Development of new forms of spring and winter wheat with the involvement of the gene pool of wheatgrass and soybean and confirmation of the applicability of these methods in practical breeding

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Abstract: A technology has been developed for obtaining new forms of hybrid wheat by the method of remote hybridization with wheatgrass androgenic plants and an original leaf-nurse method. As the result of the application of this technology, 68 variety samples of hybrid winter wheat were obtained and brought to competitive tests. 30 promising genotypes exceeding in their characteristics the standard variety 'Novosibirskaya-40' were identified. 425 spring wheat-wheatgrass F_4 hybrids were obtained. 129 best varieties were selected and tested.

Key words: spring and winter breed wheat; wheatgrass; remote hybridization; leaf nurse.

1. Introduction

Producing commercial cultivars with significantly altered properties has always been the cherished desire of plant breeders. With intraspecific hybridization, significant changes are not achieved. Remote hybridization, genetic engineering methods, vaccinations, various types of mutagenesis, etc. are used to achieve this goal. Each of these methods has its advantages and disadvantages. Breeders widely use the method of remote hybridization of existing wheat cultivars with its wild relatives, in particular, with different species of wheatgrass to increase biodiversity and improve the quality of wheat. Wheatgrass has the following valuable characteristics: winter hardiness, salt and drought resistance, high content of protein and gluten in grains, strong root system, resistance to diseases, etc. (Tsitsin, 1981). It is desirable to transfer all these characteristics to the cultivated cereals. Work with wheatgrass has been going on for over 45 years in the Institute of Cytology and Genetics of the Siberian Branch of the RAS. The source material for the production of wheat-wheatgrass hybrids (WWHs) was the collection of seeds of wheatgrass *Agropyron glaucum* (syn. *Elytrigia intermedium*) collected in 1971 in East Kazakhstan in a wild-growing population, growing on a high and a low snow place. Such harsh growing conditions of wheatgrass plants caused, first of all, the presence of high frost resistance. Since 1985, we have been working on the creation of androgenic wheatgrass lines using the method of androgenesis *in vitro* and using these lines as donors of valuable traits for obtaining new forms of hybrid wheat. Using the haploid technology, we have created a collection of androgenic haploids, seed generation of doubled haploids as well as parental plants of wheatgrass, possessing high-quality androgenic characteristics and a number of other valuable features, among which the main ones can be distinguished: high cross-breeding with wheat and cold resistance (Razmakhnin, 2017). This made it possible to use – with high efficiency – the obtained lines in further work on the transfer of valuable traits from wheatgrass to wheat using the method of remote hybridization and an original method of leaf nurse (Razmakhnin et al., 2012).

2. Materials and methods

The main methods that we used for creation of new forms of wheat were intraspecific and interspecific hybridization and the method of leaf nurse (LN-mehod) (Razmakhnin et al., 2015). The winter wheat 'Filativka' and androgenic clones of wheatgrass were used for the development of WWHs. The winter wheat 'Bagrationovka' and leaves of soybean and frost-resistant plants of wheatgrass were used for the development of LN-lines by the method of leaf nurse. Evaluation of frost resistance of wheatgrass and wheat plants was carried out by the laboratory express method (Razmakhnin et al., 2009). To reduce the height of the wheat lines developed and to improve their grain quality, we carried out their reciprocal crossing with the short-stem winter wheat variety 'Lars'. Spring forms of WWHs were obtained by backcrossing the WWHs obtained to spring introgression lines of wheat resistant to brown rust. The best spring WWH genotypes were crossed among themselves and with the spring wheat varieties 'Novosibirskaya-31' and 'Omskaya-37'. The selection process took place in the field and in the greenhouse.

3. Results and discussion

3.1 The results of the research on the creation of new genotypes of winter wheat using wheatgrass and soybean as a donor of valuable traits

In 2017, we carried out at competitive test of 68 promising genotypes of WWHs and LN-lines. Most of the genotypes had higher rates of productivity and quality of grain than the standard variety 'Novosibirskaya-40'. Table 1 shows the results of the competitive test of 2017-2018 of the best varieties of WWHs and LN-lines. It is important to note that the root

Table 1
Comparative assessment of winter breed wheat lines of the 2017–2018 competition test

Cultivar, line	Winter hardiness, %	Plant height, cm	1000 kernel-weight, g	Nature, g/l	Glassy, %	Gluten, %	Power of flour, e.a.	Bread volume, cm^3/100 g	Overall baking assessment	Yield, t/ha	
										average	+/– to st
Novosibir-skaya-40	63.5	109	37.3	790	50	37	228	680	4.1	5.29	st
LN 7b	59.7	120	44.7	798	52	33.8	417	620	3.9	6.19	+0.9
WWH × Lars 2	65.7	118	44.7	802	60	34.4	269	740	4.1	5.90	+0.61
WWH 45c	61.0	130	43.1	792	55	32.8	302	600	4.1	5.98	+0.69
WWH 53	61.2	123	41.5	784	57	33.3	268	640	4.6	6.02	+0.72
DS 2	59.2	118	48.3	800	55	30.8	332	620	4.5	6.52	+1.22
WWH × Lars 9	64.2	121	39.1	774	52	27.9	193	720	4.4	6.56	+1.27
WWH × Lars 19	66.0	126	43.6	800	57	25.8	258	600	4.3	7.04	+1.75
WWH × Lars 18	60.5	96	37.9	768	54	23	205	600	4.4	6.29	+1.0
LN 20	61.7	117	47.2	800	54	29.9	277	560	4.0	6.01	+0.71
WWH × Lars 12	66.0	116	43.7	794	57	29.6	355	640	4.4	6.24	+0.95
WWH 48a	60.5	126	45.9	780	57	32.2	269	600	4.0	5.97	+0.68
WWH 48b	61.7	126	49.4	792	65	34.0	294	640	4.2	6.19	+0.90
WWH × Lars 11	63.7	116	47.6	786	66	31.2	292	800	4.6	5.82	+0.53
WWH × Lars 7	62.5	120	44.5	778	60	33.7	264	580	3.8	6.22	+0.93
WWH × Lars 15	62.5	117	44.5	770	69	31.6	318	560	4.0	5.78	+0.49
WWH × Lars 20	62.0	107	44	774	64	31.6	216	600	4.3	5.39	+0.1
LN ZS × soybean 1	61.5	110	47.8	782	64	33.0	284	700	4.4	5.7	+0.45
LN DS × soybean 2	61.7	113	48.3	780	64	33.0	336	600	4.2	5.5	+0.3

Table 2
The average weight of roots of winter bread wheat

Cultivar, lines	Novosibirskaya-40 st	WWH × Lars 11	WWH × Lars 12	WWH × Lars 19	LN ZS × soybean	LN DS × soybean	LN WWH 20× soybean
weight of roots, g	0.49	0.88	1.38	1.43	1.0	0.93	1.2
% of standard (st)	100	180	282	291	201	190	244

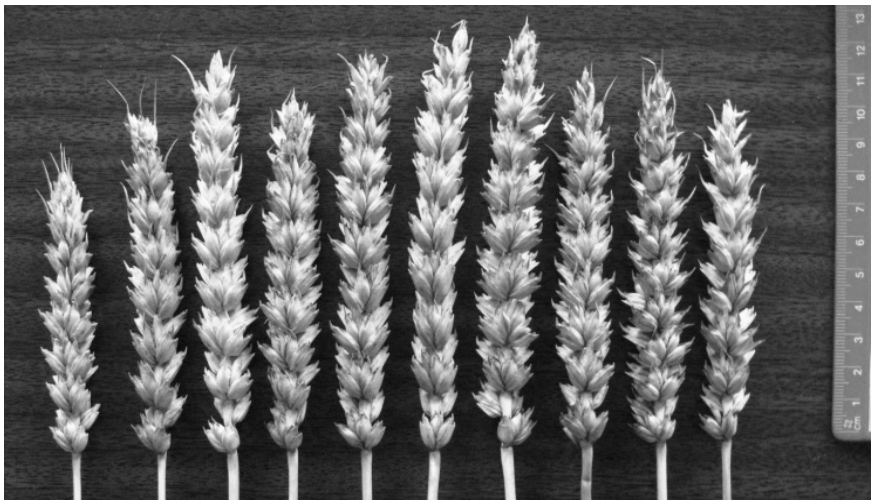

Figure 1. Spikes of the winter wheat 'Novosibirskaya-40' and lines of new forms of winter wheat.

Figure 2. Field competition test of developed WWHs and LN-lines.

Figure 3. Spikes of the spring wheat 'Omskaya-37', 'Novosibirskaya-31' and developed lines of new forms of spring wheat.

system of the genotypes was significantly more developed (Table 2). This trait was clearly transmitted from wheatgrass, which has a powerful root system.

Figure 1 shows spikes of the winter wheat 'Novosibirskaya-40' and developed lines of new forms of winter wheat. Figure 2 shows the field competition test of the developed WWHs and LN-lines in 2018.

The results of the research on the creation of new genotypes of spring wheat using wheatgrass and soybean as donors of valuable traits

In 2017, 17 genotypes of spring WWHs and LN-lines out of 32 obtained in 2016 were tested. The spring wheat varieties 'Novosibirskaya-31' and 'Omskaya-37' were taken as standards. Productivity and 1000-kernel weight of the majority of the samples studied exceeded grades-standards. In order to expand the genetic diversity and improve the quality of grain, the best samples were crossed with each other and with two varieties of spring wheat, 'Novosibirskaya-31' and 'Omskaya-37'. As a result, 2563 grains of 91 reciprocal hybrids were developed. Selection, reproduction and structural analysis of these variants were carried out during the two vegetation periods of 2017–2018 in the greenhouse. Figure 3 shows spikes of the spring wheat varieties 'Omskaya-37', 'Novosibirskaya-31' and lines of new forms of spring wheat. In 2019, 5762 grains of 425 genotype variants were obtained. From these variants, 129 best genotypes were choose for breeding.

4. Conclusion

The results obtained prove the great prospects for the application of the method of remote hybridization and the method of leaf nurse to create new forms of hybrid wheat with the use of wheatgrass and soybean as donors of valuable traits. The created collection of androgenic plants of wheatgrass can serve as a good base for further breeding and genetic research.

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Conflict of interest. The authors declare no conflict of interest.