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ITEMS FROM THE RUSSIAN FEDERATION

AGRICULTURAL RESEARCH INSTITUTE OF THE CENTRAL REGION OF NON-CHENOZEM ZONE
143026, Moscow region, Nemchinovka, Kalinina 1, Russian Federation.

Amphimixis in soft wheat and apomixis in rye after mutual pollination of flowers.

V.G. Kyzlasov.

Pseudogamy of metasperms is a type of apomixis where the ovocyte of the fetal sac in the pistil grows parthenogenetically, and the endosperm originates from the fertilized central cell (Shishinskaya 2005). Kandelaki (1970) managed to induce pseudogamy in soft wheat by means of pollinating the flowers with pollen from other species. Apomictic development of soft wheat seed does not occur in practice. In experiments previously conducted by Kyzlasov (2005), matromorphic development of the germ was discovered in soft wheat, rye, and triticale after pollination with pollen from related species. The percentage of seeds formed in these experiments varied from 6.9% to 7.9% of the total number of pollinated flowers. R-1 winter rye, Nemchinovskaya 24 winter wheat, and Victor triticale were used as the initial material in these experiments. The technology for obtaining matromorphic plants has found practical application in creating lines of Nemchinovskaya 24, a SWWW with consistent stem length (Kyzlasov 2007). Initially, for unknown reasons, this cultivar always segregates for stem length. However, matromorphic families of this wheat obtained after pollinating with pollen from R-1 winter rye were found to have similar stem length.

Table 1. Productivity indices of the spike and percentage of seed set for parental lines and their crosses.

Parent lines and crosses	Number of polllinated flowers/ spike	Number of grain/ spike	% seed set (mg)	Caryopsis weight (g)	Spike productivity
A-1 spring wheat	39	37	95	31	1.16
R-2 spring rye	28	26	93	31	0.80
F_0 A-1 / R-2	36	22	61	10	0.21
F_0 R-2 / A-1	24	21	88	27	0.58

The soft spring wheat line A-1 and R-2 spring rye were used for crosses (Table 1). R-2 spring rye was created by hybridizing R-1 winter rye and spring rye. A-1 spring wheat was pollinated with R-2 spring rye and R-2 spring rye was pollinated with A-1 spring wheat in the field. We observed that the percent seed set was extraordinarily high. The percentage for the 'A-1/R-2' combination was 61%, whereas that for the 'R-2/A-1' cross was 88%. For the 'A-1/R-2' combination, F_0 caryopses were small (10 mg), the germ was missing in the majority of the caryopses and, thus, seed germination was low. Slow sprouting of seed was observed after sowing. Productivity also was low (0.21 g). The influence of pollinating R-1 rye with A-1 soft wheat on the size of the caryopses formed and the productivity of the spike was insignificant.

For the 'A-1/R-2' hybridization combination, all 153 grown plants were common hybrids of wheat and rye. Examination of F_1 obtained in the greenhouse after self-pollination showed numerous flowers in the spike (Table 2, p. 108), but a very low seed set because of the lack of pollen. More than 100 caryopses similar to triticale were obtained without paternal pollination. All of these caryopses are distinguished from other wheat and rye cultivars by their large grain size (44 mg). We are interested in tracing the inheritance of the features of productivity and ability for matromor-

Table 2. Productivity indices of the spike and percentage of seed set for self-pollinated parental lines and their crosses.

Parent lines and crosses	Number of polllinated flowers/ spike	Number of grain/ spike	% seed set (mg)	Caryopsis weight (g)	Spike productivity
A-1 spring wheat	39	36	92	25	0.90
R-2 spring rye	40	4	10	15	0.06
F_1 A-1 / R-2	100	1	1	44	0.04
F_1 R-2 / A-1	37	7	19	20	0.14

phic development in the lines of these caryopses. For all the other F_1 wheat/rye hybridization combinations, no caryopses formed.

For the 'R-2 rye/A-1 wheat' hybrids, all 127 F_1 plants were completely identical to the maternal R-2 rye. No significant inbreeding depression was observed in these plants. Seed set after self-pollination was 19%, almost twice that of R-2 rye. Caryopsis size and productivity of the spike in these slightly surpassed R-2 rye. The absence of wheat protein fractions in the endosperm of the F_0 'R-2 / A-1' caryopses means that the obtained plants were true apomicts. Pseudogamy is not present in this case. Meister and Tyumyakov (1926) were the first in Russia to report matromorphic development of rye caryopses after pollination with wheat pollen.

While creating the A-1 soft spring wheat cultivar, seed formation without participation of the paternal parent was discovered. Initially, the flowers of soft wheat with light-colored grains and polygynous flowers were pollinated with plants with dark-colored grains and xenia-colored caryopses. Creation of the line with polygynous flowers and dark-colored grains with xenia-colored caryopses has been described in previously (Kyzlasov 1991, 2001). All hybrid F_0 grains of 'light-grained wheat/dark-grained wheat' grown as with the maternal plants with light-colored grains were found to have dark-colored grains and xenia color. For 441 F_1 plants, segregation by caryopsis color within separate spikes was observed (9 pigmented caryopses : 7 colorless caryopses). At the same time, in nine F_1 plants, all the caryopses were colorless. They were completely similar to the maternal line. No plants with polygynous flowers were discovered. The formation of seed with light-colored grains similar to the maternal line among the F_1 plants after crossing light-colored grains with dark-colored grains was a surprise. The pigmentation of the aleuron layer, which appeared in hybrid F_0 caryopses did not disappear. Perhaps these plants appeared as a result of pseudogamy.

In the next generation, seeds of each of nine F_1 plants with light-colored grain were sown separately. Stamens were removed from 108 spikes during the spike formation. Approximately 5,400 flowers were sterilized. No grain formed in unpollinated flowers of eight families. In one family, 22 caryopses appeared in six spikes without any paternal parent pollen (Table 3). The letter 'A' in Table 3 denotes apomictic development of caryopses in three generations. On average, 3.7 caryopses/spike formed in the A_1. Two spikes had nine caryopses/spike, and four spikes had one caryopsis/spike. The caryopses were very small, light-colored, with an average weight of one caryopsis equal to 7 mg.

Table 3. Apomictic development of caryopses in unpollinated flowers of soft wheat.

Apomictic generation	Number of sterilized flowers	Number of formed caryopses		
		Total	Per spike	% seed set
A_1	300	22	3.7	7.3
A_2	350	35	5.0	10.0
A_3	400	52	6.5	13.0

Twenty-two A_2 caryopses formed in the A_1 plants without participation of paternal parent were sown. Nine plants sprouted and formed spikes. Stamens were removed from 350 flowers in these plants, and 35 caryopses appeared in the flowers without pollination. On average, five caryopses/spike formed without pollination. The percent seed set, compared with the number of sterilized flowers, was 10%. Seeds in plants of the A_2 apomictic generation after self-pollination were found to be substantially larger than those in unpollinated flowers. The weight of one caryopsis for self-pollinated plants was 28.0 ± 3.6 mg and, for apomictic seed, almost three times less (11.6 ± 2.1 mg). Formation of apomictic caryopses in sterilized flowers took 5 to 8 days longer compared with those from self-pollination in the same plants. In the apomictic A_3 generation, stamens were removed from 400 flowers and 52 caryopses were set in unpollinated flowers. An average of 6.5 caryopses/spike formed. The percent seed set, compared to the number of sterilized flowers, was 13%. Many other spikes where no grains were formed after removal of stamen were not taken into consideration in this calculation.

Line A-1 was selected in an F_3 hybrid population (wheat with light-colored grains and polygynous flowers/ wheat with dark-colored grains and xenia-colored caryopses) is similar to common wheat cultivars with regard to morphological features. Erythrospermum has an aristate, white spike and red grain. Stems of the plants are thin and long (100–120 cm). The spike contains 18–20 spikelets and the grains are small (1,000-kernel weight < 30 g). Under favorable cultivation, up to 80 caryopses/spike form; the fertility of flowers is high. Glumes of the spike are gentle and thin. The plants tiller intensely and produce many stems. The stems show tendency to branch. The tillering period is longer than for other wheat cultivars. The source maternal line with polygynous flowers has a high shade tolerance. When cultivated under low-light conditions in the greenhouse in the winter, substantially more caryopses in the spikes are formed than in the standard cultivars. Due to this advantage over other lines, erythrospermum was selected for hybridization, and the A-1 line was selected among the offspring. In some sister lines of A-1 (Table 3), the seeds are formed without pollination. Under usual conditions, these lines reproduce by way of gamogenesis. Pollen of the A-1 line can induce large-scale apomictic development of caryopses in R-2 rye.

Until now, no wheat with apomictic type reproduction is known in the world collection and no one managed to create such a cultivar artificially. Among wheats, apomixis occurs *Ag. scabrum* (Hair 1956). This species can hybridize with wheat and the resulting hybrids are fertile. During our research, the occurrence of apomictic lines of soft wheat having haploid (n = 21) chromosome number and germ-less seeds was observed. The formation of such plants also has been observed in case of pollinating wheat flowers with wild species such as *Ag. glaucum* and *Ae. speltoides*. The search for apomicts has taken a very long time, however with no positive results. We have found a line of soft spring wheat that can be satisfactorily hybridized with the diploid (2n = 14) species *T. sinskajae* (Kyzlasov 1997). The existing diploid species of wheat can hybridize with hexaploid species with great difficulty. A soft wheat has been created in which the flower stamens transform into pistils (Kyzlasov 1998). A hexaploid line has been selected having three stamens and from two to five pistils formed in each normally developed flower (Kyzlasov 1996). The number of caryopses formed in polygynous flowers corresponds to the number of pollinated pistils. Kyzlasov (2006) discovered that the additional pistils in the flowers of soft wheat are formed from lodicules. From two to four lodicules-pistils are formed in the flowers of this wheat and up to five caryopses formed in a flower. Apomictic development of soft wheat seed has been induced by pollinating wheat with rye (Kyzlasov 2005).

More than 17 species of Gramineous plants have the capability of apomictic reproduction. The gametophytic type of apomixis was discovered in the family of Gramineous plants (Khokhlov 1970). The germ may develop from the cells of the archesporium, nucellus, unfertilized ovule, synergid, or antipode. According to Kandelaki (1970), the occurrence of apomictic plants may be linked with diploidization of ovule nucleus. The mechanism of embryogeny in unpollinated flowers of apomictic soft wheats is still unknown. The genetic structure of the caryopses apomictic development is also unclear. Some features of organisms are known to appear as a result of gene interaction. If such genes are localized in nonhomologous chromosomes, the feature is inherited stably by double or triple homozygotes, for example, the xenia color of wheat caryopses, absence of stamens in the flowers, or polygynous flowers (Kyzlasov 2005). If such genes are allelic or if they are localized in homologous chromosomes, obtaining homozygous lines is not possible. Preserving such features by inbreeding also is impossible. This fact was discovered while investigating caryopsis apomictic development of the described soft wheat cultivars. All lines that appeared without participation of a paternal parent did not inherit this feature (Table 3). For this reason, an obligate soft wheat apomict could not be created. The main element of detecting apomicts in plant populations is the selection of matromorphic breeds. Apomictic wheat plants described here were discovered as the result of formation of seeds of maternal type in unpollinated flowers and xenia-colored caryopses served as an indicating attribute for identifying these plants.

In summary, a high percentage of hybrid F_0 caryopses was detected after hybridizing A-1 soft spring wheat with R-2 spring rye. Numerous, apomictic rye caryopses were formed as a result of pollinating flowers of R-2 rye with A-1 soft wheat. Protein fractions of wheat are absent in the endosperm of such caryopses. Matromorphic breeds of the F_1 hybrid (wheat with polygynous flowers/wheat with xenia-colored caryopses) obtained without pollination do not inherit this feature. The investigation of large-grained, F_1 hybrids (A-1 wheat/R-2 rye) obtained without participation of paternal parent are continuing.

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AGRICULTURAL RESEARCH INSTITUTE FOR THE SOUTH-EAST REGIONS
Department of Genetics, 7 Toulaikov St., Saratov, 410010, Russian Federation.

Laboratory of Winter Bread Wheat Breeding: New winter wheat cultivar Zhemchuzhina Povolzhjya.

A.I. Pryanichnicov, S.V. Lyascheva, A.D. Zavorotina, V.V. Uvarova, Yu.P. Batischev, N.Yu. Larionova, and A.I. Sergeeva.

Winter wheat is a priority for grain production in the Saratov Region of the Russian Federation. Since the mid-1990s, a number of the Saratov winter wheat cultivars were established, including Saratovskaya 90, Victoria 95, and Gubernia. These cultivars are high-yielding with adaptability to the steppe conditions of the region. In addition, the cultivars have a wide range of individual characteristics that allow them to compete in the climatic conditions of Volga region.

To further enhance the yield of winter wheat, we have released the cultivar **Zhemchuzhina Povolzhjya**, which has a higher yield potential compared with the existing popular cultivars. The description of this new cultivar is presented in Table 1. According to winter hardiness, this cultivar belongs to the Saratovskaya 90 group, which is the most resistant to stable cold temperatures. Zhemchuzhina Povolzhjya also is resistant to leaf rust and has high grain quality.

Table 1. Grain yield, 1,000-kernel weight, test weight, protein content, and SDS-sedimentation test of winter wheat in the ecological test. All data is the mean from plants grown at Saratov in 2000–07.

Cultivar	Yield (t/ha)	1,000-kernel weight (g)	Test weight (g/l)	Protein content (%)	SDS sedimentation (mm)
Mironovskaya 808 (check)	3.47	43.0	753	13.88	53
Donskaya bezostaya (check)	2.72	39.6	746	15.58	67
Saratovskaya 90	3.35	43.7	747	14.42	59
Victoria 95	3.42	41.9	738	14.68	50