Efficiency of methods for selecting elite winter triticale plants and evaluating their offspring in a breeding nursery

T A Babaytseva*, M V Solovyeva, V G Kolesnikova and E F Vafina
Federal State Budgetary Educational Institution of Higher Education "Izhevsk State Agricultural Academy", Izhevsk, Russia

* E-mail: taan62@mail.ru

Abstract. Triticale is an artificially created crop. When creating new varieties of this crop, different types of wheat, rye, and wild cereals are used in modern breeding. In connection with the origin uniqueness of triticale, its genetic characteristics, questions of a methodological nature often arise in breeding work. One of these questions is the method choice of selection and evaluation of parent plants, the establishment of breeding nurseries. In this regard, the aim of the research was to improve the selection method of winter triticale parental plants and the establishment of a breeding nursery of the 1st year. Field and laboratory studies were carried out in 2019-2021 in the Izhevsk State Agricultural Academy. A comparative characteristic of the initial inflorescences' selection methods and establishment of a breeding nursery of the first year was given. Inflorescences' selection was carried out based on visual inspection without threshing and based on a morphological assessment of the ear and grain after thrashing. The breeding nursery of the 1st year was founded in two ways - by sowing seeds and unthreaded ears. The effectiveness of the breeding nursery establishment method was assessed by comparing the yield of breeding lines and the number of culled forms. It was found that at the initial stage of winter triticale breeding process, it is advisable to select the initial forms based on the weight of the ear, establish the 1st year breeding nursery with an unthreaded ear and carry out a comprehensive assessment and culling of breeding material based on field and laboratory methods. This will significantly increase the volume of breeding material and improve the quality of assessments, reduce labor intensity in the culling of selected inflorescences and lines.

1. Introduction

Triticale (× Triticosecale Wittmack) is an artificially created cereal obtained from the crossing of rye and wheat. It attracts attention with its high yield potential, versatility of its use, increased resistance to stress factors [1, 2, 3, 4, 5, 6]. However, it is not widespread both in Russia as a whole and in Udmurtia. Among the many reasons for the low popularity of this crop, there is an insufficient range of adaptive varieties. And, therefore, the selective improvement of the crop is an urgent task.

There are three main areas in triticale selection that are closely related to its use - creation of grain varieties (for forage and food purposes), universal (grain fodder) and fodder mowing. As practice shows, the direction triticale use can have regional characteristics. So, for the conditions of Udmurtia, the priority direction of triticale selection is the creation of grain fodder varieties [7].

The success of triticale selection is due to the development of genetics and the implementation of classical breeding methods - hybridization and selection. The synthesis basics of winter hexaploid two-species and three-species triticale in our country were developed by V. E. Pisarev. Modern samples of initial triticale were obtained based on different wheat species - T. aestivum, T. durum, T. turgidum, T.
polonicum, T. timofeevii, T. sphaerococcum, etc. and rye S. cereale, S. montanum [8, 9, 10]. There are known examples of involving plants of the Aegilops genus in crossing [10]. Such source material is very diverse in morphological, biochemical, and other traits [9]. The selection of many scientific institutions is currently based on the creation of genetic variability using intraspecific hybridization [9, 11, 12, 13, 14], in vitro culture [15], and haploidy [16]. In the Izhevsk SAA, the main method for creating source material is intraspecific hybridization of geographically distant forms. The selection of parental forms is carried out from hybrid populations F3-F5.

In connection with triticale’s hybrid origin and genotypic features, several methodological questions arise already at the early stages of the breeding process. Some authors consider it justified to carry out repeated selections in the II-year breeding nursery and the control nursery, which better stabilizes the traits [12]. Others believe that it is advisable to carry out selection in later generations (F7-F11) [13].

In the scientific literature, one can find individual publications of scientists on the effectiveness of various plants’ selection methods and the subsequent establishment of nurseries for testing their offspring. But they are either rather old [17, 18], or the methods are more applicable at the later stages of the breeding process [19, 20]. So, A. M. Shishlova et al. [17] recommend using the grain inflorescence index for the selection of parent plants and leaving the forms with the maximum value of this indicator for further work. Yu. L. Guzhov [18] found that there is a close correlation between the weight of the ear grain and the weight of the ear, therefore, he recommends using the weight of the ear in order to reduce the selection time. I.R. Manukyan et al. [19] propose to use the index of plant productivity to assess breeding samples, and G. A. Kozlechkov et al. [20] - coefficient of shoot specific productivity.

Nevertheless, this issue remains poorly understood, since the methods' effectiveness can depend on both the object (crop) and agroecological conditions. In this regard, the research was carried out aimed at improving the method of winter triticale parental plants' selection and the establishment of the 1st year breeding nursery.

2. Materials and methods

Field studies were carried out in 2019-2021 on the experimental field "UNPK AgrotekhnoPark" Izhevsk SAA, laboratory - at the Department of Plant Growing. The studies were carried out on soddy medium podzolic medium loamy soil typical for the Udmurt Republic, which is characterized by an average content of organic matter (2.4...2.5%), a reaction of the soil medium from medium acid to slightly acidic (pH 5.0...5.1). The content of mobile phosphorus and exchange potassium in the soil is from increased to high, respectively 132...202 mg/kg of soil and 121...201 mg/kg of soil.

The weather conditions during the study period were very different from the long-term average, which was reflected in the obtained results. In 2019 during the period of grain swelling and ripening, cool and humid weather was established - the average daily air temperature in July was 16.7 °C, in August - 14.1 °C (lower than the average annual values by 2.1 and 2.2 °C, respectively) with the amount of precipitation of 73.1 and 136.5 mm (which is 103 and 228% relative to the norm). This extended the growing season, led to mass plant lodging, germination of grain on the root and its enzyme-mycotic depletion. Conditions of 2019-2020 autumn-winter period were relatively favorable for winter triticale. The entire period was characterized by abnormally high average daily air temperatures exceeding the average long-term values by 4.4 ... 7.6 °C and precipitation was also higher than the norm by 43-133%. However, the snow melting was early and amicable, which prevented the spread of wintering diseases and did not reduce the winter hardiness of winter triticale plants. The start of the growing season was marked in the third decade of April. Subsequently, the established warm weather contributed to the rapid regrowth and tillering of plants. July was warm (the average daily air temperature was by 1.9 °C higher than the average annual values) with a large amount of precipitation (168% of the norm), which somewhat postponed the ripening of winter triticale, but ensured the formation of heavy kernel. The harvesting ripeness of the plant was reached in early August. The growing season of winter triticale 2020-2021 passed in conditions of high average daily air temperatures (higher than average annual values by
0.5...4.6 °C) and insufficient precipitation (41...85% of the norm). Overwintering conditions were optimal, insufficient precipitation in May-June caused low productive tillering and the formation of a small ear. The harvesting ripeness of the plants was reached in mid-July.

In 2019, an ear-by-ear selection was carried out in the hybrid nursery from two populations (78/07 × 6418–145 and Izhevskaya 2 × Nemchinovsky 56), the main criterion of which was productivity and the absence of diseases. 100 inflorescences were selected for each combination. A morphological analysis of 50 inflorescences from each population was carried out in laboratory conditions according to ear and grain traits; culling was carried out. Based on the data obtained, the following were calculated:

- ear density index (EPI) - the number of spikelets per 10 cm of the ear length;
- lax ear (LE) - the percentage of the number of sterile spikelets from the total number of spikelets in an ear;
- grain inflorescence index (GII) - the ratio of the weight of the ear grain to the weight of the ear expressed as a percentage.

The second half of the inflorescences (50 pcs.) was subjected only to visual assessment by external traits without threshing. Culling was carried out.

The selected ears were used for the establishment of the 1st year breeding nursery in two ways - by seeds and unthreaded ear (Table 1).

| Hybrid combination               | Seeded lines, pcs. |          |          |
|----------------------------------|--------------------|----------|----------|
|                                  | with seeds         | with unthreaded ear |
| 78/07 × 6418-145                 | 14                 | 37       |
| Izhevskaya 2 × Nemchinovsky 56    | 18                 | 34       |
| Total                            | 32                 | 71       |

To verify the conclusion made based on the results of the breeding nursery establishment in 2020, the 1st year breeding nursery was also established in two ways for the harvest of 2021, but on a larger scale. A total of 330 ears were selected, 233 lines were sown, of which 45 lines were sown with seeds, 188 lines were sown with ears.

The 1st year breeding nursery was established in both years without repetitions. When sowing with seeds, the area of the plot was 0.3 m² (single-row plot 1 m long with a width between adjacent rows of 0.3 m), when sowing with an unthreaded ear - 0.09 m² (nesting method according to the scheme 0.3 × 0.3 m).

The cultivation technology of winter triticale corresponded to the zonal recommendations. The predecessor was spring rape for green manure; its green mass was crushed by KIR-1.5 and embedded in the soil by BDT-3 disking in two tracks. Before sowing, KMN-4 cultivation was carried out. Sowing was carried out manually in the first decade of September. The seeding rate of germinating seeds when sowing with threshed seeds is 1.5 million pcs/ha. In the spring, fertilizing with ammonium nitrate at a dose of 1 cwt/ha (N15) and harrowing with BZSS-1 were carried out. During the summer, manual weeding was carried out as weeds appeared. Harvesting - manually followed by threshing on the MPS-1M thresher.

The studies were carried out in accordance with the VIR methodology [20]: assessment of the seedlings' state, winter hardiness - on a 5-point scale, plant productivity and its structure - upon reaching wax ripeness. The density of the productive stems and the yield per 1 m² are converted considering the plots' area.

Statistical processing of the results obtained was done by methods of variational and correlation analyzes using Microsoft Office Excel (2007).
3. Results
After laboratory analysis and culling, 14 samples from 50 selected ears were left for further study from the hybrid combination 78/07 × 6418-145 (table 2). The culling rate was 72%.

Table 2. Characteristics of the selected inflorescences of winter triticale from a hybrid combination 78/07 × 6418-145.

| Plant number | weight, g | ear length, cm | number of spikelets, pcs. | productive | sterile | density index | lax ear, % | grains per ear, pcs. | weight, g | 1000 ear grains | 1000 grains index, % |
|--------------|-----------|----------------|--------------------------|------------|---------|---------------|-----------|---------------------|-----------|----------------|---------------------|
| 1            | 4.76      | 11.6           | 32                       | 0          | 27      | 0.0           | 88        | 3.55                | 40.3      | 74.6            |                     |
| 2            | 2.35      | 7.9            | 23                       | 1          | 29      | 4.1           | 45        | 1.81                | 40.2      | 77.0            |                     |
| 3            | 3.50      | 9.8            | 28                       | 0          | 29      | 0.0           | 64        | 2.57                | 40.0      | 73.4            |                     |
| 4            | 1.82      | 8.0            | 19                       | 4          | 29      | 17.0          | 41        | 1.40                | 34.0      | 76.9            |                     |
| 5            | 2.86      | 8.5            | 23                       | 1          | 27      | 4.0           | 53        | 2.23                | 42.0      | 78.0            |                     |
| 6            | 1.79      | 7.7            | 18                       | 2          | 25      | 10.0          | 43        | 1.40                | 33.0      | 78.2            |                     |
| 7            | 2.19      | 8.5            | 27                       | 2          | 33      | 6.9           | 42        | 1.51                | 36.0      | 68.9            |                     |
| 8            | 2.12      | 9.0            | 24                       | 0          | 26      | 0.0           | 50        | 1.53                | 30.6      | 72.2            |                     |
| 9            | 1.92      | 8.0            | 21                       | 2          | 28      | 8.7           | 43        | 1.35                | 31.4      | 70.3            |                     |
| 10           | 2.75      | 8.5            | 26                       | 2          | 32      | 7.1           | 50        | 1.62                | 32.4      | 58.9            |                     |
| 11           | 2.79      | 10.0           | 27                       | 3          | 29      | 10.0          | 49        | 1.95                | 39.8      | 69.9            |                     |
| 12           | 2.59      | 9.0            | 23                       | 1          | 26      | 4.1           | 59        | 1.99                | 33.7      | 76.8            |                     |
| 13           | 1.80      | 8.0            | 21                       | 2          | 28      | 8.7           | 42        | 1.33                | 31.6      | 73.9            |                     |
| 14           | 2.53      | 8.5            | 25                       | 3          | 32      | 10.7          | 50        | 1.97                | 39.4      | 77.9            |                     |

Average  2.56  8.8  24  2  28  6.5  51  1.87  36.0  73.4

V, %*  32  12  16  74  9  75  24  32  11.3  7

σ **  0.80  1.1  4  1  1  2  4.9  13  0.61  4.1  5.2

* - coefficient of variation
** - standard deviation

The grain index of the selected inflorescences (GII) was relatively high (on average for the analyzed inflorescences 73.4%) with a low coefficient of variation (7%). Only one plant (No. 10) had a low grain index. But the seeds of this inflorescence were left for the subsequent offspring testing as they were distinguished by good alignment, completeness and high vitreousness.

One of the selectable indicators of triticale is the ear density index (EPI). With EPI = 17...28 the ear is considered medium dense, with 29 or more spikelets - dense. In this case, an ear of medium density is preferable. EPI in 7 plants indicated a medium-dense ear (from 25 to 28 spikelets), in the same number - dense ear (above 29).

A very serious problem for the triticale culture is lax ear. “In wheat, as one of the parental forms of triticale, it occurs under extreme growing conditions and is due to physiological reasons, while in rye, being the second parental form, it is associated with biology peculiarities of flowering, pollination and self-incompatibility. As an evolutionarily young crop, triticale's lax ear is manifested mainly due to disturbances in gameto- and embryogenesis” [20]. A very small lax ear is considered when the number of sterile spikelets in an ear is less than 10%. Plants No. 1, 3, and 8 did not have sterile spikelets, while plants No. 2, 5, 7, 9, 10, 12, 13 had less than 10% lax ear.

The second hybrid combination, from where the initial inflorescences were selected, was Izhevskaya 2 × Nemchinovsky 56, where 18 inflorescences remained after laboratory evaluation (table 3). The culling rate was 64%.
were mainly the ones that did not correspond to the parameters of the developed model of the variety laboratory cullings for the formation of subsequent nurseries, 8 lines remained from the number of sown

26% for the combination 78/07 × 6418-145, and 32% for the combination Izhevskaya 2 × Nemchinovskiy 56.

The selected inflorescences had an average grain index of 69.8% with a variation coefficient of 15%.

In 14 inflorescences, the density index indicated a dense ear (EPI above 29). Plants No. 2, 6, 8, 9 had a medium-dense ear with an index of 25-28.

Plants No. 9 and 15 did not have sterile spikelets, and in plants No. 2, 3, 6, 10, 12, 13, 14, 16, lax ear was less than 10%.

The selected inflorescences had an average grain index of 69.8% with a variation coefficient of 15%. This indicator of plants No. 12 and 14 was very low - 36.2 and 49.0%, respectively, but the inflorescences were left for further study considering other indicators.

Thus, based on the morphological analysis of the ears, 72% of the selected inflorescences were culled from the first population, and 64% - from the second.

The second half of the selected inflorescences (50 pcs. from each hybrid combination) was subjected to only visual inspection and culling. As a result, the inflorescences' culling was lower and amounted to 26% for the combination 78/07 × 6418-145, and 32% for the combination Izhevskaya 2 × Nemchinovskiy 56.

All lines left for testing were sown in the 1st year breeding nursery. After carrying out field and laboratory cullings for the formation of subsequent nurseries, 8 lines remained from the number of sown seeds (or 28% of the total number of sown ones) and 7 lines - unthreaded spike (or 10%). Culled lines were mainly the ones that did not correspond to the parameters of the developed model of the variety

| Plant number | weight, g | ear length, cm | number of spikelets, pcs. | productive | sterile | density index | lax ear, % | grains per ear, pcs. | weight, g | ear grains | 1000 grains | Grain inflorescence index, % |
|--------------|-----------|----------------|---------------------------|------------|---------|---------------|-----------|---------------------|-----------|-------------|--------------|-----------------------------|
| 1            | 2.39      | 7.6            | 27                        | 3          | 38      | 10.0          | 46        | 1.77                | 38.5      | 74.1        |              |                             |
| 2            | 2.01      | 7.8            | 21                        | 2          | 28      | 8.7           | 44        | 1.49                | 33.9      | 74.1        |              |                             |
| 3            | 2.94      | 8.5            | 26                        | 1          | 31      | 3.7           | 55        | 2.28                | 41.4      | 77.6        |              |                             |
| 4            | 2.19      | 7.0            | 21                        | 4          | 34      | 16.0          | 42        | 1.71                | 40.7      | 78.1        |              |                             |
| 5            | 3.36      | 8.0            | 25                        | 3          | 34      | 10.7          | 48        | 2.49                | 51.9      | 74.1        |              |                             |
| 6            | 3.82      | 11.0           | 28                        | 2          | 26      | 6.7           | 62        | 2.85                | 45.9      | 74.6        |              |                             |
| 7            | 1.44      | 7.5            | 24                        | 3          | 35      | 11.1          | 34        | 1.03                | 30.3      | 71.5        |              |                             |
| 8            | 2.61      | 8.5            | 18                        | 4          | 25      | 18.2          | 47        | 1.94                | 41.3      | 74.3        |              |                             |
| 9            | 4.03      | 11.5           | 30                        | 0          | 25      | 0.0           | 68        | 2.85                | 41.9      | 70.7        |              |                             |
| 10           | 2.36      | 8.0            | 24                        | 2          | 31      | 8.0           | 43        | 1.79                | 41.6      | 75.8        |              |                             |
| 11           | 2.32      | 8.0            | 21                        | 3          | 29      | 12.0          | 49        | 1.53                | 31.2      | 65.9        |              |                             |
| 12           | 2.32      | 7.8            | 26                        | 2          | 36      | 7.0           | 47        | 0.84                | 20.0      | 36.2        |              |                             |
| 13           | 3.70      | 8.8            | 29                        | 2          | 34      | 6.5           | 60        | 2.72                | 45.3      | 73.5        |              |                             |
| 14           | 2.00      | 9.0            | 27                        | 2          | 31      | 6.9           | 30        | 0.98                | 32.7      | 49.0        |              |                             |
| 15           | 2.80      | 9.3            | 30                        | 0          | 31      | 0.0           | 47        | 2.10                | 44.7      | 75.0        |              |                             |
| 16           | 3.10      | 10.2           | 32                        | 1          | 31      | 3.0           | 62        | 2.09                | 33.7      | 67.4        |              |                             |
| 17           | 2.10      | 6.0            | 22                        | 5          | 43      | 18.5          | 36        | 1.62                | 60.0      | 77.1        |              |                             |
| 18           | 3.20      | 8.3            | 27                        | 5          | 37      | 15.6          | 59        | 2.15                | 36.0      | 67.2        |              |                             |
| Average      |           |                |                           |            |         |               |           |                     |           |             |              |                             |
| V, %*        | 26        | 16             | 15                        | 60         | 15      | 62            | 21        | 32                  | 23        | 15          |              |                             |
| σ**          | 0.71      | 1.4            | 4                         | 2          | 5       | 5.6           | 10        | 0.61                | 8.9       | 10.7        |              |                             |

* - coefficient of variation
** - standard deviation
This is firstly in terms of winter hardiness, plant height, lodging resistance, the presence of clavuses, ear productivity, etc. Further, the results of evaluating only the remaining lines are presented.

Field germination of lines sown with seeds in the 1st year breeding nursery ranged from 3.0 to 5.0 points (Table 4). Favorable conditions during the overwintering period contributed to the good winter hardiness of all breeding lines, which amounted to 5 points.

**Table 4.** Formation of grain yield of breeding lines in BN-1 sown with seeds.

| Breeding line* | Plant number | Field germination, score | Height, cm | Productive stems, pcs/m² | Grains per ear, pcs. | Ear grain weight, g | Weight of 1000 grains, g | Productivity, g/m² |
|---------------|--------------|--------------------------|-----------|--------------------------|----------------------|---------------------|------------------------|-------------------|
| Izhevskaya 2, st. | 3            | 124                      | 207       | 36                       | 1.31                 | 36.9                | 271                    |
| B-183         | 1            | 4                        | 115       | 147                      | 29                   | 1.24                | 42.7                   | 182               |
| B-184         | 3            | 5                        | 100       | 270                      | 37                   | 1.49                | 40.3                   | 403               |
| B-185         | 6            | 4                        | 90        | 210                      | 32                   | 1.54                | 48.9                   | 324               |
| B-186         | 11           | 3                        | 120       | 223                      | 34                   | 1.54                | 45.3                   | 345               |
| B-187         | 12           | 3                        | 105       | 140                      | 34                   | 1.53                | 44.5                   | 215               |
| B-188         | 16           | 5                        | 115       | 167                      | 40                   | 1.55                | 39.2                   | 258               |
| B-189         | 18           | 3                        | 110       | 123                      | 42                   | 1.71                | 40.8                   | 211               |
| C-132         | 13           | 4                        | 130       | 133                      | 39                   | 1.41                | 36.5                   | 188               |
| Average       | 4            | 111                      | 177       | 36                       | 1.50                 | 42.3                | 266                    |
| Coefficient of variation (V), % | 22          | 11                       | 30        | 12                       | 9                   | 9                   | 31                     |
| Standard deviation (σ) | 1          | 12                       | 52        | 4                        | 0.13                | 3.9                 | 82                     |

* - lines C-183...C-189 are selected from the hybrid combination Izhevskaya 2 × Nemchinovsky 56; line C-132 - from a hybrid combination 78/07 × 6418-145

For further study, lines with a plant height of no more than that of the Izhevskaya 2 variety (124 cm) were selected. The selection lines B-185 (90 cm high), B-184 (100 cm) were the best in height with a standard deviation of σ = 12 cm. Thicker productive density was formed by B-184 breeding line, which amounted to 270 pcs/m² and substantially exceeded the standard variety Izhevskaya 2 by 63 pcs/m² with a standard deviation of σ = 52 pcs/m². The selection line B-189 had the highest grain content of the ear - 42 pcs. and the weight of grain per ear - 1.71 g. The selection line B-185 (48.9 g) was distinguished by the weight of 1000 grains.

Biological yield of breeding lines greatly varied (V = 31%) and was in the range of 182 to 403 g/m². The highest yield (403 g/m²) was formed by the selection line B-184. The yield of the remaining lines was at the level of the Izhevskaya 2 variety.

The breeding lines sown with an unthreaded ear showed the maximum field germination and very high winter hardiness - 5 points. The most selectively attractive in terms of plant height was the B-193 line (85 cm), which was lower than the other lines by 15-35 cm with a standard deviation of σ = 13 cm (Table 5).

**Table 5.** Yield formation of breeding lines in BN-1 sown with unthreaded ear.

| Breeding line* | Height, cm | Productive stems, pcs/m² | Grains per ear, pcs. | Weight of ear grain, g | Weight of 1000 grains, g | Productivity, g/m² |
|---------------|------------|--------------------------|----------------------|------------------------|-------------------------|-------------------|

For further study, lines with a plant height of no more than that of the Izhevskaya 2 variety (124 cm) were selected. The selection lines B-185 (90 cm high), B-184 (100 cm) were the best in height with a standard deviation of σ = 12 cm. Thicker productive density was formed by B-184 breeding line, which amounted to 270 pcs/m² and substantially exceeded the standard variety Izhevskaya 2 by 63 pcs/m² with a standard deviation of σ = 52 pcs/m². The selection line B-189 had the highest grain content of the ear - 42 pcs. and the weight of grain per ear - 1.71 g. The selection line B-185 (48.9 g) was distinguished by the weight of 1000 grains.

Biological yield of breeding lines greatly varied (V = 31%) and was in the range of 182 to 403 g/m². The highest yield (403 g/m²) was formed by the selection line B-184. The yield of the remaining lines was at the level of the Izhevskaya 2 variety.

The breeding lines sown with an unthreaded ear showed the maximum field germination and very high winter hardiness - 5 points. The most selectively attractive in terms of plant height was the B-193 line (85 cm), which was lower than the other lines by 15-35 cm with a standard deviation of σ = 13 cm (Table 5).
There was a strong variation in the density of the productive stems, the weight of the ear grain, the grain yield of the selection lines (V = 32-41%). The greatest density of productive stems was formed by breeding lines C-133 and C-135, the latter remained inferior by 144-344 pcs/m² with a standard deviation of σ = 128 pcs/m².

The C-134 line was distinguished by the ear productivity and its components. It formed the largest grain, the weight of 1000 grains was higher than that of other lines by 13.6-21.7 g (σ = 7.2 g). With a high grain content of an ear, its productivity was the highest - higher than that of other lines by 0.43-1.03 g (σ = 0.36 g). The same line showed the greatest yield - 637 g/m², which was higher than the other lines by 183-413 g/m² (σ = 146 g/m²), or 29-65%.

4. Discussion
Calculation of the correlation between the weight of the ear grain and the weight of the ear in the selected inflorescences showed the presence of a close direct correlation in both analyzed hybrid populations (r = 0.974 and 0.918). The data obtained are consistent with the results of studies by Yu. L. Guzhov [18] and his recommendations to select the initial inflorescences by the weight of the ear and thereby reduce labor costs for threshing plants and the time for selection.

However, the correlation analysis of the ear grain weight of the initial inflorescences and the grain yield of the lines remaining after culling revealed the presence of an insignificant relation (r = 0.48 ± 0.88) between the analyzed parameters. This means that the ear grain weight during selection with a relatively low probability (coefficient of determination d = 0.23) may indicate the selection of highly productive forms. So, the offspring of the initial inflorescences with an ear grain weight of 2.23-3.55 g from the hybrid combination 78/07 × 6418-145 and with the weight of 2.10-2.85 g from a hybrid combination Izhevskaya 2 × Nemchinovsky 56 were subsequently culled. At the same time, a line remained from the first combination, in which the weight of the ear grain during selection was 1.33 g, and in the second - from 0.84 to 2.85 g.

The selection of parent plants based on the grain index of inflorescences (GII) recommended by A. M. Shishlov et al. [17] did not find complete confirmation in the results of these studies. Correlation analysis between the grain index of the inflorescence and the grain yield of the lines remaining after the cullings revealed the presence of an insignificant relation (r = 0.28 ± 0.78) between the analyzed indicators. The initial inflorescences of the selection lines C-183 and C-132 had a high grain index of 74.1% and 73.9%, respectively, but a relatively low grain yield of 182 g/m² and 188 g/m² was obtained at testing. At the same time, line B-187 with a yield of 215 g/m² originated from the initial inflorescence with a low GII = 36.2%. But there are also examples of a direct close relation. In the 1st year breeding
nursery, lines B-184 and B-185 formed a grain yield of 403 and 324 g/m² respectively and originated from the original inflorescences with a high grain index of 77.6% and 74.6%.

Thus, the selection of the initial winter triticale inflorescences based on the weight of the ear and the grain index is possible but does not guarantee the selection of highly productive forms. The authors believe that this is due to that the culling of inflorescences and breeding lines of winter triticale was carried out not only based on quantitative indicators, but also based on crop-specific qualitative indicators (grain plumpness, surface wrinkling, grain evenness).

Comparison of the yield obtained when setting up the 1st year breeding nursery with seeds and unthreaded ears showed the advantage of the second method. The average yield of the lines when sown with seeds was 266 g/m² with a variation of 182-403 g/m²; when sown with an unthreaded ear - 377 g/m² (or 42% higher) with a variation of 157-738 g/m². Perhaps this is due to that the seeds' germination and further plants' development when sown with a whole unthreaded ear is close to what occurs in natural conditions. A special microclimate is created around the germinating seed due to the spikelet lamellas, and young plants receive additional nutrition from the elements of the spike decomposing in the soil. In addition, auto-competition appears with a denser arrangement of seeds than when sowing with threshed seeds, which makes it possible to preserve and yield by only the strongest specimens. There is another advantage in the practical application of this sowing method - it is less difficult to conduct a visual assessment and culling of breeding lines.

In terms of overall performance, both methods of selecting the initial inflorescences for the 1st year breeding nursery and the method of its establishment turned out to be the same (Table 6).

**Table 6. Culling of initial inflorescences and breeding lines for different methods of selection and establishment of the 1st year breeding nursery, %.

| Hybrid combination       | Method for selecting initial inflorescences and the establishment of the 1st year breeding nursery | with seeds | with unthreaded ear |
|--------------------------|-------------------------------------------------------------------------------------------------|-----------|---------------------|
|                          | grain lines inflorescences lines                                                                | 72        | 50                  |
| 78/07 × 6418-145         |                                                                                                 |           |                     |
| Izhevskaya 2 × Nemchinovsky 56 |                                                                                                 | 64        | 94                  |
| General by sowing method*|                                                                                                 | 64        | 94                  |

* - calculated based on the initial number of inflorescences - 50 pcs. for each hybrid combination

Regardless of the hybrid combination, when selecting the initial inflorescences based on the morphological analysis of the ear and grain, the labor intensity of the work and the number of rejected inflorescences increased relative to culling based on visual inflorescences' inspection. The number of culled inflorescences was on average 39% higher. This is primarily due to that in the first case, the state of the grain and its biometric characteristics were considered.

When the lines were culled in the breeding nursery, the number of indicators considered for rejections increased: field indicators were added to the laboratory ones (winter hardiness, resistance to diseases, lodging, density evenness, yield, etc.). In this case, the number of culled lines in the 1st year breeding nursery established with an unthreaded ear increased sharply.

Thus, the selection of the initial inflorescences based on visual inspection reduced the labor intensity but did not affect the total number of culled forms in the selection of inflorescences and the assessment of their offspring in the 1st year breeding nursery.

Similar results were obtained when using these methods for selecting the initial inflorescences and establishing the first-year breeding nursery in 2020-2021. Out of the selected 130 inflorescences, 45 lines were sown in the 1st year breeding nursery after morphological assessment and culling. The culling rate was 65%. In the 1st year breeding nursery, 19 more lines (or 42%) were culled from these lines. Thus, the total culling rate was 80%. When preparing the seed for the establishment of the 1st year
breeding nursery with unthreaded ear, 12 inflorescences were rejected from the selected 200 inflorescences during visual inspection (or 6%), in the 1st year breeding nursery - 91% of the sown lines. Thus, the total culling rate was 93%.

When comparing the yield obtained in the 1st year breeding nursery established in different ways, the advantage was for sowing with an unthreaded ear. The yield averaged to 225 g/m², while it amounted to 141 g/m² when sown with seeds (that is, 37% lower).

5. Conclusion
1. The selection of the initial inflorescences by the weight of the ear allows to reduce labor costs for threshing and the selection time but does not always guarantee the selection of highly productive forms.
2. The selection of the initial inflorescences with their subsequent morphological analysis and calculation of the inflorescence grain index (GII) is laborious, but it makes it possible to consider the quality indicators of grain (completeness, surface wrinkling, evenness).
3. The method of setting up the first-year breeding nursery with an unthreaded ear facilitates visual assessment and breeding lines' culling, ensures better development of plants and the formation of higher yields. But at the same time, it significantly increases the number of culled lines.
4. Both selection methods of the initial winter triticale inflorescences and establishment of the 1st year breeding nursery from the point of view of the general culling of inflorescences and lines turned out to be the same.

Recommendations
At the initial stage of winter triticale breeding process, it is advisable to select the initial forms based on the weight of the ear, establish the 1st year breeding nursery with an unthreaded ear and carry out a comprehensive assessment and breeding material culling on the basis of field and laboratory methods. This will significantly increase the volume of breeding material and improve the quality of assessments, reduce the labor intensity in the culling of selected inflorescences and lines.

References
[1] Kshnikatkina A N 2009 Main productivity factors of winter triticale Volga Region Farmland 3(12) 73-79 eLIBRARY ID: 12805452
[2] Zasorina E V 2013 Prospects for triticale cultivation in the Central Black Earth Region Bulletin of the Kursk State Agricultural Academy 6 66-68 eLIBRARY ID: 20900741
[3] Shchipak G V 2013 Baking qualities of winter hexaploid triticale varieties Reports of the Russian Academy of Agricultural Sciences 1 3-7 eLIBRARY ID: 18317737
[4] Blum A 2014 The abiotic stress response and adaptation of triticale-A review Cereal Research Communications 42(3) 359-375 doi: 10.1556/CRC.42.2014.3.1
[5] Babaytseva T A 2019 Assessment of the source material for breeding winter triticale in the Middle Urals: monograph Izhevsk: FSBEI HE Izhevsk SAA 156
[6] Derejko A Studnicki M Wójcik-Gront E Gacek E 2020 Adaptive Grain Yield Patterns of Triticale (×Triticosecale Wittmack) Cultivars in Six Regions of Poland Agronomy 10 415 10.3390/agronomy10030415.
[7] Babaytseva T A 2018 Model of a winter triticale variety for the conditions of the Middle Urals Agrarian science of the Euro-North-East 1 27–31 DOI: 10.30766 /2072-9081.2018.62.1.27-31
[8] Leshchenko N I, Shakirzyanov A Kh, Myzgaeva V A Karachurina G R 2010 Main directions and results of winter triticale selection in Bashkortostan Achievements of science and technology of the AIC 1 16-18 eLIBRARY ID: 15100802
[9] Krokhmal A V 2013 The role of recombinations in the breeding of winter triticale for productivity Izvestiya Orenburg State Agrarian University 5 (43) 62-64 eLIBRARY ID: 20518216
[10] Medvedev A M Poma N G Osipov V V Zhikharev S D 2017 On the directions and methods of increasing the morphogenetic diversity and breeding value of winter triticale Legumes and cereals 3 (23) 50-58 eLIBRARY ID: 29924507
[11] Medvedev A M, Medvedeva L M, Komarov N M, Postovaya O V and Sokolenko N I 2009 On the selection of triticale for increased resistance to unfavorable environmental factors, grain productivity and quality *Fruit and berry growing in Russia* **21** 456-467 eLIBRARY ID: 12972012

[12] Rubets V S 2014 Selection of winter triticale in the RSAU-MAA named after K. A. Timiryazev: history, features, achievements *Bulletin of Timiryazev Agricultural Academy* **1** 115-124 eLIBRARY ID: 21437908

[13] Grabovets A I 2015 Climate change and methodology for creating new varieties of wheat and triticale with high ecological plasticity *Advances in science and technology in the AIC* **29** (12) 16-19 eLIBRARY ID: 25279735

[14] Diordieva I, Ryabovol L, Ryabovol Ya and Golubenko O 2021 Enrichment of the triticale gene pool by intraspecific hybridization *Collected Works of Uman National University of Horticulture* **1** 84-91 Doi: 10.31395/2415-8240-2021-98-1-84-91.

[15] Pykalo S 2019 In vitro selection of triticale for tolerance to abiotic stress factors (a review). *Myronivka Bulletin* Doi. org.10.31073/mvis201909-12.

[16] Maheshwari P Laurie John 2021 Triticale Isolated Microspore Culture for Doubled Haploid Production. Doi: 10.1007/978-1-0716-1315-3_16.

[17] Shishlova A M, Grib S I and Shishlov M P Selection method of productive forms of grain crops: patent SU 1454323A1, IPC A01N 1/04 Applicant and patentee - Belarusian Research Institute of Agriculture. - No. 4219538/30-13; appl. 01.04.1987; publ. 30.01.1989, Bul. No. 4 6 URL: https://patents.su/4-1454323-sposob-otbora-produktivnykh-zernovyykh-kultur.html

[18] Guzhov Yu L Selection method of productive cereal crops: patent SU 1060151A, IPC A01N 1/04/ Applicant and patent holder - Peoples' Friendship University named after Patrice Lumumba No. 3217754/30-15; appl. 12.12.1980; publ. 15.12.1983, Bul. **46** 8 URL: https://yandex.ru/patents/doc/SU1060151A1_19831215

[19] Manukyan I R Bekuzarova S A Basieva M A Miroshnikova E S Selection method of highly productive breeding samples of winter grain crops: patent RU 2710056 C1, SPK A01N 1/04 / Patent holder FSBSI FSC "Vladikavkaz Scientific Center of the Russian Academy of Sciences" No. 2019121471; appl. 05.07.2019; publ. 24.12.2019, Bul. **36** 7 URL: https://yandex.ru/patents/doc/RU2710056C1_20191224

[20] Kozlechkov G A Pasko S V Romanov B V Selection method of wheat plants with high productivity: patent RU 2676000 C1, IPC A01G 7/00, A01H 1/04 / Patent holder FSBSI "Federal Rostov Scientific Center" No. 2017137096 Appl. 20.10.2017; publ. 25.12.2018, Bul. **36** 14 URL: https://yandex.ru/patents/doc/RU2676000C1_20181225

[21] Merezhko A F, Udachin R A and Zuev V E 1999 Replenishment, preservation in a living form and study of the world collection of wheat, aegilops and triticale: methodological guidelines St. Petersburg 50-58