Selection of festulolium for the steppe conditions of the Central Black Earth region

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Abstract. In recent decades, a new fodder crop, festulolium, has become widespread in fodder production in Russia. (×Festulolium F. Aschers. et Graebn.). In this regard, an important task is the permanent creation of a line of varieties of festulolium, ensuring high efficiency of the use of this crop in various climatic and environmental conditions. Festulolium breeding has gained great importance in recent years as a means of combating climate change and increasing the efficiency of using perennial grasses to obtain high quality animal feed. The article presents material on the assessment of the initial material of festulolium in the steppe conditions of the Central Black Earth region. In recent years, 22 specimens have undergone a comprehensive assessment of festulolium in the collection and selection nurseries of the station. Of these, according to a complex of economically valuable traits, first of all - the productivity of green mass and seeds in arid conditions, 12 best were selected, which are further evaluated in order to create a new promising variety.

Key words: festulolium, source material, yield of green mass and seeds

1. Introduction
The efficiency of forage production is largely determined by the possibility of a wide choice of crops and varieties with the necessary useful traits and high productivity, most adapted to the soil-climatic and economic conditions of specific regions [1]. One of the main conditions for the fulfillment of this direction of scientific work is the permanent creation of a system of climatically and ecologically differentiated varieties of forage plants complementary in terms of the main ecological-biological and economically valuable characteristics [2]. The new fodder crop Festulolium is a hybrid in the Festuca spp. and Lolium spp., which may have the agronomic benefits of both genera. As a result of DNA recombination, chromosomes in festulolium alternate with DNA from two genera [3]. Hybrids between the genera Festuca and Lolium have many useful agronomic traits obtained from both parents, combine high seed productivity of ryegrass with abiotic stress resistance of fescue with good feed parameters of plant raw materials [4, 5, 6]. Unlike Lolium species, festulolium survives without serious damage in regions where the winter period of continuous snow cover usually reaches 120 days [7]. In the long term, taking into account the tendencies of climate change towards its aridization, the use of festulolium, which has a higher adaptive potential in comparison with Lolium to arid conditions, will increase [8].
Thus, the cultivation of festulolium in the Central Black Earth Region (Voronezh Region) showed the possibility of obtaining high yields of this crop [9, 10]. At the same time, it was revealed that certain varieties of festulolium had a reduced resistance to a lack of moisture, reduced winter hardiness. Breeding varieties of festulolium has gained great importance in recent years as a means of combating climate change and achieving more sustainable pasture farming [11]. The efficiency of cultivation of festulolium is largely determined by the effectiveness of selection in a particular natural region and the advantages of new varieties, their adaptive properties and operational characteristics.

**Purpose of work.** To assess the initial material of festulolium in order to create a promising variety for the conditions of the steppe zone of the Central Black Earth region with a high potential productivity of green mass and seeds, good fodder qualities, and resistance to the stress effects of abiotic and biotic environmental factors

2. Materials and Methods
Breeding work on festulolium was carried out at the Voronezh Experimental Station on perennial grasses of the VR Williams VIK Research Center. The meteorological conditions during the years of the research were significantly different from each other and from the average long-term indicators. Nurseries were established in meadow crop rotation in the near-channel part of the Osered River floodplain. For the establishment of nurseries, a site with fertile, cultivated soils typical for the zone and leveled relief was chosen. The meadow area is well drained, the groundwater level has dropped below two meters since spring, and the duration of flooding varies from 0 to 30 days over the years. For the establishment of nurseries, a site with fertile, cultivated soils typical for the zone and leveled relief was chosen. The soil of the site is floodplain, buried with thin, calcareous sediments, heavy loamy with a content of humus in the arable layer according to Tyurin 4.06 - 4.10%, mobile phosphorus 4.0 mg, potassium 32 mg per 100 g of soil according to Machigin. The thickness of the humus horizon is up to 1 m. The pH reaction of the water extract of the upper soil horizon is 7.0. Plot area 5 m², the VIK-90 variety was used as a standard. The work was carried out according to generally accepted methods for the selection of perennial grasses.

3. Results and Discussion
For festulolium in the collection and selection nurseries of the station in recent years, 22 samples have been comprehensively evaluated, created at the V.N. V.R. Williams and transferred to an experimental station for study in other climatic conditions. On their basis, using the methods of selection in collection and breeding nurseries and free cross-pollination of the best populations, a new source material was created, with which work was continued in floodplain conditions in a breeding nursery in 2014-2017. In 2018, in floodplain conditions, on May 17, a breeding nursery was established from the newly selected best variety populations. The germination commenced on May 30. The growing season of this year was characterized by a moisture deficit (Table 1), therefore the herbage grew slowly and no counts were carried out in the year of sowing.

| Year | Indicators | April | May | June | July | August | September |
|------|------------|-------|-----|------|------|--------|-----------|
| 2018 | Precipitation, mm | 23.3 | 12.5 | 18.7 | 119.3 | 9.5 | 48.2 |
|      | % to the norm | 63.0 | 24.5 | 30.6 | 198.0 | 15.0 | 130.0 |
|      | Air temperature, °C | 10.6 | 21.5 | 23.0 | 24.7 | 23.6 | 18.0 |
|      | Deviation from the norm, °C | +3.7 | +6.4 | +4.0 | +3.7 | +3.7 | +4.4 |
|      | Productive moisture reserves in the layer, mm: 0-20 cm. 0-100 cm | - | 12.8 | 1.1 | 2.8 | 5.1 | 13.6 |
|      | | - | 118.2 | 64.2 | 44.6 | 42.2 | 136.2 |
| 2019 | Precipitation, mm | 17.9 | 87.6 | 29.8 | 114.9 | 33.5 | 12.7 |
|      | % to the norm | 48.3 | 171.8 | 48.9 | 188.0 | 52.0 | 34.0 |
In 2019, heavy rainfall in May and July, as well as reserves of productive moisture in a meter layer of soil within 100 mm contributed to the formation of three mows of the studied samples of festulolium (Table 2). The green mass yield of the best samples ranged from 42.94 to 35.62 t / ha, against 27.8 t / ha for the standard VIK 90 variety. In dry 2020, due to a large moisture deficit and high air temperatures, plants could not accumulate a large phytomass. As a result, only one cut was obtained. The collection of green mass from different samples varied from 2.86 to 5.3 t / ha, versus 2.48 t / ha for the standard. On average, over two years, all new source material for the collection of green mass exceeded the standard from 32 to 55% (Table 2).

Winter 2019-2020 was warm: January was 7.7 ° C, February was 8.7 ° C, March was 8.0 ° C higher than the average long-term norms. The winter was snowless, in January - March there was only 75.7 mm of precipitation, for comparison in 2019 - 101.4 mm, in 2018 - 193.1 mm. The weather conditions in winter 2020 were different from normal years. Positive temperatures during overwintering made it possible to extend the growing season of perennial grasses. Perennial grasses started growing very early - in early March, then in April in the second ten-day period there were frosts down to - 6ºC. Precipitation in May was 87% of the average long-term norm. In June, warm weather prevailed, with insufficient moisture (precipitation - 44% of the norm). The average temperature in June was 24.9 ° C, which is 5.9 ° C higher than the average multiyear average. July was hot, with a great lack of moisture, precipitation was 20.4% of the average annual rate. The average monthly temperature in July was 5.6 ° C above the norm and amounted to 26.6 ° C. The month of August was also very dry and with an increased temperature regime (precipitation fell 13.8% of the norm, the temperature was recorded at 4.6 ° C above the average long-term norm). During May - August, 95.2 mm of precipitation fell, which characterizes the very low moisture supply of this period (drought). The amount of precipitation for the year was 282 mm. Therefore, in 2020, only one cut of festulolium was obtained.

**Table 2.** Fodder and seed productivity of the best samples in the breeding nursery of festulolium (setting of experience in 2018, accounting for 2019-2020).

| Sample name | Harvesting green mass, t / ha | Yield seeds, kg / ha |
|-------------|-----------------------------|---------------------|
|             | 2019                        | 2020               | В среднем за 2 years | | |
|             | 1 cut | 2 + 3 cut | Total | % after math | 1 cut | Harvest | % to St. | |
| F-3         | 23,54 | 21,18    | 44,72 | 47,4 | 2,12 | 23,42 | 154,7 | 272,0 |
| F-5         | 23,94 | 17,70    | 41,64 | 42,5 | 5,30 | 23,47 | 155,0 | 277,8 |
| F-6         | 18,80 | 19,40    | 38,20 | 50,8 | 4,66 | 21,43 | 141,5 | 243,2 |
| F-7         | 20,52 | 21,14    | 41,66 | 50,7 | 4,40 | 23,03 | 152,1 | 200,6 |
| F-8         | 22,74 | 16,74    | 39,48 | 42,4 | 2,74 | 21,11 | 139,4 | 268,0 |
Evaluation according to the level of seed yield showed that a number of samples (F-3, F-5, F-12, etc.) exceeded the standard by 11% or more. At the same time, samples F-3, F-5 also formed a higher yield of green mass by 55%.

| Sample name | Plant height, cm |
|-------------|------------------|
|             | 2019        | 2020    |
| F-3         | 72,0        | 42,4    | 50,5 | 57,4 |
| F-5         | 63,0        | 38,6    | 47,9 | 59,4 |
| F-6         | 76,0        | 56,6    | 64,0 | 66,0 |
| F-7         | 73,0        | 40,6    | 51,8 | 65,4 |
| F-8         | 76,0        | 41,4    | 53,7 | 57,8 |
| F-12        | 77,0        | 40,0    | 52,7 | 60,4 |
| F-13        | 71,0        | 36,0    | 48,5 | 59,8 |
| F-14        | 61,0        | 41,4    | 48,7 | 56,8 |
| F-19        | 77,8        | 38,4    | 53,0 | 63,0 |
| F-20        | 80,0        | 37,2    | 52,3 | 68,0 |
| F-22        | 73,6        | 39,2    | 51,2 | 54,4 |
| F-23        | 74,6        | 43,0    | 57,1 | 65,4 |
| St. VIK 90  | 89,0        | 35,1    | 53,8 | 53,5 |

* - in the first cut

Plant height is an indirect indicator of the yield of the forage mass of the studied varieties and the intensity of regrowth after mowing. For this indicator, the variation between samples and by cut was quite significant. In the first cut in 2019, in conditions of sufficient and excessive moisture supply for the region due to a large amount of precipitation and good reserves of productive moisture in the soil, all samples were inferior to the standard from 31 to 10% (Table 3). However, already in the second cut, the new material was characterized by a higher growth rate and almost the entire collection already exceeded the standard by 6-61%. A similar pattern was preserved in the third cut. In the arid conditions of 2020, in the first cut, all selected samples exceeded the standard in height, the best ones - by 13-23% (Table 3). This indicates a better adaptation of the new starting material to growing in arid conditions.

4. Conclusion
The conditions that have developed over the years of research, contrasting in the mode of moisture and the level of heat supply, made it possible to distinguish samples of festulolium with resistance to stress factors and higher fodder and seed productivity.

References
[1] Zolotarev V.N. Adaptive Fodder Production. 2021. Economically useful signs and features cultivation of tetraploid variety meadow fescue 'BINARA'. № 2. Pp. 31-43. (URL:...
[2] Shamsutdinov Z. Sh. Agrarian Bulletin of the South-East. 2014. Breeding and Seed Production of Forage Crops in Russia: Results and Strategic Directions in the Context of Sustainable Development. No. 1-2 (10-11). S. 48-52.

[3] Kubota A., Akiyama Y., Fujimori M. Crop Science. 2019. The Relationship between f Ratio and Seed Yield-Related Traits in Festulolium. Vol. 59. №. 5. Pp. 1992-1996. DOI: 10.1111 / grs.12103

[4] Akiyama Y., et al. Genome. 2012. Genomic characteristics of a diploid F4 festulolium hybrid (Lolium multiflorum × Festuca arundinacea). Vol. 55. №. 8. Pp. 599-603.

[5] Kopecký D., et al. Cytogenetic and genome research. 2017. Stability of genome composition and recombination between homoeologous chromosomes in Festulolium (Festuca × Lolium) cultivars. Vol. 151. №. 2. Pp. 106-114. DOI: org/10.1159/000458746

[6] Østrem L., Volden B., Larsen A. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science. 2013. Morphology, dry matter yield and phenological characters at different maturity stages of× Festulolium compared with other grass species. Vol. 63. – №. 6. – pp. 531-542.

[7] Ueyama Y., et al. Bulletin of Tohoku Agricultural Research Center. 2014. Breeding of a new festulolium cultivar, "Icarus",. №. 116. Pp. 55-68

[8] Ghesquière M., Humphreys M. W., Zwierzykowski Z. Fodder crops and amenity grasses. – Springer, New York, NY, 2010. Festulolium. . 288-311.

[9] Obraztsov V. N., Shchedrina D. I., Kadyrov S. V. Festulolium seed productivity depending on methods and seeding rates. IOP Conference Series: Earth and Environmental Science. 6th International Conference on Agriproducts Processing and Farming. 2020. P. 012025.

[10] Obraztsov V. N., Shchedrina D. I., Kadyrov S. V. Seed productivity of different Festulolium varieties. IOP Conference Series: Earth and Environmental Science. 6th International Conference on Agriproducts Processing and Farming. 2020. P. 012026.

[11] Humphreys M. W., O’ Donovan S. A., Farrell M. S. et al. Food and Energy Security. 2014. The potential of novel Festulolium (2n= 4x= 28) hybrids as productive, nutrient-use-efficient fodder for ruminants. Vol. 3. №. 2. Pp. 98-110. DOI: org/10.1002/fes3.50