  |
| 6           | Spelt Runo                 |

### Table 5. Characteristics of clusters in terms of grain quality and yield.

| Cluster no. | Yield, t/ha | 1000 grain weight, g | Protein, % | Gluten, % | Starch, % | grain unit, g/l | Protein yield, t/ha |
|-------------|-------------|----------------------|------------|-----------|-----------|-----------------|---------------------|
| 1           | 5.43        | 41.20                | 12.73      | 21.00     | 66.60     | 797.50          | 0.69                |
| 2           | 6.22        | 41.50                | 13.30      | 23.90     | 66.50     | 808.00          | 0.83                |
| 3           | 5.77        | 51.48                | 13.85      | 25.71     | 63.96     | 824.25          | 0.80                |
| 4           | 5.25        | 51.97                | 15.07      | 28.75     | 63.33     | 828.25          | 0.79                |
| 5           | 5.12        | 57.00                | 13.80      | 26.05     | 64.20     | 837.00          | 0.71                |
| 6           | 4.03        | 41.00                | 15.50      | 20.90     | 61.30     | 615.00          | 0.62                |

### 4. Summary
On the basis of comprehensive studies, it has been established that new modern varieties and breeding lines of durum spring wheat, breeding material of interspecific hybrids grown in conditions in the northwestern part of the Central Black Earth region, are not inferior in yield and are superior in grain quality to spring varieties of soft wheat, which opens up real prospects for grain production for the production of pasta flour and cereals. As a result of structural and cluster analyzes, a new valuable source material with a complex of positive traits for breeding for high productivity was revealed (varieties Triada, Donskaya elegy, hybrid Hordeiform1461-15) These genotypes are a platform for further breeding of spring durum wheat and naked spelt in central Russia.

### 5. References
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