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CROP PRODUCTION

Features of the Winter Wheat Varieties Genotype Cultivated in the Russian Federation's Non-Chernozem Earth Zone

B. I. Sanduhadze[a], *, V. V. Bugrova[a], M. S. Krakhmalyova[a], and R. Z. Mamedov[a]
[a] *Federal Research Center Nemchinovka, Moscow oblast, 143026 Russia*
**e-mail: sanduchadze@mail.ru*
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Abstract—A brief description of the stages of winter wheat breeding in the Non-Chernozem Zone of the Russian Federation is given. The characteristics of the Mironovskaya 808, Pamyati Fedina, Inna, and Moskovskaya 39 varieties were given in comparison with the new Nemchinovskaya 85 and Moskovskaya 27 varieties in terms of yield, productivity elements, and protein content in grain for 5 years of research (2015–2019). The grain yield in the Nemchinovskaya 85 variety (submitted for state variety testing in 2018) was 7.9 t/ha (maximum yield was 10.1 t/ha), while that in the Moskovskaya 27 variety (2019) was 7.7 t/ha (8.89 t/ha); the protein content in grain was 15.0 and 14.4%, respectively. A significant excess of these varieties in terms of yield over the varieties of the earlier breeding stages and the Moskovskaya 39 standard was shown. The data on the constant lines of the F_5 generation of the hybrid combination Boema × Mera, combining large-grain, short-stemming, and high protein content in the grain, are presented. Correlation analysis confirmed the possibility of combining a low plant height and a high mass of 1000 grains in one genotype. The best lines of this combination are seeded in the breeding and control nurseries.

Keywords: winter wheat, breeding, variety, yield, quality, short-stemming
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INTRODUCTION

The creation of a winter wheat variety takes over 10–15 years. Continuity and focus are of paramount importance in this breeding process. Historically, the so-called gray breads (rye and oats) were cultivated on poor acidic soils of the central Non-Chernozem Region of Russia under unfavorable winter conditions. Currently, the area under winter wheat crops in the region reaches millions of hectares. The bulk of winter wheat varieties grown in the Non-Chernozem Region was created at the Federal Research Center (FRC) Nemchinovka. It is the result of decades of painstaking and hard work.

A.A. Zhuchenko [1] noted that varieties are needed that are adapted to agro-climatic conditions and high-tech technologies, combining high productivity potential (size and quality of the crop) with resistance to the most typical abiotic and biotic stressors for the region of cultivation due to the prevalence of the "genotype" over unregulated environmental factors. This point of view is supported by other authors [2–6].

The difficulties in breeding winter wheat when creating a variety for the Non-Chernozem Region included the combination of yield, winter hardiness, short stem, and grain quality in one genotype. Approximate breeding stages of this crop are presented in Table 1. The production of high-quality winter wheat grain in the central region of Russia has always been relevant because of its highest biological productivity potential among cereals. This is explained by the fact that the winter cycle of plant development allows them to make the most of the soil moisture reserves accumulated in the autumn-winter period, which puts them in a more advantageous position in comparison with spring crops, especially in dry years [7–9].

In the 1920s, N.I. Vavilov and his associates persistently substantiated the expediency of growing winter wheat in the Non-Chernozem Region [10]. Local varieties of this crop were grown in the Central Region. Kostromka, Glebovskaya, Sandomirki, and Botanki varieties are among them. Old-local varieties included populations of varieties and sometimes species that had low yields due to poor winter hardiness.

The next stage of breeding included the distant hybridization, crossing wheat with wheatgrass [11]. The work was started under the leadership of Academician N.V. Tsitsin and Professor G.D. Lapchenko. Sowing of winter wheat in the Non-Chernozem Region began to expand significantly only from the middle of the 20th century by PPG 599, PPG 186, and Mironovskaya 808. The Zarya variety, which has a phenotype similar to Mironovskaya 808 and possesses unique resistance to smut, was zoned in 1978. A unique breeding scheme using the method of inter-

Table 1. Stages of winter wheat breeding in the Central Non-Chernozem region

Stage	Cultivated varieties	Year of zoning
I	Kostromka, Glebovskaya, Sandomirki, Botanki, Moskovskaya 2453	1920–1950
II	PPG 599, PPG 186, Mironovskaya 808 others	1950–1960
III	Zarya, Yantarnaya 50 others	1970–1980
IV	Inna, Pamyati Fedina, Moskovskaya nizkostebelnaya others	1980–1995
V	Moskovskaya 39	1999
VI	Galina, Nemchinovskaya 24, Moskovskaya 56, Nemchinovskaya 57, Moskovskaya 40, Nemchinovskaya 17	2000–2017
VII	Nemchinovskaya 85, Moskovskaya 27	Transferred to the State Variety Test in 2018 and 2019

Table 2. Pedigree of winter wheat varieties

Variety	Year of zoning	Hybrid combination
Winter wheat varieties with the Inna variety in the pedigree ((Mironovskaya 808 × Krasnodarskiy Karlik 1) F_3 × Mironovskaya 808 F_3) × Mironovskaya 808 × Zarya);		
Nemchinovskaya 24	2006	Donschina × Inna
Moskovskaya 56	2008	(Mironovskaya poluintensivnaya × Inna) × Moskovskaya 39
Nemchinovskaya 17	2013	Nemchinovskaya 24 × Moskovskaya 39
Viola (in collaboration with the Ryazan Research Institute of Agriculture)	2013	(Mironovskaya 29 × Inna) × Inna
Winter wheat varieties with the Pamyati Fedina variety in the pedigree (obtained by the intermittent backcross method ((Krasnodarskiy Karlik 1 × Mironovskaya 808) F_3 × Zarya) F_3 × Yantarnaya 50 with subsequent individual selection)		
Galina	2005	(Obriy × Pamyati Fedina) F_3 × Inna
Nemchinovskaya 57	2009	(Donschina × Pamyati Fedina) × Moskovskaya 39
Nemchinovskaya 85	Transferred in 2018	Agapik × Pamyati Fedina
Moskovskaya 27	Transferred in 2019	Lutescens 982/08 × Pamyati Fedina

mittent backcrossing, resulting in varieties Inna, Pamyati Fedina, Moskovskaya 70, and Moskovskaya low-stemmed varieties, was created in the Laboratory of Winter Wheat Breeding of the Federal Research Center Nemchinovka under the leadership of Academician B.I. Sandukhadze. Their genotypes consistently combine winter hardiness, productivity, and short-stemming.

The unique variety Moskovskaya 39 (Obriy × Yantarnaya 50) of domestic breeding should be singled out separately [12–14]. The variety was zoned in 1999. Moskovskaya 39 belongs to the strong wheat-improvers. Variety Inna (zoned in 1991) was one of the parental forms of varieties Nemchinovskaya 24, Moskovskaya 56, Nemchinovskaya 17, and Viola. Pamyati Fedina variety (zoned in 1993) is included in the pedigree of Galina, Nemchinovskaya 57, Nemchinovskaya 85, and Moskovskaya 27 varieties (Table 2). Moskovskaya 39, Moskovskaya 40, Moskovskaya 56, Nemchinovskaya 57, and other varieties are especially popular with producers whose cultivated areas in the Non-Chernozen Region occupy more than 3 million hectares.

At present, it is important to create short-stemmed varieties with a consistently high productivity potential and a highly intensive technology of winter wheat cultivation [15, 16]. For this purpose, collection samples of geographically distant forms and local adapted varieties are used in crosses. Among the breeding varieties of the institute, Zarya, Inna, Pamyati Fedina, Yantarnaya 50, and Moskovskaya 56 varieties are used in crosses, more often as recurrent parents. Inna and Pamyati Fedina varieties deserve special attention as one of the most effective parental forms. Both varieties were obtained by intermittent backcrossing between Krasnodarskiy Karlik 1 and Mironovskaya 808.

MATERIALS AND METHODS

All studies were performed in 2015–2019 in the Laboratory of Breeding and Primary Seed Production of Winter Wheat and the Analytical Laboratory of the

Table 3. Results of competitive variety testing of winter wheat, 2015–2019

Variety	Year of zoning	Yield, t/ha	Height, cm	Number of spikelets/m^2/pcs.	1000-grain weight, g	Protein, %
Mironovskaya 808	1963	6.1* / 6.14–7.34**	111.0 / 107–117	518.4 / 380–772	48.7 / 40.8–55.9	15.0 / 14.0–16.9
Pamyati Fedina	1993	7.0 / 6.76–7.84	93.0 / 90–95	522.0 / 408–782	44.1 / 36.7–54.3	13.2 / 11.9– 13.8
Inna	1991	7.1 / 6.81–7.91	99.0 / 94–106.5	493.3 / 352–851	44.4 / 39.2–54.3	13.3 / 13.0–13.5
Average		7.05 / 6.14–7.84	96.0 / 90–106.5	507.5 / 352–851	44.2 / 36.7–54.3	13.25 / 11.9–13.8
Nemchinovskaya 85	Transferred to the State Variety Test in 2018	7.9 / 7.51–10.1	85.1 / 78.5–95	480.0 / 312–822	45.7 / 39.8–51.4	15.0 / 13.3–16.0
Moskovskaya 27	Transferred to the State Variety Test in 2019	7.7 / 7.32–8.89	92.6 / 84–96.5	604.3 / 328–1079	49.6 / 37–63.4	14.4 / 13.6–15.5
Average		7.8 / 7.32–10.1	88.9 / 78.5–96.5	542.2 / 312–1079	47.7 / 37–63.4	14.7 / 13.3–16.0
Moskovskaya 39-standard	1999	6.5 / 4.91–7.07	106.6 / 100–120	562.0 / 426–946	47.6 / 43.5–55.9	16.0 / 14.8–17.5
$LSD_{0.5}$		1.2	12.0	56.6	5.6	1.4

* Average value of the feature. ** Limits.

Breeding Center. Experiments were carried out in the fields of breeding crop rotation. The soil is sod-podzolic, loamy. The humus content is 2.1–2.5%, the pH of the salt extract in the 0–20 cm soil layer is 5.4, the hydrolytic acidity is 2.51 mmol/100 g of soil; content of P_2O_5 (according to Kirsanov) is 237 mg/kg of soil (according to Maslova), and content of K_2O is 134 mg/kg of soil. The thickness of the arable layer is 28 cm. Winter wheat in the experiment was cultivated according to the agricultural technology generally accepted for the zone. Pure fallow served as the predecessor of winter wheat. Mineral fertilizers were applied for cultivation at the rate of $N_{24}P_{60}K_{60}$ (diammophoska).

A comparative study of new varieties and varieties of some of the earlier stages of breeding was carried out according to the data of the competitive variety testing of varieties of the Federal Research Center Nemchinovka. The experiments were set up in accordance with the generally accepted methodology [17]. The structural analysis of the ear was carried out according to [18]. Mathematical processing of experimental data was carried out by methods of variance and correlation analysis using Microsoft Office Excel 2010. Mironovskaya 808, Inna, and Pamyati Fedina varieties, obtained using intermittent backcrossing; non-zoned Nemchinovskaya 85, Moskovskaya 27 and standard Moskovskaya 39; and hybrid generation F_5 Boema × Mera were studied in the breeding nursery to assess the results of breeding work. The earing date was noted and the height, 1000-grain weight, and protein content of the grain were measured.

The weather conditions of the studied years were characterized by a high contrast in air temperature, precipitation, and overwintering of winter crops. Large amounts of precipitation fell in 2016, 2017, and 2018. A good overwintering was noted in 2015 and 2018. Weather conditions of 2015 contributed to an exceptionally high harvest.

RESULTS AND DISCUSSION

According to the level of winter hardiness, the new varieties were at the level of the standard variety and favorably tolerated various weather conditions of the studied years in the conditions of the center of the Non-Chernozem Region. Inna and Pamyati Fedina varieties, obtained according to the scheme of intermittent backcrossing, surpassed the parental form Mironovskaya 808 by 0.95 t/ha in yield, and were significantly less in height by 15 cm ($LSD_{0.5} = 12$) (Table 3). The new generation of varieties in terms of yield significantly ($LSD_{0.5} = 1.2$) exceeded not only Mironovskaya 808 and Moskovskaya 39 standards but also the paternal form (Pamyat Fedina). Nemchinovskaya 85 and Moskovskaya 27 varieties were submitted for state variety testing in 2018 and 2019, respectively.

Table 4. Feature of the best lines of the F5 generation of the Boema × Mera hybrid combination (2019)

Line	Earring date	Height, cm	1000-grain weight, g	Content of protein in grain	Sown in 2020
Er100	04.06	55	50.7	15.4	CN
Er101	04.06	55	49.2	18.6	CN
Er 102	05.06	55	51.2	15.7	CN, BN
Er111	04.06	75	**62.0**	16.8	CN
Er113	05.06	70	48.4	15.9	CN
Average	–	62	53.0	16.5	–
Krasnodarskiy Karlik 1	10.06	60	32.6	15.1	–
Moskovskaya 39-standard	11.06	101	48.9	15.3	–
LSD_{05}		8.0	5.3	1.0	–

The Nemchinovskaya 85 variety was obtained by individual selection from a hybrid combination Agapik (Italy) × Pamyati Fedina. The average yield over the years of the study was 7.9 t/ha (maximum yield was 10.1 t/ha). It had a significant excess of the standard by 1.4 t/ha. The plant height reached 85.1 cm, which is 21.5 cm significantly lower than the height of the standard variety. It has a high protein content in grain (15%) and a high content of gluten in flour (30.8%). In 2019, the yield of the variety in ecological variety testing (Dubovitskoe, Oryol region) was 9.45 t/ha.

Moskovskaya 27 variety was obtained by individual selection from the hybrid combination Lutescens 982/08 × Pamyati Fedina. The average yield was 7.7 t/ha (the maximum yield was 8.89 t/ha) and plant height was 92.6 cm. In terms of the elements of the yield structure, the variety had maximum values among the studied accessions: the number of ears per 1 m^2 was 604.3 pcs., the 1000-grain weight was 49.6 g; the protein content in the grain was 14.4%.

Nemchinovskaya 85 and Moskovskaya 27 significantly exceeded the standard Moskovskaya 39 by 1.3 t/ha and Mironovskaya 808 by 1.7 t/ha. In terms of plant height (as a result of selection), new varieties were consistently shorter than the standard (by 17.7 cm) and shorter than the Mironovskaya 808 variety (by 22.1 cm). During the years of research, no lodging was noted in new varieties. At the same time, the varieties transferred for variety testing turned out to be at the level of Mironovskaya 808 in terms of grain quality and were not inferior to the standard Moskovskaya 39 variety. No significant differences ($LSD_{0.5}$ = 1.4) were found. According to the data of variety testing, new varieties, with an increase in yield and a decrease in plant height, retain good grain quality in comparison not only with the Mironovskaya 808 variety but also with the standard Moskovskaya 39.

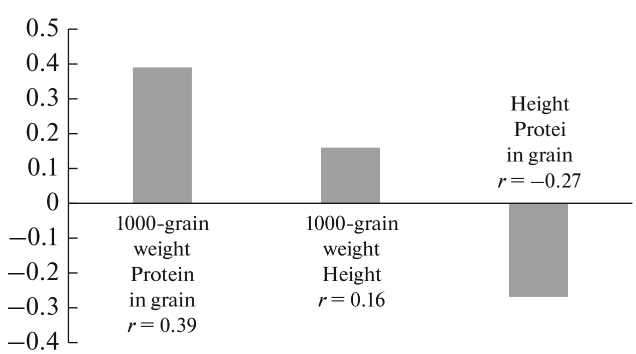

Fig. 1. Correlation coefficient (*r*) between plant height, 1000 grain weight, and grain protein content.

More modern breeding material is now studied in the nurseries of the Laboratory of Winter Wheat (Table 4). The early maturing lines of the F_5 generation of the Boema × Mera hybrid combination are particularly noteworthy. Heading occurs a week earlier than in the Moskovskaya 39 standard. The best lines have an average plant height of 62 cm (reliably lower than the standard variety by 39 cm, $LSD_{0.5}$ = 8.0). The average 1000-grain weight along the lines is 53 g (a significant excess over the Krasnodarskiy Karlik 1), and up to 62 g for the Er111 line (a significant excess over the Moskovskaya 39 standard). These lines have exceptional grain quality and a significant excess over the standard for the amount of protein in the grain (1.2 and 3.3% for the Er101 line (protein content is 18.6%)). There is an average positive correlation between the 1000-grain weight and protein content in the grain (r = 0.39) (Fig. 1). Comparing the height, coarse-grain, and grain quality of studied lines with the short-stemmed donor Krasnodarskiy Karlik 1, we can talk about overcoming the known positive correlation between plant height and 1000-grain weight (r = 0.16). The best lines were seeded in breeding and control nurseries for further studying.

CONCLUSIONS

Thus, the value of the Inna and Pamyati Fedina varieties as effective parental forms is shown. Short-stemmed Nemchinovskaya 85 and Moskovskaya 27 varieties, which are under State variety testing, have a high yield (over 10 t/ha) in combination with valuable baking properties. The breeding material created in the Laboratory of Winter Wheat Breeding is unique. For the first time in the Non-Chernozem Region, a combination of short-stemming (62 cm), coarse grain (53 g), and high protein content in grain (16.5%) was achieved in one genotype. These data indicate the possibility of further increases in productivity, grain quality, and other economically valuable traits in new varieties of winter wheat.

COMPLIANCE WITH ETHICAL STANDARDS

The authors declare that they have no conflict of interest. This article does not contain any studies involving animals or human participants performed by any of the authors.

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