Creation of new soft winter wheat varieties for cultivation in the conditions of the central region of the Non-Chernozem zone of Russia

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Abstract. Winter wheat is the most valuable agricultural crop, which occupies one of the first places in the balance of grain crops of the Central region of the Non-Chernozem zone of Russia. Year after year, there is an increasing need to expand the production of grain products, which can be provided by varieties that give high and stable yields over the years. Creation of environmentally plastic varieties is a promising and popular direction of breeding work in recent years. The evaluation of samples in the breeding process for ecological plasticity and yield stability allows to identify varieties most adapted to growing conditions, as well as having high potential productivity. To identify the most valuable samples for the complex of economically useful traits a breeding evaluation of soft winter wheat promising lines obtained using source material of various ecological and geographical origin was carried out in the FSEI HE RSAU-MAA named after K.A. Timiryazev. As a result of the study, the most valuable sample 50h (Azotfixifuyushchaya x Moscovskaya 40) was selected in a competitive variety testing, which significantly exceeded the yield standard, and was also characterized by high grain quality and resistance to powdery mildew. This promising sample, which has high indicators for a complex of economically valuable traits, is planned to be transferred to the State variety testing. Variety samples were identified that showed high resistance to snow mold 32h (Sharada × Nemchinovskaya 24) and 52h (Nemchinovskaya 24× Zimorodok), which we recommend to use in further breeding for resistance to this disease.

1 Introduction

Winter wheat is one of the most important food crops, occupying a significant share in the structure of the grain area of Russia [1-3]. The cultivated area occupied under this crop in

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2021, according to Rosstat, in farms of all categories amounted to 15,719.3 thousand hectares, which is equal to 56.3% of all wheat crops in the country [4].

Currently, the needs of the rapidly growing population of the planet have begun to significantly outpace the increase in agricultural production. In such conditions, the need to increase the productivity of agricultural plants, in particular winter wheat, as the main, strategically important crop has become obvious [5].

Variety (or hybrid), as a means of agricultural production, is one of the most important elements of scientific and technological progress in agriculture, since it ensures the production of high-quality products in necessary amount. The creation of new varieties is the most effective means of obtaining high yields at minimal cost [1, 6, 7, 9].

The evaluation of varieties in the breeding process for ecological plasticity and yield stability, resistance to adverse environmental factors, allows to identify varieties most adapted to growing conditions, as well as having high potential productivity. It is such varieties that can provide high stable yields over the years and in different natural and climatic zones.

For this purpose, in the FSEI HE RSAU-MAA named after K.A. Timiryazev in 2019-2020, a breeding evaluation of promising samples of soft winter wheat obtained using source material of various ecological and geographical origin, as well as the creation of new varieties of winter wheat with high potential yield and good grain quality, was carried out.

2 Material and research methods

The material for breeding work with winter wheat were varieties and breeding samples in different parts of the breeding process: 1. Collection nursery – 35 varieties of Russian and foreign breeding. 2. Hybridization nursery – 31 hybrid combinations. 3. Selection nursery – 25 hybrid combinations. 4. Nursery of 1st generation hybrids (F_1) – 18 hybrid combinations. 5. Breeding nursery of the 1st year (SP-1) – 44 hybrid combinations (2268 plots). 6. Breeding nursery of the 2nd year (SP-2) – 21 variety samples (126 plots). 7. Competitive variety testing (KSI) – 11 varieties and variety samples (33 plots).

The evaluation of breeding material in nurseries and variety testing was carried out according to the methodology of the State Commission of the Russian Federation for Testing and Protection of Breeding Achievements [11].

Sowing of the collection, selection nursery, breeding nurseries of the 1st and 2nd year, was carried out with a cassette seeder SKS-6A. The seeding rate of the collection nursery is 4.0 million germinating seeds per hectare. The plot area is 1 m^2, the number of rows is 6, the repetition is twofold.

Breeding success largely depends on the selection and evaluation of the source material that will be involved in the crossing. The main source of genetic diversity, from which the parental forms necessary for subsequent breeding work are selected, is the collection nursery [11, 12]. For a more objective assessment of the source material, all varieties studied in the collection nursery are divided into 3 groups, based on the place and country of origin. The first group is represented by varieties created in the SRIA CRNZ and RSAU-MAA named after K.A. Timiryazev, this group of varieties is most adapted to the conditions of the Non-Chernozem zone. The second group is also represented by varieties of Russian breeding (Krasnodar SRIA , Don Zonal SRIA, ARSRI for Grain Crops, Samara SRIA, etc.), these are varieties of the southern biotype, characterized by high yield and good grain quality. The third group includes varieties of Belarusian and Western European breeding. European varieties are characterized by very high yields (up to 11 t/ ha), but at the same time they are characterized by low frost and winter hardiness, and relatively low grain quality. A comprehensive assessment of the samples in the collection nursery for yield, grain quality, disease resistance, winter hardiness, lodging resistance, and growing season duration, allows to select the best forms for further crossing.

Simple pair crosses were used to create hybrid populations. During hybridization, in most cases, varieties created in the Research Institute of the CRNZ and the SRIA CRNZ and RSAU-MAA named after K.A. Timiryazev were chosen as the female parent, as the most adapted to the conditions of the Non-Chernozem zone.

Competitive variety testing is one of the final stages of the breeding process, so special attention in the article will be paid to this nursery.

Sowing of competitive variety testing was carried out with a seeder CN–10C with a seeding rate of 5.0 million germinating seeds per hectare. The registered area of the plot was 10 m^2, the number of rows was 7. The repetition is three-fold, the placement of options is randomized.

The origin (breeding record) of the variety samples tested in the competitive variety testing is presented in Table 1.

Table 1. Origin of winter wheat varieties in competitive variety testing.

No.	Hybrid combination number	Hybrid combination decoding
1	Nemchinovskaya 24 st	Moscow SRIA (Donshchina x Inna)
2	Moskovskaya 56 st	Moscow SRIA (Mironovskaya poluintensivnaya x Inna) x Moskovskaya 39
3	10h	Ermak×Moscovskaya 39
4	32h (awnless form)	Sharada × Nemchinovskaya 24
5	32h (awned form)	Sharada × Nemchinovskaya 24
6	50h	Azotfixiruyushchaya×Moscovskaya 40
7	51h	Nemchinovskaya 24×Vassa
8	52h	Nemchinovskaya 24×Zimorodok
9	66h	Azotfixiruyushchaya x Nemchinovskaya 24
10	97h	Erytrospermum 902×3675 (Austria)
11	101h	Azotfixiruyushchaya × 3897 (Austria)

Phenological observations were carried out throughout the growing season. The onset of the development phases of winter wheat plants was noted: seedlings, tillering, stem elongation, earing, full ripeness. The onset of the phases was noted when 10-15% of plants entered it, and the full onset of the phase - 75% of plants. The dates of plant autumn vegetation termination, snowfall and the beginning of plant spring regrowth were also recorded.

After the beginning of plant spring regrowth, a point assessment of overwintering varieties was carried out on a 5-point scale: 5 - death of plants on the plot is not noticeable. 4 - at least 70-80% of plants have been preserved. 3 - about half of the plants have been preserved. 2 - more than half of the plants died. 1 - insignificant part of the plants has been preserved [13, 14].

At the same time, it should be borne in mind that such a visual estimation of overwintering plants is quite objective if the plants have developed normally since autumn.

The degree of damage to plants by snow mold was assessed according to a 9-point system: 1,3,5,7,9, where 9 points means the highest resistance. The assessment of plant resistance to snow mold was carried out in the spring after snowfall and beginning of plant regrowth [13].

Grain harvesting was carried out in the phase of full ripeness of winter wheat plants with a Sampo 130 selection combine. After harvesting, the grain was dried to a standard humidity of 14%, after which it was weighed separately.

Grain quality assessment (protein and gluten content) was carried out on a spectrophotometer "Spectran IT", calibrated according to the methods of the ARSRI For Grain [13].

The obtained data were mathematically processed by the method of one-factor analysis of variance. The significance of the differences in varieties was evaluated considering the value of LSD_{05} [15].

Comparative assessment of the varieties was carried out at a high agricultural background: the predecessor is white mustard, pre-sowing application of complex mineral fertilizers (azofoska) at the rate of $N_{32}P_{32}K_{32}$, the first spring fertilization with ammonium nitrate N_{75} during the beginning of spring regrowth of plants (VVSN–23) and the second nitrogen fertilization, in the stem elongation end phase (VVSN–32). To control weeds and prevent damage to plants in winter by snow mold, autumn crops were treated with a tank mixture of herbicide Alister Grant (0.6 l/ha) and fungicide Alto super (0.5 l/ha).

Meteorological conditions of the experiments are provided by the Meteorological Observatory named after V.A. Mikhelson RSAU-MAA named after K.A. Timiryazev.

A record low amount of precipitation during sowing, only 25% of the average long-term and the first decade of September 0.4 mm, at higher average daily temperatures, negatively affected field germination and germination density. Heavy rains that took place at the end of September and the first decade of October somewhat corrected the situation, the beginning of autumn tillering of winter wheat plants took place in relatively comfortable conditions.

By the end of the autumn vegetation period, the plants were in the tillering phase, with a well-developed tillering node and the presence of nodal roots.

The average daily temperatures in December, January, and February were higher than the annual average with relatively high snow cover, as 48.5 and 61.4 mm of precipitation fell in December and January, which in total is significantly higher than the annual average. The coldest in winter was the third decade of January, when the average daily temperature dropped below -8.4 ^{0}C, which is not dangerous for winter crops. All of the above indicators evidence sufficiently favorable conditions for overwintering of winter cereals.

The early snowfall from the fields, the lack of precipitation in April, only 7.6 mm with an average long-term value of 44 mm, high average daily temperatures in April and May, led to the fact that winter wheat plants quickly passed the spring tillering phase and could not form enough productive lateral stems.

A small amount of precipitation in the third decade of May, as well as in the first and second decades of June, negatively affected the formation of the number of grains in the ear and the mass of 1000 seeds. All these negative factors combined led to a significant decrease in the yield of the tested samples of winter wheat. Such a temperature-water regime can be characterized as unfavorable for the growth and development of soft winter wheat plants.

3 Results and Discussion

The growing season duration is the most important biological property that must be considered when characterizing new breeding samples. Because the growing season duration of new varieties created for a certain soil-climatic zone should correspond to the period of time during which the most favorable conditions for plant growth and development are observed [16]. The duration of the growing season, due to the importance of this indicator, is studied at all stages of the breeding process, from the collection to the competitive variety testing.

The peculiarity of the 2019-2020 growing season was that in the spring period, higher average daily temperatures were observed relative to the average long-term, with significantly less precipitation. Especially little precipitation fell in April, only 17.3% of the long-term average. The prevailing weather conditions significantly affected the dates of the onset of plant development phenological phases, shortening the duration of interphase periods, especially tillering-stem elongation and stem elongation-earing, which led to a decrease in the total length of the growing season of winter wheat varieties by 7-10 days.

One of the main requirements for varieties is their complex resistance to adverse environmental factors, diseases, and pests. Therefore, the study of the resistance of variety samples to the main most dangerous diseases on a natural background is one of the main test elements [17]. The most dangerous disease in the winter-spring period for winter wheat in the Non-Chernozem zone is snow mold.

We have evaluated the varieties of winter wheat for winter hardiness, resistance to snow mold and powdery mildew (Table 2).

The relatively early snow cover and the beginning of the spring vegetation of plants did not contribute to the massive development of snow mold. Therefore, all varieties of winter wheat have shown high resistance to this disease. Variety samples 10h, 32h, and 50h have the maximum stability score.

For winter wheat, the problem of winter hardiness and frost resistance continues to be very relevant [18]. Thus, unfavorable conditions in winter during the growing season can lead to the complete death of sowings [19]. Therefore, new winter wheat varieties should have high frost and winter hardiness. Favorable conditions for overwintering, and in particular, air temperature in winter did not fall below the critical, and sufficient snow cover height, contributed to the excellent preservation of plants. The differentiation of the tested winter wheat samples by winter hardiness is small, within 4-4.5 points.

Table 2. Assessment of overwintering and resistance of winter wheat varieties to diseases.

No.	Variety sample	Winter hardiness, score	Resistance to snow mold, score	Resistance to powdery mildew, score
1	Nemchinovskaya 24 st	4.0	7.0	9.0
2	Moskovskaya 56 st	4.0	7.0	9.0
3	10h	4.5	9.0	7.0
4	32h (awnless form)	4.0	7.0	7.0
5	32h (awned form)	4.5	9.0	7.0
6	50h	4.5	9.0	9.0
7	51h	4.0	7.0	5.0
8	52h	4.5	7.0	5.0
9	66h	4.0	7.0	5.0
10	97h	4.0	7.0	7.0
11	101h	4.5	7.0	7.0

Assessment of the resistance of the samples to powdery mildew showed that of all the tested variety samples, three samples 51h, 52h, and 66h are significantly affected by this disease. The highest stability score was shown by the Moscovskaya 56 and Nemchinovskaya 24 standards, as well as the 50h sample. A comparative assessment of winter wheat variety samples for resistance to powdery mildew has shown that most promising samples are inferior to the standard for resistance to this disease. It is necessary to expand breeding work in this direction by searching for new donors of resistance to powdery mildew and involving them in the breeding process.

Yield is the main indicator of the influence of climatic and technological conditions on growth [10, 12]. In the first column of the table 3, the yield of samples in t/ha is indicated, in the second, the difference between the yield of the standard and the compared samples, in the third, the tested samples are ranked by groups relative to the value of the smallest significant difference: group 1 – samples that significantly exceed the standard in yield; group 2 - the yield of samples at the standard level. Based on the data presented in Table 3, the following conclusion can be drawn, that in the conditions of the growing season 2019-2020, all winter wheat samples showed low yields. The maximum yield was observed in winter wheat variety samples 32h and 50h.

Table 3. Yield of winter wheat varieties in competitive variety testing.

No.	Sample name	Yield, t/ha	Difference from the standard, t/ha	Group
1.	Nemchinovskaya 24 st	4.77	+0.72	1
2.	Moskovskaya 56 st	4.05	-	-
3.	10h	4.57	+ 0.52	2
4.	32h (awnless form)	5.26	+ 1.21	1
5.	32h (awned form)	5.24	+1.19	1
6.	50h	5.07	+1.02	1
7.	51h	4.13	+0.08	2
8.	52h	4.74	+ 0.69	1
9.	66h	4.37	+ 0.32	2
10.	97h	4.40	+ 0.35	2
11.	101h	4.53	+ 0.48	2
	LSD_{05}	0.64		

Along with the yield, grain quality indicators are of great importance for the variety. The main criteria for wheat grain quality are indicators of protein and gluten percentage. These indicators vary widely depending on the variety, fertilizers, meteorological conditions, and other factors [20].

Plant proteins play a huge role in human and animal life, since only plants can synthesize essential amino acids that cannot be synthesized in the body.

The results of the grain quality analysis of winter wheat samples studied in the competitive variety testing are presented in Table 4.

For the use of wheat grain for baking purposes, the main qualitative indicators are the protein and gluten content, as well as grain unit and vitreousness. Most of the winter wheat samples meet the requirements of Class 3 in terms of grain quality. One 52h variety sample corresponds to the 4th quality class. All the studied samples had a high grain unit and total vitreousness. The good quality of grain samples of competitive variety testing is due to low yields and favorable conditions during the period of grain filling and ripening.

Table 4. Assessment of grain quality of winter wheat variety samples in competitive variety testing.

No.	Variety sample	Content in grain, %		Grain unit, g/l	Total vitreousness, %	Plant protein collection, c/ha
		Protein	Gluten			
1	Nemchinovskaya 24 st	14.4	24.5	777	76	6,87
2	Moskovskaya 56 st	15.6	27.2	795	76	6,32
3	10h	14.1	24.1	761	74	6,44
4	32h (awnless form)	14.2	24.0	720	73	7,47
5	32h (awned form)	13.8	23.3	779	74	7,23
6	50h	14.8	25.2	752	80	7,50
7	51h	14.3	24.3	741	75	5,91
8	52h	12.8	21.3	769	75	6,07
9	66h	14.1	24.5	750	81	6,16
10	97h	14.0	24.1	790	74	6,17
11	101h	13.9	23.7	767	75	6,29
LSD_{05}		0,25	0.55	10.07	-	-

For winter wheat varieties in the grain-forage direction of use, in addition to the percentage of protein in the grain, the most important characteristic of the variety economic value is the collection of vegetable protein per unit area [20].

The characteristics of varietal samples of winter wheat for collecting protein from a hectare are shown in Table 4.

The analysis of the data shows that the greatest collection of vegetable protein per unit area is provided by varietal samples that combine high yield with an increased protein content in grain. Of the studied samples, these include 32h and 50h.

4 Conclusions

As a result of a comprehensive assessment of the variety samples in the competitive variety testing, the most valuable winter wheat sample was identified: 50h (Azotfixiruyushchaya x Moscovskaya 40), which significantly exceeded the yield standard, and was also characterized by high grain quality and resistance to powdery mildew. This promising sample, which has high indicators for a complex of economically valuable traits, is planned to be transferred to the State variety testing. Variety samples 32h (Sharada× Nemchinovskaya 24) and 52h (Nemchinovskaya 24×Zimorodok) are characterized by high yields. High resistance to snow mold in our studies was shown by variety samples 10h (Ermak×Moscovskaya 39) and 32h (Sharada× Nemchinovskaya 24). They can be used in further breeding as donors of resistance to this dangerous disease. Assessment of sample resistance to powdery mildew showed that of all the tested variety samples, three 51h (Nemchinovskaya 24×Vassa), 52h (Nemchinovskaya 24×Zimorodok) and 66h (Azotfixiruyushchaya × Nemchinovskaya 24) are significantly affected by this disease. Therefore, an urgent task is to find donors of resistance to powdery mildew and involve them in the breeding process.

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