

ITEMS FROM THE RUSSIAN FEDERATION

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

V.G. Kyzlasov.

Zea mays L. ssp. *mays* and *Tripsacum dactyloides* L. hybrids are known among the cultivated cereals for regular apomixis (Sokolov et al. 2007). Hybrid lines of *Z. mays* with nine additional *Tr. dactyloides* chromosomes reproduce by apomixis. Nine is the minimum number of *Tr. dactyloides* chromosomes required for apomixis in the phenotype. The apomict was patented in the U.S. No other examples of apomictic reproduction among the cultivated cereals have been described in the literature. A high seed-set rate of plump seeds was discovered during experiments on the fertilization of an R-2 diploid spring rye with pollen of a A-1 soft spring wheat (Kyzlasov 2008). All offspring were found to be diploid ($2n = 14$) rye plants. The $2n = 42$ pollen of soft wheat induced apomixis in rye. Because of this fact, diploid rye can be reproduced by fertilization with soft wheat pollen. Polyhaploid offspring with partially fertile pollen arose in the reciprocal combination (wheat/rye, $2n = 28$).

After long-term research, we have succeeded in creating an apomict of winter rye. The parent plant, R-1 rye, was found in a soft winter wheat crop as a species admixture (Kyzlasov 2005). Flowers were fertilized by the pollen of Nemchinovskaya 24 soft winter wheat. Seed set rate was ~20% of the number of fertilized flowers in the fertilization year. The formed caryopses were all plump and had a high germination rate. All offspring in the first generation contained fertile pollen, and they were completely identical with the diploid maternal plant. There were no hybrid plants. After refertilizing the maternal plants with soft wheat pollen, the offspring also was identical to the maternal plant. The results of the previous experiment have been repeated. The apomixis induced by soft wheat pollen in R-1 rye was manifested in both first and second generations. The maternal offspring varied in quantitative characteristics (stem length, spike productivity). The R-1 rye plant was heterozygous. This population was reproduced on an isolated plot under wind pollination. Apomictic embryo development in the flowers of soft wheat and triticale induced by R-1 winter rye pollen was known from previous experiments (Kyzlasov 2005, 2007). The technique for creating plants showing no segregation in the offspring has a practical application in breeding in the creation of lines of Nemchinovskaya 24 soft winter wheat with similar stem lengths. Initially, this cultivar was segregating for stem length for some obscure reasons. However, maternal families of Nemchinovskaya 24 obtained after fertilization with R-1 winter rye pollen were similar for stem length.

Plants with sterile pollen and abortive anthers were found in the next generation within the studied rye population offspring. Plants with sterile pollen showed involution in the development of quantitative characters; approximately 6% of the total number of plants in the population. Abortive anthers were removed to eliminate the possibility of self-pollination and emasculated spikes covered with paper cages. Isolated caryopses were formed in unpollinated flowers without the participation of a paternal parent. The caryopses from the paper cages without pollination were sown in a glass house and their offspring produced no seeds unless pollinated with a paternal plant. Their pollen was sterile. Plants with fertile pollen were allowed to wind pollinate on an isolated plot with the pollen of their own population. The derived seeds were sown in the field. Approximately 25% of offspring had sterile pollen at anthesis. Plants with fertile pollen and plants with sterile pollen were grown in wheat crops free from wind pollination. Seeds from the plants with sterile pollen were used for further research. Making genetic analysis of self-sterile plants with wind pollination presents great difficulties.

Seeds taken from plants without pollen were sown in the field. Among the derived offspring, approximately 67% formed normal pollen and 33% formed sterile pollen. At the beginning of anthesis, plants with fertile pollen were removed. The plants with sterile pollen were reproduced in a winter wheat crop. However, the fact that rye pollen brought in by wind from remote parts of the field on to pistils of the flowers with sterile pollen could not be absolutely excluded. Mean seed set of the plants without pollen under free wind pollination was 55.4%. The number of flowers in

a spike was 60.9, grains/spike was 33.8, 1,000-kernel weight was 28.9, and spike productivity was 0.98. The indices of the five best plants are presented in Table 1.

Table 1. Seed set and the development of spike productivity features of rye plants with sterile pollen under free wind pollination in a wheat crop.

Plant number	Seed set (%)	Flowers/spike	Grains/spike	1,000-kernel weight (g)	Spike productivity (g)
1	75.7	75.6	57.2	29.2	1.67
2	73.0	63.8	46.6	29.9	1.39
3	72.7	60.0	43.6	37.4	1.63
4	72.5	76.4	55.4	28.2	1.56
5	70.6	52.4	37.0	30.0	1.11

From the maternal plants of the previous generation with sterile pollen, 279 rye offspring were reproduced. The spikes of every plant were covered with paper cages before the beginning of flowering. One hundred eighty-eight plants produced normal pollen under the paper cages. Most likely, these plants were produced as a result of cross pollination of male-sterile flowers by rye pollen in the previous generation. Under self pollination, an average of 182 plants with fertile pollen produced one caryopsis/spike. The autosterility genes of these plants worked normally. Another six self-pollinated plants had from 32 to 65 caryopses/spike. These were self-fertile plants. Pollen fertility is a dominant feature. The distinctive feature of the 58 plants with sterile pollen was the ability to set seed without pollination under the paper cages. The other 33 plants with sterile pollen did not set seed under the paper cages. Small, nonviable germination of plants in the shape of a lamina rosette were produced instead of pistils within one such offspring. Apomictic reproduction and sterile pollen were inherited by the rye offspring as linked features. The distribution of rye plants with sterile pollen in the various series by seed-set rate under paper cages is given in Table 2. On average, 12.2 caryopses were produced per spike within the best group of plants. The ratio of produced seeds to flowers/spike was 18.4%.

Table 2. Distribution of rye plants in various series by the number of caryopses produced/spike.

Grain number class	No of families studied	Grains/spike	Flowers/spike	Seed set
0	33	0.0	60	0.0
< 1-3	36	0.7	58	1.2
> 3	22	11.2	61	18.4

Table 3. Rate of seed set and development of spike productivity features of apomictic rye plants under paper cages without pollination.

Plant number	Seed set (%)	Flowers/spike	Grains/spike	1,000-kernel weight (g)	Spike productivity (g)
1	82	73	60.3	22.9	1.38
2	37	70	27.3	26.5	0.72
3	34	67	23.0	17.2	0.40
4	29	64	18.4	32.0	0.59
5	25	68	16.7	33.3	0.56
6	19	65	12.4	27.8	0.34
7	22	60	13.4	25.0	0.33
8	18	56	10.1	14.6	0.15

Productivity rates of the eight best apomictic plants are presented in Table 3. High variation was discovered in the manifestation of all features excluding 1,000-grain weight.

Pistils

of the apomictic rye produced develop with normal germinating ability. Hybrid F₁ plants, produced after pollination of paternally sterile flowers by pollen from other plants, produce fertile pollen, indicating that the fetal sac cells in the rye are reduced. Diploid plants produced without a paternal parent inherit the sterile pollen feature, which is recessive. Apomictic plants with sterile pollen can be reproduced without pollination on isolated plots. They can be used for production of heterosis plants and genotypes, which are resistible to some pathogens. The production and identification of such offspring in allogamous species are complicated. Tetraploid apomicts can be produced by duplication of the chromosome set. High seed set is possible in the produced tetraploids. At the same time, they will be unable to cross with the source diploid rye. The ability of rye for apomictic reproduction may be transferred to other cultivated cereals species using genetic engineering techniques. Haploids are not seen among plants with both sterile and fertile pollen. The phenomenon of polyembryony was noticed in the apomictic offspring. Up to five viable germs are formed in a caryopsis without pollination.

The study of apomictic offspring was continued under glasshouse conditions. From an unknown cause, anthers with pollen formed in approximately a half of the studied offspring under insufficient light conditions, a surprising fact. However, almost all the pollen in these anthers was nonviable. Up to 12 caryopses were set in unpollinated flowers of each spike. Analysis of the genetic organization of the described rye apomixis is hampered by the fact that autosterility genes are manifested in the phenotype. The mechanism of embryogenesis also remains unknown. Perhaps, the endosperm of apomictic rye is diploid. Starch grains in apomictic rye endosperm are smaller to those in the endosperm of amphimixis plants. The aleurone layer is thinner than in amphimixis plants and is missing in some. The caryopsis coat is contiguous with the starchy endosperm in these irregular places. Apomictic endosperm and embryo are not produced in every flower. Seed set under paper cages varies from 0 to 82% of the number of flowers in the spike. Sometimes endosperm or embryo remains abortive. When there is no budlet in the embryo, a scutellum will normally develop. If there is no embryo, but there is an endosperm in a caryopsis, the micropyle will be occluded thoroughly. As a result of the proliferation of external seed coat cells, a tightly closed protuberance in the shape of denticle or papilla, called a caruncle, is formed around the micropyle. The micropyle of apomictic plants, as a rule is, occluded (Shishkinskaya 2005). In nearly all ripe, apomictic caryopses, the micropyle cavity and space between the embryo bottom and caryopsis coat is filled with a pink, vitreous substance. This pigment is not usually present in amphimictic rye. Amphimictic rye, unlike normal rye, has very thin floral glumes, especially the inner glumes.

Diploidy of apomictic rye offspring produced without a paternal parent indicates that they can develop from unreduced cells of the fetal sac or nucellus, such as in *Poa bulbosa* (Kordum 1970). There is no digenesis in these cases. Offspring completely identical to the maternal parent are produced. The nature of origin of adventive fetal sacs from the nucellus cells is similar to the origin of the budlet in the sporophyte phase. In apomictic plants, haploid cells of the fetal sac can give birth to a diploid embryo as a result of chromosome endoduplication (Maheshwari 1954). Apomictic rye plants have a prolonged period from the beginning of stem formation until anthesis. Perhaps that is why the pyles of the stigma and flower lodicules are overgrown. Kyzlasov (2006) discovered earlier that in rye with polygynous flowers, lodicules are converted into pistils. With no pollination, the life of the pistil in apomictic rye plants was 10–15 days longer; with no pollination, the stigmas die earlier than the ovaries.

In apomictic caryopses, the seed coat and endosperm are wrinkled. The seed coat hangs down from the endosperm. A translucent bubble of fetal integument forms at the bottom of embryo. In cross section, the caryopsis covering is porous and vesicular. Apomictic rye has a tendency to break between the cell proliferation layer of the seed coat and other parts of the caryopsis. The endosperm grows together poorly with a caryopsis cover and only partly occupies the pericarp. Sometimes a gap in the lower part of the suspensor of a ripe caryopsis consists of dark, mortified tissue that does not fasten at the micropyle and does not adjoin the caryopsis covering. A cavity often forms in the middle of the caryopsis. Caryopses are flat and compressed from two opposite sides and sometimes only a caryopsis cover without endosperm is formed in them. A large part of the caryopsis rises to the surface if submerged. The main root is often abortive.

The produced apomictic rye has the ability for sexual reproduction but differs from normal rye by pollen sterility. Seeds form after pollination with pollen from other plants. Normal rye plants are produced under such conditions. However, with no pollination, overripening and perishing pistils transform into caryopses without the participation of a paternal parent. The offspring are diploid plants. The study of winter rye apomict described in this article will be continued.

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One hundred years of breeding spring bread wheats in Saratov.

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Scientific selection at Saratov began on 1 March, 1910. During the long history of the spring bread wheat breeding laboratory, 52 cultivars were created and entered into the State Variety Testing Commission, 32 of which were released. Lutestsens 62, Sarrubra, Albidum 43, Saratovskaya 29 and others were created thanks to the joint efforts of a team-oriented staff consisting of laboratory specialists and talented scientists who headed the work, Drs. A.P. Shekhurdin (1911–51), V.N. Mamontova (1952–71), and L.G. Ilyina (1972–86). The first directors of the Saratov Agricultural Experimental Station, A.I. Stebut and academician G.K. Meyster, made great contributions in developing spring soft wheat selections.

Each new cultivar from the spring bread wheat breeding laboratory increases the yield capacity when compared with the standard cultivar, and the increase indicator does not decrease after one year of selection. For more than 50 years, the increasing yield rates in the red-grained wheat cultivar group is about 12 kg/ha/year, compared with the white-grained cultivars where only recently has the level reached 10 kg/ha/year. Compared to Lutestsens 62, the yield capacity of Saratovskaya 74 and Saratovskaya 68 has increased up to 184% and 192%, respectively, almost double.

In 2010, the prospective new cultivar Saratovskaya 74 was given to the State Variety Testing Commission. Saratovskaya 74 is an albidum-type wheat, a typical Volga steppe ecological group representative. On average during the 4-year period (2006–09), considering fallow land production under grain yields of 2.43 t/ha, Saratovskaya 74 produced 0.95 t/ha more than Saratovskaya 55 (the standard cultivar). With a fore crop, winter wheat yielded 1.45 t/ha, producing 0.32 t/ha more. Saratovskaya 74 is medium ripening in the conditions of the Saratov region, ripening at the same time as Saratovskaya 55, 84–87 days. This new cultivar is practically resistant to red rust, loose smut, and has average resistance to mildew. Vulnerability and damage by stem pests of Saratovskaya 74 is at the same as standard cultivar. Flour capacity corresponds to the standards required for the strong wheats, although for this trait Saratovskaya may have an advantage. Although both cultivars have equal of albumin and crude gluten content, Saratovskaya 74 greatly exceeds Saratovskaya 55 in volume bread output. Saratovskaya 74 is suggested for use in the Lower Volga area and the Ural region of the Russian Federation.

The evaluation of spring bread wheat cultivars, NILs, and promising introgression lines in the hard drought vegetation conditions of 2009.

S.N. Sibikeev, A.E. Druzhin, V.A. Krupnov, T.D. Golubeva, and T.V. Kalintseva.

A hard drought was observed in 2009 during the spring bread wheat vegetative period. In the initial vegetation stage, the crop was highly infested with frit flies (*Oscinella frit* (L.) and *O. pusilla* (Mg.)). Further degeneration of plants after defeat by insects was accompanied by an increasing drought. Lack of precipitation was observed during the entire vegetative period. Evaluation of a set NILs with alien leaf rust-resistance genes and their combinations and promising introgression lines with genetic material from *T. turgidum* subsps. *durum*, *dicoccum*, and *dicoccoides*, *Ae. speltoides*, *Ae. umbellulata*, *Th. elongatum*, and *Th. intermedium* were evaluated for drought resistance.

Material from *T. turgidum* subsps. *durum* (cultivar Saratovskaya zolotistaya), *dicoccum*, and *dicoccoides*, *Ae. speltoides* (T2D·2S), *Ae. umbellulata* (Lr9 translocation), and *Th. intermedium* (6Agi(6D) in bread wheat background does not confer resistance, but genetic material from *T. turgidum* subsp. *durum* (cultivar Melyanopus 26), *Th. elongatum* (Lr19 translocation), and the combinations *T. turgidum* subsp. *dicoccoides* + *T. turgidum* subsp. *durum* (cultivar Ludmila + Saratovskaya zolotistaya) and *Th. elongatum* + *S. cereale* (Lr19+Lr26 translocations) increase resistance to drought. The combinations with translocations Lr19+Lr24 (*Th. elongatum*) and Lr19+Lr25 (*Th. elongatum* + *S. cereale*) significantly decreased resistance to drought. In these lines, except for the direct influence on drought resistance, the other

significant influence were from the genes determining tolerance to frit flies and ensuring a fast regeneration of injured plants.

Agronomic performance of multilinear mixes on the basis of spring bread wheat cultivar Dobrynya in 2009.

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Previously, we reported on studying multilinear mixes of the spring bread wheat cultivar Dobrynya in the vegetative conditions of 2008, characterized by moderate precipitations and a moderate leaf rust epidemic (Ann Wheat Newslet 55:174-175). The vegetative period in 2009 was characterized by a hard drought. We were interested in determining the reaction of the multilinear mixes to this very important abiotic stress.

The investigated mixes included four components: Dobrynya, Dobrynya *Lr19+Lr9*, Dobrynya *Lr19+Lr24*, Dobrynya *Lr19+Lr25*. All components were tested in equal parts. We also used mixes from the first (prepared in 2009), second (after cultivation in 2008), and third (after cultivation in 2007 and 2008) years. The control mix used all lines and the cultivar Dobrynya. We estimated heading date, plant height, 1,000-kernel weight, grain productivity, grain protein content, gluten content, gluten strength, and SDS evaluation.

For heading date, the multilinear mixes did not differ from components or the cultivar Dobrynya. For plant height, the components did not significantly differ among themselves, except for Dobrynya *Lr19+*, which had a smaller plant height. Multilinear mixes did not significantly differ for plant height from the components average. For 1,000-kernel weight, significant differences were not observed, but among the component lines, Dobrynya *Lr19+Lr24* had the highest. For grain productivity, the mixes did not differ significantly from the component average although the increase in grain productivity of mixes in the third year was 18%. In the second year, mixes had lower grain productivity. For grain protein content, gluten content, gluten strength, and SDS evaluation, the mixes did not significantly differ from the component average. However, among the component lines and mixes, the cultivar Dobrynya had the highest values for all estimated agronomical traits.

Resistance of wheat–*Thinopyrum elongatum* substitution line L3065 (3Age/3D) to a complex of fungal diseases.

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Thinopyrum elongatum is the donor of many genes for resistance to pathogens and pests, including leaf rust-resistance genes *Lr19*, *Lr24*, and *Lr29*; stem rust-resistance genes *Sr24*, *Sr25*, *Sr26*, and *Sr43*; and *Cmc2*, resistance to the mite *Aceria tosic hilla* (Acari: Eriophyidae). We studied the spring bread wheat line L3065 (Saratovskaya 55/*Th. elongatum* *3/Saratovskaya 29) for resistance to leaf rust, powdery mildew, stem rust, loose smut, and common bunt. Studies have shown that this line is susceptible to leaf rust, powdery mildew, and stem rust similar to the recipient cultivars Saratovskaya 55 and Saratovskaya 29, but is affected significantly less by loose smut and common bunt (Table 1). The line also has race-specific resistance to races of loose smut. The C-banding pattern of this lines showed *Th. elongatum* substitutions with chromosomes 3Age (3D), indicating that chromosome 3Age carries the gene(s) for resistance to loose smut and common bunt.

Table 1. The infection type of spring bread wheat lines and cultivars to leaf rust, powdery mildew, loose smut, and common bunt averaged over 6 years on cultivars and lines to race T18, F*=12.6

Cultivar, line	Leaf rust	Powdery mildew	Stem rust	Race pathotypes					
				Loose smut				Common bunt	
				T18*	I-505	I-164	I-C36	894	Tu15
L3065	3	2	3	21.38 a	8.8	26.3	24.0	0.0	0.0
Saratovskaya 55	3	3	3	66.85 c	63.2	62.5	65.5	25.0	8.6
Saratovskaya 29	3	3	3	52.22 b	36.8	22.7	52.9	38.6	24.5

Haploid plants production in triticale-wheat hybrids.

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Triticale-wheat hybrids developed using modern local wheat and rye cultivar are a valuable, initial breeding stock with introgressions of D-genome genetic material. Plants in the F_3 - F_4 of two selfed hybrids were used for haploid plant production using anther culture. An induction medium with sucrose, maltose, and 2 mg/L 2,4-D was used to obtain haploid embryo-like structures. Responding anthers were transferred for callus development on a regeneration medium with 2% sucrose and 1 mg/L IAA. The number of green and albino plants was counted after about 30 days depending on plant development. Well-rooted regenerants were subjected to colchicine treatment.

Our results did not confirm the role of a cold pretreatment of the donor spikes prior to culturing as a trigger for sporophytic microspore development. Altogether, 128 viable green plants and 104 androgenetic albino plants were obtained from 527 embryo-like structures. The frequency of embryogenic anthers (the number of embryogenic anthers/100 anthers) was 8.9–10.5%. The rate of embryo-like structures (the number of embryo-like structures/100 anthers) was 15.5–15.7%. Molecular techniques for DNA, storage protein analysis, and FISH will be used to identify alien chromosome insertions or substitutions in the callus. The DH lines will be multiplied and investigated for resistance to biotic and abiotic stresses.

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Physiological-morphological changes in wheat seedlings inoculated with Azospirillum bacteria.

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The physiological-biochemical bases for the functioning of plant-microbial symbioses is a topical problem in current agrobiology. With the known positive effects of interaction between the macro- and micropartners in symbioses, little attention has been paid to the functioning of root apical meristems, which serve as the formative and regulatory centers in the plant host (Ivanov 2004) and are a major site for the localization of associated bacteria (Bashan and Levanony 1989). We have investigated the mitotic activity of root meristem cells and the morphological parameters of wheat (cv. Saratovskaya 29) seedlings after root inoculation with the associative bacteria *Azospirillum brasilense* Sp7 and Sp245.

Etiolated, 3-day-old wheat seedlings were inoculated for 24 h in suspensions of *A. brasilense* Sp7 and Sp245 and the enterobacterium *Escherichia coli* K12 (cell density, 108 cells/ml). Other seedlings were treated with *A. brasilense* Sp245 prefixed with 2% glutaraldehyde. After inoculation, the seedlings were placed in water. The control was uninoculated plants grown in hydroponic culture. Samples were taken 2 days after inoculation. The functional activity of the root meristem cells was assessed by using two parameters: (1) determining the cell mitotic index and (2) comparative estimates of the content of the proliferative antigen of initials (PAI), a molecular marker for wheat meristem cells (Evseeva et al. 2002). To determine the mitotic index, root apex meristems were fixed in acetic acid-ethanol (1:3), stained with acetohematoxylin, macerated with cytase enzyme, and visualized at 400× magnification. PAI was revealed by enzyme immunoassay by using rabbit monospecific anti-PAI antibodies.

Inoculating wheat seedlings with live *Azospirillum* cells led to an approximately 2-fold increase in the mitotic activity of the root meristem cells and to an almost 1.5-fold increase in the PAI content in these cells. The effect of strain Sp245 did not differ essentially from that of strain Sp7. Shoot length increased by 30–40% and root length increased by 20–30%. The treatment of the seedlings with glutaraldehyde-fixed *A. brasilense* Sp245 did not substantially change the values for mitotic index of the root meristem cells, PAI content, or the morphological parameters. Our data agree with

those of Bashan et al. (1986), who showed that heat-killed azospirilla lose their adsorption ability, which indicates that active bacterial metabolism is needed for bacterial attachment to roots. *E. coli* K12 did not have a significant growth-promoting effect on wheat seedlings. The inoculation-induced enhancement of mitotic activity in root meristem cells is probably the main cause for the increase in the morphological parameters, although our results may indicate that the change in PAI content in root meristems is a parameter that characterizes the effectiveness of plant interactions with the soil microflora.

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Growth activation testing of wheat cultivars for aluminum toxicity.

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The toxic influence of Al ions on plants is real and urgent in breeding Al-resistant cultivars. Al-tolerance investigations have been conducted in solutions with 10, 30, 50, and 200 μM Al all over the world. Growth and changes in plants processes were researched in the investigations. At the genomic level, some cultivars have tolerance genes to Al ions, but the toxic effects of such ions appears in root shortening and chromosome aberrations.

At the same time, we discovered that Al ions cause root shortening as often as not and sometimes cause forcing of the vegetative part of wheat germ. Leaf length and area in several cultivars increase considerably Al (Tables 1 and 2). The length of the Lada seedlings in the Al variant increased by 74.74% over the control by the 12th growth day. Leaf area also increased in cultivars Voronezhskaya by 31.1 %, Omskaya 24 by 16.4%, and Kerba by 11.6% over the control. Stimulation of leaf growth could be caused by early sensitivity to Al toxicity.

The Al solution stimulated leaf growth but to different degrees among the three cultivars tested (Fig.1). The greatest

Table 1. Increase of the vegetative part (cm) of the spring wheat cultivar Lada with the addition of Al (3 mg/L) into soil and solution.

Variant	Days-after-germination			
	6	8	10	12
Control	1.09 ± 0.35	1.76 ± 0.84	2.43 ± 0.81	3.16 ± 0.79
AlCl ₃	1.63 ± 0.50	3.49 ± 1.45	4.67 ± 1.25	5.52 ± 1.29

Table 2. Increase in the leaf area (cm²) of spring wheat cultivars with the addition of Al (0.72 mg/10 g soil) into soil and solution.

Variant	Cultivar		
	Voronezhskaya 14	Omskaya 24	Kerba
Control	51.98 ± 6.81	38.71 ± 7.65	38.18 ± 3.87
AlCl ₃	68.16 ± 14.84	45.07 ± 6.06	42.62 ± 3.78

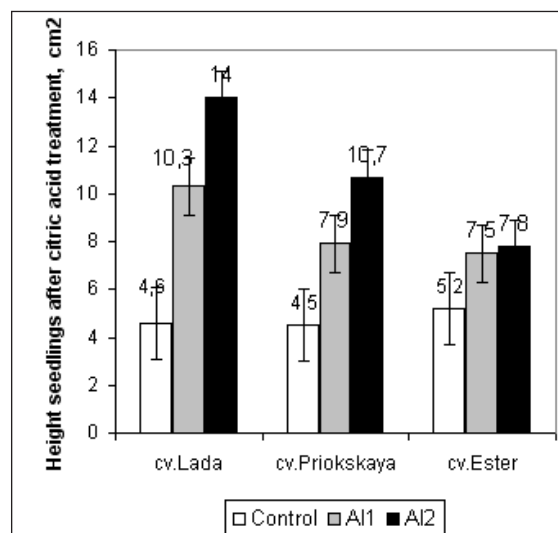


Fig. 1. Area of assimilating leaf surface (cm²) of the spring wheat cultivars Lada, Priokskaya, and Ester after a preplanting seed treatment with citric acid.

increase was in the leaf area of the cultivar Lada, which was 2.0% times the control. The leaf area of the cultivar Priokskaya increased 1.06% over the control and the cultivar Ester increased by 47.0%. The relationship between stimulation of leaf growth and plant productivity in Al-weak soils is the capability of greater productivity. We suggest that there is a possible adaptation mechanism of wheat cultivars that are able to initiate early growth because of Al in soils.

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Effect of bacterial lipopolysaccharide on the morphogenetic potential of wheat callus cells in vitro.

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The major problem when cultivating plants *in vitro* is ensuring that the cells preserve their morphogenetic potential. Plant-associated methylobacteria stimulate plant growth and morphogenesis *in vitro* (Kalyaeva et al. 2001). Volkogon et al. (2006) also found that the nitrogen-fixing bacteria *Azospirillum* promote potato growth in an *in vitro* culture. However, inoculation of plants with whole bacterial cells in a *in vitro* culture is fraught with methodology-related difficulties. In view of this, a problem is using bacterial cell components that are responsible for plant–bacterial interaction, and not a bacterial suspension, to treat explants. The outer-membrane lipopolysaccharide (LPS) of the nitrogen-fixing bacteria *Azospirillum* is an active cell component that not only determines bacterial contact interactions with the roots of plants but also is involved in processes inducing plant responses to these interactions (Matora et al. 1995; Evseeva et al. 2009). Our work examined the influence of LPS on the morphogenetic parameters of cultivation of somatic wheat calli differing in the *Rht-B1c* gene.

Immature embryos of two near-isogenic wheat lines (genetic background of cultivar Saratovskaya 29) differing in the *Rht-B1c* gene were placed on Linsmaier–Skoog medium, an experimental nutrient medium for callus initiation, that contained LPS at 1, 2.5, 10, and 100 $\mu\text{g}/\text{mL}$. The resulting morphogenic calli were transferred to a regeneration medium with the same LPS content. The standard medium did not contain LPS. The morphological characteristics of the calli were assessed on day 30 of culturing by using two parameters: yield of morphogenic calli and their content of proliferative antigen of initials (PAI), a molecular marker for wheat meristematic cells (Evseeva et al. 2002).

Callus formation in the wheat lines was high (close to 100%) in all treatments. The addition of 10 $\mu\text{g}/\text{ml}$ of LPS to the nutrient medium had a positive effect on morphogenic callus formation in the line with the *Rht-B1c* gene. The yield of morphogenic calli in this line increased almost twofold. LPS at 10 $\mu\text{g}/\text{ml}$ also increased the content of PAI in the callus cells of all genotypes studied. Compared with the tall sister line and the original cultivar, the line with *Rht-B1c* showed a significant difference. In other treatments, we did not record any significant effect of LPS on the morphogenetic activity of the calli. Similarly, no substantial differences in the ‘mass of morphogenic calli’ parameter were found between the standard and experimental nutrient–medium versions. Overall, this study confirmed the previously found positive effect of the *Rht-B1c* gene on all stages of *in vitro* tissue culture compared with the *Rht-B1a* allele (Tkachenko and Lobachev 2008). In most cases, the influence of genotype was greater than the effect of introducing LPS into the nutrient medium.

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**STATE SCIENTIFIC INSTITUTION ALL-RUSSIAN SCIENTIFIC-RESEARCH
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Drought resistance in winter wheat.

Drought resistance is the ability of a plant to change metabolic processes as little as possible during conditions of insufficient water supply. The adaptiveness of a plant determines the structural degree of the fibers. The physiological functions of a plant are connected closely with its morphology and anatomy. The xerophytic structure of winter wheat promotes its resistance to drought during all vegetative periods. The harder and longer the drought, the greater the influence of xerophytic characters on yield elements.

The xerophytic nature of a plant can be assessed using stomata number per leaf area. To determine this value in wheat, we measured stomata/leaf area in flag leaves, in the middle of the leaf, and along the both sides of a central vein. The greater the number of stomata, the more xerophytic the cultivar. Other criteria for drought resistance are a water deficit determination, such as the lack of water present in a plant during a drought and residual water deficit, which is the amount of water present in the early morning. Our work revealed a correlation between residual water deficit signs with a level of variety drought resistance ($r = 0.91$). Field observations were made during the drought conditions in 2003, 2005, 2007, and 2009.

Xerophytic cultivars possess high levels of complex plant stability index (distinguished at the primary developmental stages). The greatest number of stomata/leaf area, i.e., more xerophytic, and water and temperature stress resistance were the cultivars Don 93, Ermak, and Zarnitsa. Winter wheat cultivars have a high ($r = 0.99$) correlation dependence of xerophytes value and complex resistance index. Xerophytic structure promotes the economic and efficient consumption of water by the leaves and is expressed more in genotypes resistant to drought. These conclusions were confirmed in the laboratory and by evaluating the drought resistance of winter wheat in a field experiment.

In the field, increased water content in the leaves increases drought resistance if not accompanied by a decrease in ventilation. We took into consideration the degree of leaf ventilation, i.e., we determined a number of open stomata per leaf square. Cultivars with an increase in xerophytic characteristics possess a high water holding ability. For example, Don 105 has the lowest residual water deficit at flowering (10%) and has the greatest number of stomata/leaf area (27/mm²). The cultivars Deviz, Don 95, and Don Kolos, which had the greatest moisture deficits of 27, 30, and 36%, respectively, possessed the smallest number of stomata/leaf area, 13, 12, and 8/mm², respectively. The correlation between xerophytic value and the residual deficit is $r = 0.42$ (medium).

Drought-resistant cultivars can lose water without harm and need not close stomata significantly longer, even in periods of a harvest drought, positively influencing assimilation speed, increasing CO₂, and strengthening the photosyn-

thesis process; these processes increase stomata conductivity. Drought-resistant cultivars have a better developed system for conserving water in the plant fibers, the greatest number of stomata/leaf area, and a more developed water conducting system in the stem and leaves.

Lodging in winter durum wheat.

E.V. Ionova, N.N. Anisimova, V.L. Gaze, and N.E. Samofalova.

Lodging significantly decreases the productivity of grain crops. Early and intense lodging can cause a productivity loss of 60%. All grain crops are subject to lodging, including such stable plants as sorghum and maize. In the field, lodging is preceded by a gradually increase of unfavorable changes in anatomic-morphologic and physiologic processes. Comparing the morphologic and anatomic characteristics during lodging reveals plant reaction during sprouting.

The level of lodging was determined after assessing the density of supporting fibers in durum winter wheat cultivars resistant and susceptible to lodging. Cross sections of the lower part of the first two main stem internodes at milky ripe phase of grain were stained with a 1% safranin solution. Using an ocular-micrometer, the hypoderm thickness was measured the number of cells calculated. The hypoderm consists of a number of vascular-fibro bundles in hypodermis and parenchyma.

The thickness of the mechanical fibers in cultivars resistant to lodging are larger than those of susceptible cultivars. The thickness in resistant cultivars at the first internode is 8.7 mkm and 8.6 mkm at the second, compared to 7.4 mkm and 7.5 mkm, respectively, for susceptible cultivars. Cultivars resistant to lodging have 4.1 and 4.2 rows of mechanical internode fibers and susceptible cultivars have only 3.5 and 3.6 rows. The vascular bundles are situated in the stem walls. Bundles coming through the hypoderm are very tiny, located at great distances from each other. In the parenchyma next to the large vascular bundles form an inner ring in the stem. The bundle walls consist of mechanical fibers, comprised of thin, stretched fibers that strengthen the stalk. In resistant cultivars, 18.8 conducting bundles are in the mechanical fibers at the first internode and 20.0 at the second internode. In lodging-susceptible cultivars, there are 13.0 mechanical fiber conducting bundles at the first internode and 13.8 at the second internode. Stable cultivars have 29.1 conducting bundles in the parenchyma at the first internode and 30.6 at the second internode, whereas susceptible cultivars have 26.1 and 26.7 at the first and second internodes, respectively.

The diameter of the internode of resistant cultivars is 34 mkm or 18% more than that in susceptible lines. Significant differences were noted in the diameter of the first and the second internodes among the cultivars. Resistant samples have a first internode diameter of 39.8 mkm greater (390.4 mkm) compared with susceptible cultivars (350.6 mkm). The difference of the size of the second internode is a little greater among samples of the different stability groups, 418.9 mkm (resistant samples) and 377.0 mkm (susceptible samples).

Our experiments established that the growing conditions greatly influence the dimensions of the stalk fibers and their correlation. In dry conditions, the epidermal cells are larger, the walls thicker, parenchyma greatly diminishes although the dimensions of individual cells do not change much, the number of chlorophyll-carrying cells decreases, and the dimensions and number of vascular bundles change. The basic features that determine stability are those of the inner stem structure, number of vascular fiber bundles, thickness of the mechanical fabric ring, and the degree of sclerification of all cell walls.

Lodging occurs more frequently when soil is extra moist. Stems in the lower part of the plant stretch, cell walls become thinner, mechanical fabrics develop weaker, and stem firmness decreases. The principal way to fight lodging is selection and introduction of nonlodging cultivars in agricultural production.

Root system development of winter wheat in drought conditions.

E.V. Ionova, N.N. Anisimova, V.L. Gaze, and T.A. Gritchankova.

All structures and plant organs, including the root system, help form drought and heat resistance properties. The development of the primary root system of different winter wheat cultivars was evaluated in a growth chamber after 14

days with a 16-hour daylength (18,000 Lux), a day temperature of 19–20°C, and a night temperature of 11–12°C. The experiments was replicated three times. Experimental variants were optimal soil moisture, 70% PV (control), and 30% PV (soil drought). To determine the increase in roots, we germinated seed in filter paper rolls on a full nutrient mixture of Knopp’s Solution under different soil temperature regimes (8–12°C, 14–16°C, and 28–32°C). The length of the main germ root was measured after 7 and 14 days; the difference is the increase of root dimension.

At 30% PV (experimental drought), the length of the longest root varied from 17.4 to 26.5 cm and from 22.3 to 30.5 cm at optimal moisture (control). The maximum root length under insufficient water conditions was in the cultivars Ermak (26.5 cm), Donskoy Surpriz (25.3 cm), and Don 93 (24.9 cm).

The germ root varied between 0.56 and 0.86 in drought and between 0.66 and 1.12 at optimal water provision. The largest values ere noted in cultivars Ermak (0.86), Deviz (0.81), and Don 93 (0.78). In the control treatment, Donskoy Surpriz (1.12), Don 93 (1.10), Ermak (1.0), and Donskoy Prostor (1.0) had the largest values. At 30% PV, the maximum dry root mass was in Ermak (10.0 mg), Donskoy Surpriz (9.2 mg), and Don 93 (8.6 mg). The largest ratio of absolute dry root mass to the greatest root length was in Donskoy Majak (0.39 mg/sm) and Ermak (0.38 mg/sm). These results indicated the best cultivars for all parameters of primary root system development were Ermak, Donskoy Surpriz, and Don 93.

Besides moisture, air and soil temperature greatly influence root system formation in wheat (Table 1). A maximum root increase (105.5–148.3%) was noted at 14–16°C. The greatest increase at this temperature was in Ermak, Dar Zernograda, Don 93, and Deviz. At 8–12°C, root increase was not more than 94.4–133.4% with the greatest increases in Ermak, Dar Zernograda, and Don 93. The increase in roots at 28–32°C was 87.3–120.1%. The minimum reduction in the roots under the influence of high temperature was noted in Ermak (13.3 and 28.2%) and Dar Zernograda (3.1 and 12.9%). The lowest increase at all experimental temperature regimes were in Donskaya Bezostaya.

Table 1. Increase in roots of winter wheat under different temperature regimes.

Cultivar	Root increase (%) at temperature		
	8–12°C	14–16°C	28–32°C
Dar Zernograda	130.8	140.6	127.7
Donskoy Majak	120.9	130.0	114.3
Ermak	133.4	148.3	120.1
Stanitchnaya	114.7	128.9	108.8
Donskoy Surpriz	115.6	123.0	105.2
Garant	109.9	129.2	109.9
Don 93	129.0	133.4	119.2
Donskaya Bezostaya	94.4	105.5	87.3
Donskoy Prostor	107.8	114.0	99.7
Deviz	121.0	131.1	111.4
Don 95	98.1	107.0	89.9

The evaluation of winter wheat root system development under different soil warming temperature in the laboratory were practically identical to those from field experiments in 2000–09. In the field experiments, root systems growing at 8–12°C soil temperature consisted of big, strong roots. Roots growing at 14–16°C soil temperature are greatly ramified and their dimensions are greater than those of the first regime. At 28–32°C, branching of roots increases, they become thin, and their color changes from white to brown. Roots growing at 40°C become thick, nutrient absorption slows, and, as a result, a decrease of root dry mass takes place (30–40%). Thus, winter wheat roots develop better at low soil temperatures. Substantial root systems depend on temperature and moisture. Changes in root activity in the right direction and selecting the best cultivars accordingly help the selection process.

Winter wheat selection in the Don area.

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Winter wheat is one of the most significant food grain crops in Russia. Winter wheat in the Don area in some years supplies up to 70% of the gross yield of grain in the Russian Federation. The area under winter wheat in 2009 in the Rostov region was 2,071.5 ha; 53,02% were winter wheat cultivars selected by the SPI ARRIGC. In the Rostov region, which is traditionally a strong and valuable wheat production zone according to its climatic conditions, the grain quality has become noticeably worse and dependent upon the natural climatic conditions, which have become more arable during the past years. The yearly amount of high-quality grain of strong and valuable wheat were 2,640 x 10³ ton in 1990, 2.9 x 10³ ton in 2000, 30.3 x 10³ ton in 2001, and 3,526.2 x 10³ ton in 2009. To decrease dependence, it is necessary to select

agricultural crops according to the zone more favorable for their cultivation and choose cultivars that have a stable, high-quality grain production.

The State Register recommended 47 winter wheat cultivars, including 24 (51%) selected by the SPI ARRIGC for the Rostov region for 2010. Thirty-nine of the cultivars (83%) are strong and valuable wheats according to their quality, including 23 cultivars (48.9%) selected by the SPI ARRIGC. The most important priorities for wheat selection in the Don area, together with an increase in potential productivity and ecologic stability are greater protein, gluten, baking, and macaroni properties. As a result of purposeful selection, the high-quality, drought resistant, highly productive winter wheats with a potential productivity of 8–10 tons/ha were Zernogradka-10, Zernogradka-11, Rostovtchanka-3, Konkurent, Tanais, and Rostovtchanka-5 for predecessors of black pairs and Don 93, Ermak, Stanitchnaya, Don 105, and Don Surpriz for nonpair predecessors.

Lately, an interest durum winter wheat has grown. The greatest achievement of domestic selection for macaroni/cereal usage were the cultivars Don Jantar, Aksinit, Gelios, and Kurant, being highly productive with a potential productivity of 7.0–9.0 t/ha, drought resistant, and winterhardy. These cultivars may help solve the deficit of durum grain in the North-Caucasus region.

Cultivars selected by the SPI ARRIGC are able to realize a high level of productivity and quality only when recommended cultivation technology is followed, such as use of fertilizer; feeding during the vegetative period; protection from diseases and pests including insects and the harmful tortoise; and timely harvest. Using quality winter wheat cultivars and the best cultivation technologies will allow agricultural producers to increase the production of high-quality grain.

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Necrotic genotypes in winter bread wheat in the Russian Federation.

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The hybrid necrosis genes (*Ne1* and *Ne2*) are valuable tools for comparing wheat species and their groups within the genus and evaluating anthropogenic influence on genetic erosion. Hybrid necrosis genes interact by a complementary mechanism (Kostyuchenko 1936). Both genes are located in the B genome. The *Ne1* gene is located on chromosome 5BL and the *Ne2* gene on chromosome 2BS. Allele series for each gene have been demonstrated. The alleles of the *Ne1* gene are *w*, *m*, and *s*, and the alleles of the *Ne2* gene are *w*, *wm*, *m*, *ms*, and *s* (Hermsen 1960, 1963; Chu et al. 2006). Knowledge of the necrotic genotype is also important for selection and evaluation of the original material during breeding of wheat and triticale. About ten new cultivars of common wheat recommended for commercial use are registered in the Russian Federation. Although the data on yield, vegetation period, and resistance to main phytopathogens are available, information concerning genes, and hybrid necrosis genes in particular, is missing. Our work analyzes the distribution of hybrid necrosis genes among wheats of Russia and other countries (Pukhalskiy 1996; Pukhalskiy et al. 2000, 2003).

Here we present our data on necrotic genotypes in 53 cultivars of winter bread wheat (Table 1, pp. 221–222). Most were produced after 2000. The following cultivars were used as testers: Felix (*ne1ne1Ne2Ne2*), Co725082 (*Ne1sNe1sne2ne2*), Mironovskaya 808 (*ne1ne1Ne2msNe2ms*), Nemchinovskaya 52 (*ne1ne1Ne2msNe2ms*), and Berthold (*ne1ne1Ne2mNe2m*). Crossings were conducted in the field by a twel-procedure. Hybrids were grown in the field. Necrotic symptoms were evaluated at different ontogeny stages. Pedigree analysis was conducted with an analytical GRIS system.

Table 1. Necrotic genotypes in 53 cultivars of winter bread wheat from the Russian Federation.

Cultivar	Pedigree	Year of release	Genotype
Zamena	Rubin/Krasnodarskaya 46	1987	<i>ne1ne2</i>
Bezostaya 2	Lutescens 314h147/Krasnodarskaya 46	1973	<i>ne1ne2</i>
Istok	Pavlovka/Donskaya ostistaya	1988	<i>ne1ne2</i>
Novoukrainka 83	Ukrainka/Marquis	1945	<i>ne1ne2</i>
Pavlovka	(S)Krasnodarskaya 39	1982	<i>ne1Ne2m</i>
Polukarlikovaya 49	Mironovskaya Yubileynaya Yubileynaya 50/Krasnodarskii karlik 1	1979	<i>ne1ne2</i>
Severokubanka	Krasnodarskaya 39/Krasnodarskaya 6	1980	<i>ne1Ne2m</i>
Sharada	KH-4333-9-1001/Obrii	2006	<i>ne1ne2</i>
Bat'ko	Lutescens 4217-G-25908-4228/Lutescens 5126-p-58-51//Lutescens 51	2003	<i>ne1ne2</i>
Krasota	AD206 (Tritikale)/Rubin//KH-17-t-3 (Tritikale)	2002	<i>ne1ne2</i>
Prikumskaya 140	Spartanka 10/Colt//Spartanka 10	2003	<i>ne1Ne2ms</i>
Stanichnaya	BP-566-86/BP-1302-82	2002	<i>ne1Ne2m</i>
Fortuna	Lutescens –1985-t-124/Soratnitsa	2006	<i>ne1ne2</i>
Fisht	Skifyanka *2/3/Tr.MI//Kavkaz	2004	<i>ne1Ne2ms</i>
Bezenchukskaya 616	Bezenchukskaya 380/Volgodar//Bezenchukskaya 380	2005	<i>ne1Ne2s</i>
Volzhskaya 100	Khar'kovskaya92/Unknown	2004	<i>ne1Ne2s</i>
Volzhskaya K	Kinel'skaya 4/Unknown	2004	<i>ne1Ne2s</i>
Omskaya 4	Mironovskaya 25(M)/Saratovskaya 8	2001	<i>ne1Ne2s</i>
Kazanskaya 560	(S) Meshinskaya 2	2002	<i>ne1ne2</i>
Levoberezhnaya 1	Krasnodarskaya 39/Donskaya ostistaya//Donskaya bezostaya/3/Ershovskaya	2003	<i>ne1ne2</i>
Mafe	86-KPM-684/KH-4636-h-202-56//KH-4336-h-202-56	2006	<i>ne1ne2</i>
Pionerskaya 32	Albidum 114/Bogarnaya 56//Dneprovskaya 521	2006	<i>ne1ne2</i>
Omskaya 5	(S) Sibirskaya niva	2004	<i>ne1Ne2s</i>
Svetoch	Chaika/Kavkaz//Don 85	2004	<i>ne1Ne2s</i>
Tau	NS-175-2// Lutescens 2002/Mironovskaya 808/3/Velutinum 4880	2001	<i>ne1ne2</i>
Veda	Leda//Polovchanka/Rufa	2005	<i>ne1Ne2ms</i>
Vostorg	Tr.MI/Kavkaz//4473- h-144-10	2005	<i>ne1Ne2s</i>
Basalt	Donetskaya 79/Albidum 114	1993	<i>ne1Ne2ms</i>
Odesskaya 200	Yubileynaya 75/Al'batros Odesskii	2006	<i>ne1ne2</i>
Petrovchanka	Erytrospermum G-124080/Yubileynaya 75	2007	<i>ne1ne2</i>
Prikumskaya 141	Donskaya bezostaya/Lutescens G-102649	2004	<i>ne1Ne2m</i>
Stepchanka	Lutescens- G-95506/ Eritrospermum G-72134// BP-1648-KB	2006	<i>ne1Ne2m</i>
Chernozemka 88	Chernozevka 96/Ershovka 6//Odesskaya 75	2003	<i>ne1ne2</i>
Ariadna	Odesskaya 138/Ol'viya//Odesskaya 51/4/Odesskaya 51//Mironovskaya 808	2008	<i>ne1ne2</i>
Biruzha	Lutescens 1985-h-331/Lutescens 4523-h-42//Zimorodok/6687-12	2008	<i>ne1Ne2m</i>
Bogdanka	M 508-97/Volzhskaya 16	2009	<i>ne1Ne2m</i>
Volzhskaya C 3	Khar'kovskaya 92/Unknown	2006	<i>ne1Ne2m</i>
Galina	Obrii/Pamyati Fedina//Inna	2005	<i>ne1ne2</i>
Gratsia	Kupava/ BP=90-178-a-20-5	2008	<i>ne1ne2</i>
Gubernator Dona	Erytrospermum 1122-93/Ukrainka Odesskaya	2008	<i>ne1ne2</i>
Deviz	Rostovchanka/Avrora	2008	<i>ne1Ne2m</i>
Dzhangal	Donskaya bezostaya /Khar'kovskaya 63/Bezostaya 1/Ershovskaya 3	2008	<i>ne1Ne2m</i>
Don 105	Don93/Dimetra	2008	<i>ne1Ne2m</i>
Kamyshanka 3	Lutescens 332/Khar'kovskaya 92	2009	<i>ne1Ne2m</i>
Korund	Apollo/Zentos//Zentos	2008	<i>ne1Ne2m</i>

Table 1 (continued). Necrotic genotypes in 53 cultivars of winter bread wheat from the Russian Federation.

Cultivar	Pedigree	Year of release	Genotype
L'govskaya 4	L'govskaya 77//Yubileynaya 58/3/L'govskaya 167/Polukarlikovaya	2008	<i>ne1ne2</i>
Moskovskaya 56	Mironovskaya poluintensivnaya/Inna//Moskovskaya 39	2008	<i>ne1Ne2m</i>
Nemchinovskaya 24	Donshchina/Inna	2006	<i>ne1Ne2m</i>
Odesskaya 267	Odesskaya 51/Inia 66//Bezostaya 1/Mironovskaya 808/3/World Seeds	2001	<i>ne1Ne2m</i>
Odesskaya 267	Odesskaya 51/Inia 66//Bezostaya 1/Mironovskaya 808/3/World Seeds	2001	<i>ne1Ne2m</i>
Rodnik Tarasovskii	Partisanika/Zirka//Belotserkovskaya 18/Zirka/3/Donskaya Yubileynaya	2003	<i>ne1ne2</i>
Resurs	Lutescens 1956-225/Al'batros Odesskii	2008	<i>ne1ne2</i>
Rostovchanka 5	Skorospelka 35/Mironovskaya 264	2008	<i>ne1ne2</i>
Yunona	Eika/ Lutescens 5573-h-16	2008	<i>ne1Ne2m</i>

Thirty cultivars (56.6%) had the *ne1ne1Ne2Ne2* genotype and 23 (43.4%) possessed the *ne1ne1ne2ne2* genotype. The data obtained clearly demonstrate the elimination of *Ne1*-carriers, but there is no definite explanation for this phenomenon (Pukhalskiy et al. 2008), especially taking into account that practical breeders have no information on hybrid necrosis genes during selection. For still unknown reasons, the *ne1ne1Ne2Ne2* genotype has selective advantage over the *Ne1Ne1ne2ne2* genotype. The *ne1ne1ne2ne2* genotype has a certain selective advantage.

In 27 cultivars, the strength of hybrid necrosis alleles was determined. Among them the moderate *m* alleles prevailed (63%), four cultivars possessed the allele *ms* (14.8%), and six carried the allele *s* (22.2%).

A pedigree analysis of the distribution of hybrid necrosis genes (Table 2, pp. 222-223) showed that, in most cases, the donors of the dominant allele of the *Ne2* gene in *ne1Ne2*-carriers are the cultivars Mironovskaya 808 and Kras-

Table 2. A pedigree analysis of the distribution of hybrid necrosis genes in cultivars of winter bread wheat from the Russian Federation.

Cultivar	Genotype	Presumed donor	Presumed source
Zamena	<i>ne1ne2</i>	Bezostaya 1	Bezostaya 1
Bezostaya 2	<i>ne1ne2</i>	Bezostaya 1	Bezostaya 1
Istok	<i>ne1ne2</i>	Donskaya ostistaya	Bezostaya 1
Novoukrainka 83	<i>ne1ne2</i>	Marquis or Ukrainka	Ukrainka or Hard Red Calcutta
Pavlovka	<i>ne1Ne2m</i>	Krasnodarskaya-39	Gostianum 237
Polukarlikovaya 49	<i>ne1ne2</i>	Krasnodar. karlik 1	Bezostaya 1
Severokubanka	<i>ne1Ne2m</i>	Krasnodarskii-39	Gostianum 237
Sharada	<i>ne1ne2</i>	Obrii	Odesskaya-51
Bat'ko	<i>ne1ne2</i>	Donskaya ostistaya	Bezostaya
Krasota	<i>ne1ne2</i>	Bezostaya 1	Bezostaya 1
Prikumskaya 140	<i>ne1Ne2ms</i>	Spartanka	Krasnodarskaya 39
Stanichnaya	<i>ne1Ne2m</i>	Donskaya polukarlikovaya	Mironovskaya-808
Fortuna	<i>ne1ne2</i>	Soratnitsa	Odesskaya 66 or Partizanka
Fisht	<i>ne1Ne2ms</i>	Skifyanka	Krasnodarskaya-39
Bezenchukskaya 616	<i>ne1Ne2s</i>	Bezenchukskaya 380	Mironovskaya-808
Volzhskaya 100	<i>ne1Ne2s</i>	Khar'kovskaya92	Mironovskaya-808
Volzhskaya K	<i>ne1Ne2s</i>	Kinel'skaya 4	Mironovskaya-808
Omskaya 4	<i>ne1Ne2s</i>	Saratovskaya 1	Lutestsens 230
Kazanskaya 560	<i>ne1ne2</i>	Chernomorskaya	Bezostaya 4
Levoberezhnaya 1	<i>ne1ne2</i>	Donskaya ostistaya	Bezostaya 1
Mafe	<i>ne1ne2</i>	Donskaya ostistaya	Bezostaya 1
Pionerskaya 32	<i>ne1ne2</i>	Al'bidum 114	Al'bidum 11
Omskaya 5	<i>ne1Ne2s</i>	?	
Svetoch	<i>ne1Ne2s</i>	Don 85	Mironovskaya 808

Table 2 (continued). A pedigree analysis of the distribution of hybrid necrosis genes in cultivars of winter bread wheat from the Russian Federation.

Cultivar	Genotype	Presumed donor	Presumed source
Tau	<i>ne1ne2</i>	Mironovskaya 808	Mironovskaya 808
Veda	<i>ne1Ne2ms</i>	Zernogradka 6	Mironovskaya 808
Vostorg	<i>ne1Ne2s</i>	Pavlovka	Krasnodarskaya 39
Basalt	<i>ne1Ne2ms</i>	Mironovskaya 808	Mironovskaya 808
Odesskaya 200	<i>ne1ne2</i>	Yubileynaya 75 or Al'batros Odesskii	Odesskaya 51
Petrovchanka	<i>ne1ne2</i>	Yubileynay 75	Odesskaya 51
Prikumskaya 141	<i>ne1Ne2m</i>	Donskaya bezostaya	Mironovskaya 808
Stepchanka	<i>ne1Ne2m</i>	Pavlovka	Krasnodarskaya 39
Chernozemka 88	<i>ne1ne2</i>	Odesskaya 51	Ukrainka and/or Zemka
Ariadna	<i>ne1ne2</i>	Odesskaya 51	Ukrainka and/or Zemka
Biruzha	<i>ne1Ne2m</i>	Krasnodarskaya 39, Zimorodok	Krymka and/or Gostianum 237
Bogdanka	<i>ne1Ne2m</i>	Volzhskaya 16	Mironovskaya 808
Volzhskaya C 3	<i>ne1Ne2m</i>	Khar'kovskaya 92	Mironovskaya 808
Galina	<i>ne1ne2</i>	Odesskaya 51	Ukrainka and/or Zemka
Gratsia	<i>ne1ne2</i>	Leda (Odesskaya 51)	Ukrainka and/or Zemka
Gubernator Dona	<i>ne1ne2</i>	Odesskaya 51	Ukrainka and/or Zemka
Deviz	<i>ne1Ne2m</i>	Don 85, Kolos Dona	Mironovskaya 808
Dzhangal	<i>ne1Ne2m</i>	Donskaya bezostaya, Ershovskaya 3	Mironovskaya 808 and/or Lutestsens 230
Don 105	<i>ne1Ne2m</i>	Demetra, Don 93	Mironovskaya 808
Kamyshanka 3	<i>ne1Ne2m</i>	Khar'kovskaya 92	Mironovskaya 808
Korund	<i>ne1Ne2m</i>	Carstens VIII, Trumpf, Apollo	Krymka and/or Noe and/or Red Fife and/or Prince Albert
L'govskaya 4	<i>ne1ne2</i>	Yantarnaya 50, Zarya Bezostaya 1	?
Moscovskaya 56	<i>ne1Ne2m</i>	Mironovskaya poluintensivnaya	Mironovskaya 808 and/or Noe
Nemchinovskaya 24	<i>ne1Ne2m</i>	Donschina	Mironovskaya 808
Odesskaya 267	<i>ne1Ne2m</i>	Mironovskaya 808, Inia 66	Mironovskaya 808, Frontana
Rodnik Tarasovskii	<i>ne1ne2</i>	Belotserkovskaya 198, Partizanka	Ukrainka and/or Autonomia
Resurs	<i>ne1ne2</i>	Al'batros Odesskii, Odesskaya 51	Ukrainka and/or Zemka
Rostovchanka 5	<i>ne1ne2</i>	Tarasovskaya 29, Peresvet, Odesskaya 51	Mironovskaya 264 and/or Ukrainka
Yunona	<i>ne1Ne2m</i>	Yugtina	Mironovskays 808 and/or Siete Cerros

nodarskaya 39. In the latter cases, the source of the dominant *Ne2* allele is Gostianum 237, an old cultivar of the Saratovskaya region. The donors of the recessive genotype *ne1ne1ne2ne2* in most instances are Bezostaya 1 and Odesskaya 51, which originate from Bezostaya 1. The donor of recessive alleles is the old cultivar Ukrainka.

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ITEMS FROM SPAIN

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Ascorbate peroxidase induction in wheat lines infected by Heterodera avenae.

The cereal cyst nematode (CCN) (*Heterodera avenae* Woll.) is the most widely distributed and damaging species on cereals cultivated in less temperate regions. This nematode species has been detected in many countries and it is responsible for yield losses in wheat of up to 30%. The CCN induces syncytial feeding sites in the roots of its hosts. Infective, second-stage juveniles (J2) enter the plant roots at the level of the differentiation zone and penetrate intracellularly towards the vascular cylinder. Here, they select and pierce with their stylet a single cell where they release oesophageal secretions. In the following hours, the affected plant cells start to develop the feeding structures (Das et al. 2008). Plants defend themselves from nematodes using a variety of mechanisms, including rapid induction of localized necrosis at the site of infection (the hypersensitive response: HR), increased expression of defense-related proteins, production of antimicrobial compounds, lignin formation, and oxidative burst. Among the altered biochemical pathways are those involving peroxidases, which comprise a large group of enzymes that use different peroxides (ROOH) as electron acceptors. According to Welinder (1992) these enzymes in plants are classified into three classes (I, II, and III). Class-I enzymes are intracellular and are known as ascorbate peroxidase (APX, EC 1.11.1.11). Reactions catalyzed by APX and the cycle-coupled of AsA-GSH prevent the accumulation of toxic levels of H₂O₂ in photosynthetic organisms. APX activities are located in chloroplasts (chAPX), cytosol (cAPX), peroxisomes, or microbodies (pAPX) and mitochondria, each cellular compartment possessing one or several APX isoforms. In *Arabidopsis*, the same protein is dually targeted to mitochondria and chloroplast stroma (Chew et al. 2003).

Changes in APX enzyme activity in response to nematode *H. avenae* attack were studied in roots of three hexaploid wheat lines carrying *Cre2*, *Cre5*, and *Cre7* resistance genes and the susceptible *T. aestivum* cultivar Anza. Spectrophotometric analysis to study these changes was carried out with root extracts of infected and uninfected plants 4, 7, 11, and 14 days after nematode infection. APX induction in all infected resistant genotypes was higher than in the susceptible control. We analyzed whether this increase of activity was related to an increase of APX gene expression. This study was performed with the introgression wheat-*Ae. ventricosa* H-93-8 line, carrying *Cre2* gene, using its parental H-10-15 as susceptible control. APX genes of cytosolic location were induced in roots of plants attacked by the nematode. This induction took place earlier and with more intensity in the resistant line than in the susceptible one, and it was bigger in the root area where the nematode was settled down. Our results suggest that APX present in wheat roots could play a role in *Cre*-mediated resistance to *H. avenae*, either directly or indirectly. They also demonstrated that the biochemi-