III. CONTRIBUTIONS

PRIVATE COMPANIES

WESTBRED LLC – SOUTHERN GREAT PLAINS
14604 South Haven Road, Haven, KS 67543, U.S.A.

Sid Perry, Roy Dare, and Robynn Sims.

2004 was the first year of operating as WestBred LLC, formerly Goertzen Seed Research. Our research focus continues to be directed to both hard red and hard white winter wheat cultivars for the southern Great Plains. We look forward to the addition of germ plasm and expertise provided by our new association with Western Plant Breeders.

Roy Dare joined our program as a research assistant in the spring of 2004, responsible for off-site testing, and breeder seed increases. Roy had most recently worked for the USDA–ARS at Weslaco, TX.

We have released a new hard red cultivar Santa Fe, which possesses a strong foliar protection package, along with very good agronomics, and is well suited for the central corridor of the southern plains. Yields have been equal or better than the leading new cultivars for the central region. The quality of Santa Fe is acceptable. Certified seed will be available in 2005 through the AGSECO network of seed producers.

ITEMS FROM ARGENTINA

CÓRDOBA NATIONAL UNIVERSITY
College of Agriculture, P.O. Box 509, 5000 Córdoba, Argentina.

Spikelets per spike number improvement in bread wheat after six cycles of recurrent selection.

Ariel Masgrau and Ricardo Maich.

In the central, semiarid region of Argentina, wheat grain yield and its components have great variability due to drought stress conditions and warm temperature during the critical periods of heading and flowering. Four S_1-derived families per cycle (C_0 to C_6), with similar flowering dates, were cultivated during 2004. Our objective was to evaluate, in a semiarid environment under rainfed conditions, the genetic progress for grain yield and some of its components after six cycles of recurrent selection. A significant increase of the number of spikelets/spike (11 %) was observed at the most advanced cycle (C_6). However, grain yield did not increase, probably because of tiller inhibition and a prolonged drought stress after flowering.

Spikelet analysis comparing six cycles of recurrent selection.

S.P. Gil, C.S. Perrone, M.M. Cernana, and R.H. Maich.

The goal of our work was to evaluate the plant-breeding effects of six cycles of recurrent selection on the number of floret primordia and fertile florets in bread wheat.

The plants were grown at the Experimental Farm of the College of Agriculture (31º29' S and 64º00' W), Córdoba, Argentina, during three consecutive years: 2001, 2002, and 2003. We compared the C_0 (initial), C_1, C_2, C_3, C_4, and C_5 (intermediate), and C_6 (more advanced) cycles. Five main shoot spikes from each of the 12 S-derived families/population were divided in thirds (lower third, spikelets 4 and 5; middle third, spikelets 9 and 10; and upper third, subterminal spikelet) were studied. Data were evaluated with ANOVA and Duncan's Multiple Range Test ($p \leq 0.05$).

The results of the analysis, regardless of the degree of significance, pointed out that the intermediate cycles C_3 and C_4 had higher mean values than the others, whereas the more advance C_6 cycle did not show the behavior expected.

C3-00-42: An autochthonous and strong short-cycle wheat with highlighted agronomic performance.

G. Manera, D. Ortega, and R.H. Maich.

During 2004, the experimental, the short-cycle wheat line C3-00-42 was evaluated in a farmers' field. We also evaluated the following commercial, short-cycle cultivars: Klein Flecha, Klein Chaj, ProInta Gaucho, and Baguette Premium 13. This comparative yield test was made under the technical supervision of Tecnocampo (Monte Cristo, Córdoba, Argentina). Randomized blocks with three repetitions were used. Each parcel occupied a 2,100 m^2 area. Seeding under no-till on soybean stubble was done on 30 May, 2004. The land was previously chemically fallowed and fertilized with 120 kg urea/ha. At that time, 120 mm of useful water was stored in the land until a depth of 160 cm was measured. A notable 50-mm precipitation occurred during July and another 33 mm in October. This last precipitation happened more than 15 days after flowering (29 September, 2004), during grain filling. The phenologic agronomic age is less important, because the number of seeds/area already was established (20 days before and 10 days after heading). A mechanical harvest was made on 8 November, 2004, with a yield-monitoring system. The values obtained from the system were compared with means obtained on a self-weight chute. Seed yield values with 14 % humidity are expressed.

The good agronomic performance of experimental line C3-00-42 is not correlated with the qualitative profile of the current short-cycle wheats, which is not common (Table 1). Finally, because there is no preharvest loss due to the tenacious glumes that protect the grain, the farmer or contractor has some flexibility of deciding when to harvest and may anticipate planting a second crop of soybean or corn.

Information collected by the Wheat Genetic Subject Group, Faculty of Agricultural Sciences, National University of Córdoba. Argentina.

Table 1. Yield (kg seed/ha) of five wheat genotypes evaluated in farm field in Monte Cristo (Córdoba). Means with the same letter do not differ significantly at P < 0.01 (CV 2.1 %).

Genotype	kg/ha
Bagiette Premium	3.184 a
C3-00-42	2.976 b
Klein Flecha	2,801 c
Klein Chaj	2,733 c

Bread-making quality of two genotypes versus six commercial cultivars of wheat developed for the semiarid regions of Argentina.

M.E. Dubois and Z. Gaido.

Argentina, as a wheat-exporting country, should compete with others whose quality is classified into different classes and types according to end use, thus promoting diversity and guaranteeing quality. In Argentina, agroecological diversity differentiates quality, but there is limited knowledge and information about the relative wheat quality of the different regions.

We evaluated the bread-making quality of new genotypes of bread wheat compared to six commercial cultivars. The two better genotypes were obtained by recurrent selection for yield (C1-00-83 and C3-00-42). The six commercial cultivars were ProINTA Imperial, Klein Don Enrique and Martillo, Buck Halcón, Buck Sureño, and Buck Raudal. All wheats were evaluated in the field of the College of Agriculture, located in the Argentine central semiarid region (31º 29' S and 64º 00' W), in 2003. A randomized block design with four replications was used. Quality of the grain and flour and experimental panification were determined.

The bread-making quality of the C3-00-42 corresponded to a strong wheat (W = 385 x 10-4 J), very tenacious, high water absorption, and good loaf volume. The genotype C1-00-83 represents the best values for protein, gluten, and loaf volume of all those analyzed, with a high flour yield, and a very strong (W = 349 x 10-4 J), balanced (P/L 0.61), and the least mixing time (Table 2).

Table 2. Bread-making quality of two genotypes versus six commercial wheat cultivars after recurrent selection.

Characteristic	C1-00-83	C3-00-42	Buck Sureño	Buck Raudal	Buck Alcón	Klein Don Enrique	Klein Martillo	ProINTA Imperial
Grain quality								
Test weight	83.70	83.05	85.85	81.95	83.70	85.30	81.70	83.05
1,000-kernel weight	42	37	28	31	37	33	30	38
Protein content	12.7	11.1	11.5	10.5	10.4	10.6	11.6	10.1
Flour quality								
Gluten	27.3	22.8	22.6	23.6	23.1	23.4	19.6	21.2
Alveogram								
“P	80	171	124	104	123	130	65	96
“L	131	55	66	95	61	61	124	84
“W	349	385	331	331	282	298	276	263
P/L	0.61	3.14	1.88	1.10	2.01	2.14	0.52	1.15
Experimental panification								
Water absorption	62.5	64.5	63.0	62.5	62.5	62.0	62.5	62.0
Mixing time	2‘30”	4’00”	4’00”	3’30”	3’30”	3’30”	3’00”	3’00”
Loaf volume	810	590	590	625	545	550	690	680

The genotype C3-00-42 presents similar baker characteristics to Buck Sureño, categorized by the National Commission of Seeds into Group 1, which are used for flours or manufactured products that require strong wheats with a W > 350 and protein > 12 %. The excellent baking characteristics of C1-00-83 place it in Group 2 (Wheats for Traditional Panification with more than 8 h of fermentation), better than Buck Raudal and ProINTA Imperial, which also belong in group 2.

These two analyzed genotypes that were developed for the semiarid region present excellent baking characteristics and offer different industrial qualities, which responds to the demand of national and international markets for certain quality and industrial that allow the elaboration of products of more acceptance on the part of the consumer.

Integral genetic progress in hexaploid triticale (X Triticosecale Wittmack) after three cycles of recurrent selection.

R. Maich and D. Manero de Zumelzœ.

Our objective was to determine the genetic progress in grain yield and other nine associated physical and physiological characters after three recurrent selection cycles in hexaploid triticale. The selection criterion was sustained on a selection index constituted by eleven traits.

Ten $S_{1:2}$ selected progenies were analyzed for each one of the following recurrent selection cycles: C_0, C_1, C_2, and C_3. The material was sown under rainfed conditions on 19 May, 2004 at the Experimental Farm of the College of Agriculture (Córdoba National University), Córdoba, Argentina (31°29’ S, 64°00‘ W). The experimental unit consisted of 1-row plots with two replications, 1.3-m long, 0.20-m spacing, and a seeding rate of 150 grains/m^2. The traits measured were number of spikes (number/plot), grain and biological yield (g/plot), harvest index (%), 1,000-kernel weight (g), grain (number/plot), grain and biomass yield (g/spike), harvest index/spike (%), and straw yield (g/spike). Analyses of variance were computed for all traits considering the cycle of selection as variation source. Significant differences between mean values were determined using Duncan's Multiple Range Test.

We observed significant statistical differences between mean values only for harvest index/spike, a physiological grain yield component calculated as the ration between grain yield and spike biomass. Genetic progress of 14 % (C_3 with respect to C_0), which implicated an annual rate of 2.3 %, was observed. For the other characters (except straw yield/spike), positive tendencies, even if not statistically significant, through the first three cycles of recurrent selection in hexaploid triticale, were observed.

Taking into account that 2004 was an atypical period with dry environmental conditions, these results promise a repeat of the experiment in 2005 and a continuation of this genetic breeding program.

Morphological changes to the root system in wheat associated with six cycles of recurrent selection.

Gabriela Melchiorre and Laura Torres.

Our objective was to determine the wheat seedling aerial and root system morphological changes measured at the end of six cycles of recurrent selection performed under rainfed condition. For each one of the four S_1 families derived from each cycle (C_0–C_6), we made two moist paper rolls containing 25 seeds each. The seeds were germinated for 8 days under controlled conditions (8/16 h photoperiod and 20°C). We measured the seedlings for length of the first leaf (cm) and number and length of the seminal root. The results were classified as large (I), medium (II, III, and IV), and small (V). Root and aerial dry weight also were estimated. The regression coefficients between the dependent variables and the number of recurrent selection cycles (C_0–C_6) were calculated. Significant linear regression coefficients for root number and radical and aerial dry weight were obtained. With respect to the seminal root number, the lowest value was 0.06 roots/cycle. The dry weight decreased 0.004 g/cycle, whereas the weight of the first leaf decreased 0.01 g/cycle. These results suggest that the plant idiotype that best responds to drought conditions is that one with a less profuse root system, which allows the plant greater water availability during flowering.

Publication.

Ortega D, Manera G, Astolfi G, Argenti R, and Maich R. 2004. Progeso genético en trigo cultivado en secano. Agrisciencia XXI:89-92 (In Spanish).

ITEMS FROM AUSTRALIA

SOUTH AUSTRALIA

UNIVERSITY OF ADELAIDE
Grain Biochemistry Group, Waite Campus, Plant and Pest Science, School of Agriculture and Wine, Glen Osmond, SA 5064, Australia.

Research interests.

1. Biochemistry and genetic control of factors that cause deterioration of wheat quality prior to harvest (preharvest sprouting and tolerance to preharvest sprouting, grain dormancy, late maturity α-amylase, and black point).
2. Biochemical and genetic control of color and color stability in Asian noodles (grain and flour constituents involved in color of wheat flour and color and color stability in Asian noodles; xanthophylls, flavonoids, polyphenol oxidase, peroxidase, lipoxygenase, and nutritive aspects of cereal xanthophylls, lutein and lutein esters).
3. Durum germ plasm with tolerance to hostile soils and root diseases and better adaptation to southern Australia.

Preharvest sprouting tolerance in white-grained wheats.

Daryl Mares and Kolumbina Mrva.

Preharvest sprouting periodically causes massive losses to the Australian wheat industry and affects all states, albeit with different frequency. Cultivar improvement via the introgression of dormancy from landraces introduced from South Africa, AUS1408, and more recently from China, SW95-50213, is being undertaken in all Australian breeding programs. The same highly significant QTL on chromosome 4A was associated with dormancy in AUS1408, SW95-50213, and a dormant single gene red genotype, AUS1490, despite their apparent diverse origin. This QTL corresponded with the QTL previously identified in a partially dormant Australian wheat, Halberd, and a number of red-grained wheats. Two SSR markers flanking the highest LRS (Likelihood Ratio Statistic) position on 4A were used to select doubled-haploid lines (dormant / nondormant) containing the dormant parent alleles. The dormancy phenotype of lines in these subpopulations varied from dormant to intermediate. The observations appeared to be consistent with a model in which the 4A QTL is the key component of the dormant phenotype, contributing intermediate dormancy on its own and strong dormancy in combination with 1–2 additional genes. A doubled-haploid population, fixed for the 4A dormancy allele but varying with respect to the additional genes, is being mapped currently.

Late-maturity α-amylase in wheat.

Kolumbina Mrva and Daryl Mares.

Late-maturity α-amylase (LMA) is a genetic defect that can give rise to high grain α-amylase activity, low falling number (typically 200–300 sec but in some instances < 200 sec.), in the absence of sprouting and depending on the environmental conditions during the middle stages of grain filling. The defect is present at low levels in Australian wheat breeding programs and has been identified in genotypes from the U.K., Japan, China, South Africa, Mexico (CIMMYT), and possibly the U.S. (California). Once introduced, the defect is very difficult to eliminate from breeding programs. Preliminary data suggests that LMA is common in synthetic wheats and derived synthetic wheats. A number of sources have been examined and in each case the tendency to produce high α-amylase activity was linked to QTL located on 3B and 7B. These QTL appeared to be independently effective and additive. The effects of these QTL were reduced in the presence of semi-dwarfing genes, *Rht1* and *Rht2*, and increased in the presence of 1B/1R.

Current work is focused on populations involving different sources of LMA including an 'Opata/Synthetic' population, the underlying biochemical mechanisms involved, and the temperatures or temperature differential required for maximal expression.

Biochemical and genetic control of color and color stability in Asian noodles.

Robert Asenstorfer, Richard Leach, Imelda Soriano, and Daryl Mares.

Our aims are to identify and quantify the biochemical constituents, enzymes and interactions that influence quality, specifically color, and. hence. marketability of noodles; develop efficient, small-scale screening technologies for color and color constituents; identify QTL/genes associated with control of color components; develop and validate molecular markers for critical traits; and exploit available genetic variation, mutations, and synthetic wheats to develop wheat genotypes with improved or novel characteristics.

Polyphenol oxidase (PPO). Australian cultivars vary from high (unacceptable for alkaline noodles due to excessive darkening) to low in benchmark cultivars such as Sunco. Recently, a bread wheat genotype with PPO levels significantly less than Sunco and synthetic derived material with zero PPO have been identified. This material provides incremental improvements in color stability (i.e., reduced rate of darkening). In the absence of PPO, there is still significant darkening contributed by non-PPO enzymic activity. QTL associated with variation in PPO activity are located on chromosomes 2A and 2D. Current work on this trait includes introgression of very low PPO and zero PPO into locally adapted cultivars and biochemical analysis of the non-PPO component.

Flavonoids. Water and 0.1 M hydroxylamine extract compounds from whole meal or flour that are colorless at neutral pH but which turn yellow at higher pH (e.g., as in yellow alkaline noodles, YAN). The germ tissues contain free and phenolic esters of apigenin-C-diglycosides that contribute to the total yellow color of YAN. whereas the seed coat or bran contains nonflavonoid phenolics that have a minor role. The proportion of total flavonoid that is recovered in flour during milling appears to vary with both genotype and plant growth environment.

Lipoxygenase. Variation in both the 'Sunco/Tasman' and 'Opata/Synthetic' populations was associated with a QTL on chromosome 4B located close to the centromere and in the case of the 'Sunco/Tasman' population, *Rht1*.

Durum germ plasm with better adaptation to southern Australia.

David Cooper and Daryl Mares.

Durum production in the southern region of Australia expanded rapidly in the late 1990s but more recently has declined in popularity in the face of inconsistent performance and perceived deficiencies in adaptation to the local environment. This new project began in 2004 and aims to introgress tolerance to a range of hostile soil (boron toxicity, salinity, high bicarbonate, and zinc deficiency), disease (crown rot and nematodes), and grain defects (sprouting, high α-amylase, and black point) traits into elite durum genotypes. Part of the research will also be directed at improving semolina yellowness.

Publications.

Asenstorfer RE, Wang Y, and Mares DJ. 2004. Yellow colour in alkaline noodles. **In:** Cereals 2004, Proc 53rd Aus Cereal Chem Conf (Black CK, Panozzo JF, and Rebetzke GJ, Eds). Pp. 175-178.

Leach RC and Mares DJ. 2004. Quantitative trait locus associated with lipoxygenase activity in bread wheats: a tool to improve the marketability of Australian bread wheat. **In:** Cereals 2004, Proc 53rd Aus Cereal Chem Conf (Black CK, Panozzo JF, and Rebetzke GJ, Eds). Pp 130-133.

Mares DJ, Mrva K, Cheong J, Williams KJ, Cavallaro B, Storlie E, Sutherland M, and Zou Y. 2004. Genetic control of dormancy in white-grained wheats of diverse origin. In: Cereals 2004, Proc 53rd Aus Cereal Chem Conf (Black CK, Panozzo JF, and Rebetzke GJ, Eds). Pp. 231-233.
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Mares DJ and Campbell AW. 2001. Mapping components of flour and noodle colour in Australian wheat. Aus J Agric Res 52:1297-1309.
Mrva K, Mares DJ, Williams KJ, and Cheong J. 2004. Molecular markers associated with late maturity a-amylase (LMA) in wheat. In: Cereals 2004, Proc 53rd Aus Cereal Chem Conf (Black CK, Panozzo JF, and Rebetzke GJ, Eds). Pp 150-151.

ITEMS FROM CROATIA

BC INSTITUTE FOR BREEDING AND PRODUCTION OF FIELD CROPS
Marulicev trg 5/1, 10000 Zagreb, Croatia.

A newly registered winter triticale developed by the Zagreb Bc Institute.

Slobodan Tomasovic.

Bc Goran (Bc PR 1280/99) was registered in 2004 based on the results of official testing by the Board for registration, Approbation and Protection of Varieties of the Republic of Croatia over 3 years (2002–04). Some important yield and

Table 1. Average grain yield over 3 years (2002–04) of Bc Goran in comparison with the standard cultivar Clercal in official testing by the Board for Registration, Approbation and Protection of Varieties of the Republic of Croatia.

	Average grain yield (kg/ha)			
	Cultivar			
Year	Bc Goran	Clercal (check)	Relative yield against Clercal (= 100 %)	Difference (in kg) against Clercal
2002	8,664	7,552	114.72	+1,112
2003	7,605	5,402	140.78	+2,203
2004	8,043	8,432	95.39	–389
Average	**8,104**	**7,129**	**116.96**	**+975**

Table 2. Average hectoliter weight of Bc Goran kernels compared with the standard cultivar Clercal. Results of official Board for Registration, Approbation and Protection of Varieties of the Republic of Croatia.

	Average hectoliter weight (kg/ha)			
	Cultivar			
Year	Bc Goran	Clercal (check)	Relative hectoliter weight against Clercal (= 100 %)	Difference (in kg) against Clercal
2002	66.35	65.51	99.75	–0.16
2003	73.77	66.32	111.23	+7.45
2004	70.46	68.35	103.09	+2.11
Average	**69.86**	**66.73**	**104.69**	**+3.13**

quality traits of Bc Goran are given in Tables 1 and 2 (p. 23), respectively. These traits determine agronomic value and influence a cultivars acceptability among producers for marketing and distribution. The triticale-breeding program at the Zagreb Bc Institute is a new program, and this cultivar is its first for Croatia. The collecting of winter-type germ plasm began before 1995 and was followed by testing for important agronomics traits in experimental fields in Botinec. Crosses and production were by the pedigree-method. Selection of the line was made in 1999.

Comparison of three rating systems of Fusarium head blight in wheat.

Branko Palaversic and Slobodan Tomasovic.

We compared the visual rating index of Fusarium head blight, Fusarium head blight index, and Fusarium damaged kernels (Table 3 and Fig. 1). A small-scale trial with 18 winter wheat genotypes was planted in five replications in Botinec in 2002. Inoculations were made with an *F. graminearum* spore suspension using a sprayer. Significant correlation coefficients were obtained among the three rating systems of FHB in wheat. These results favor the visual rating index of FHB, because it is a quick method for suitably testing a large number of entries in the breeding process.

Table 3. Correlation coefficients among visual rating index of Fusarium head blight (VRI), Fusarium head blight index (FHB), and Fusarium damaged kernels (FDK) in a trial with 18 winter wheat genotypes in Botinec, Croatia, in 2002. Two rating times first (^{1}) and second (^{2}).

	VRI^1	VRI^2	FDK
FHB	0.60	0.79	0.82
VRI^1		0.86	0.54
VRI^2			0.77

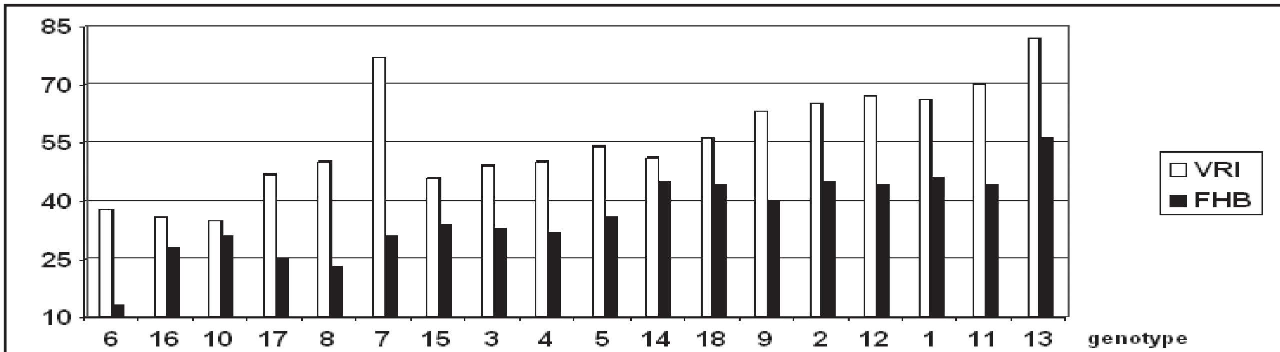

Fig. 1. Visual rating index of Fusarium head blight (VRI^2) and Fusarium head blight index (FHB) in 18 winter wheat genotypes at Botinec, Croatia, in 2002.

Stability of quantitative traits of Bc winter wheat cultivars.

Rade Mlinar, Slobodan Tomasovic, and Ivica Ikic.

In a 3-year investigation, some quantitative traits of ten winter wheat cultivars were studied under particular agroecological conditions (Table 4, p. 25). The results confirmed the existence of significant characteristic variability depending on inheritance and ecological effects. Grain yield is a highly variable character with regard to significant differences between cultivars and between years. The highest average grain yield was found in the cultivar Liberta (6,217 kg/ha), and the coefficient of variability ranged from 28.2 to 36.9. (Table 5 and Fig. 2, p. 25). The coefficient of variability in 1,000-kernel weight ranged from 7.01 to 15.07 g. The sedimentation test ranged from 8.8 to 24.3, depending on genetic factors and to a lesser extent on environmental conditions. Plant height was highly variable depending on environmental and genetic conditions. Cultivars Mihelca and Patria had the tallest plants, 80 cm; the smallest were in the check cultivar Zitarka, 70 cm. The coefficient of variability ranged from 20.5 to 28.7. Variability parameters for the most important quantitative traits indicate very suitable growing conditions under different production schemes for cultivars Patria, Marija, and Liberta. Based on the obtained yields and variability parameters, development of wheat cultivars that can meet both yield capacity and stability criteria seems to be possible.

Table 4. Basic data on the winter wheat cultivars studied for grain yield (see Table 5).

Cultivar	Origin	Year of registration	Pedigree
Sana	Bc Institut	1983	Mura x CI 14123 x Bc –2413/72
Zitarka	Poljop Institut Osijek	1985	OSK-6.30/20 x Slavonka x H-68 OSK-154/19 x Kavkaz
Marija	Bc Institut	1988	Bc-4527/68 x Kavkaz x Bc 1971/70
Tina	Bc Institut	1993	Sana/Gala
Patria	Bc Institut	1994	Odesskaya-51 x ZG IPK 82 10 x GK-32-82
Mihelca	Bc Institut	1995	Bc-1325/78/SO-1065
Zdenka	Bc Institut	1996	Beauchamp/Bc-2557/83
Liberta	Bc Institut	1997	M-441-1 x Drina x Bc-167/86
Aura	Bc Institut	1997	434 K-4CM/7903-93-1
Concordia	Bc Institut	1998	Bc-186/82/Castan

Table 5. Grain yield (kg/ha) of the ten studied cultivars, 2001–03.

	Year					
Cultivar	2001	2002	2003	Mean	CV	Rank
Liberta	8,239	6,942	3,470	6,217	32.3	8
Mihelca	7,850	7,279	3,158	6,096	34.3	6
Tina	7,659	7,482	3,017	6,053	35.5	2
Marija	7,317	7,311	3,441	6,023	30.3	9
Patria	7,452	6,951	3,633	6,012	28.2	10
Sana	7,060	7,878	3,016	5,995	35.5	3
Zdenka	7,354	7,476	2,999	5,943	35.0	4
Aura	7,084	7,276	3,165	5,842	32.4	7
Zitarka	6,829	5,484	2,471	4,928	36.9	1
Concordia	5,679	6,392	2,511	4,866	34.7	5
Mean	**7,254**	**7,047**	**3,088**	**6,796**		

Five-year testing of Bc winter wheat cultivars in large-scale trials in Croatia.

Ivica Ikic and Kristijan Puskaric.

Every year, winter wheat cultivars developed by the Bc Institute are tested in many large-scale trials in the Republic of Croatia. In addition to cultivars developed by domestic seed companies, these trials include a large number of introduced foreign cultivars that are grown in Croatia. Here we present the results of average yields of Bc winter wheat cultivars tested in a 5-year period (2000–04) at three locations in large-scale trials at Belje, Vinkovci, and Koprivnica. We tested the following Bc winter wheats: Marija, Sana, Tina, Liberta, Zdenka, Nina, Prima, and Bc Antea (Figs. 3–5, p. 26). The results of the above testing prove that a progress has been made in wheat breeding with development of winter wheat genotypes producing high and stable yields. These Bc winter wheat cultivars can satisfy the needs of wheat growers in the Republic of Croatia when yield and quality of grain, flour, and bread are concerned.

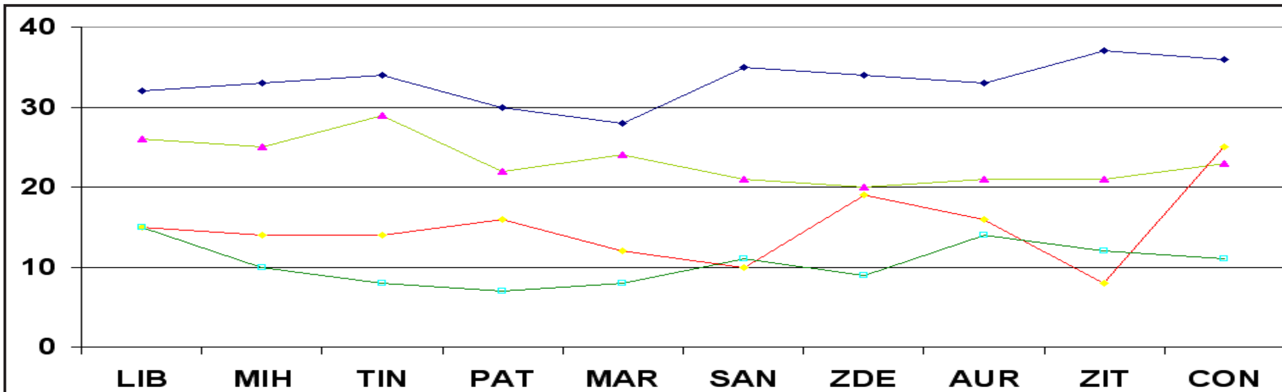

Fig. 2. Coefficient of variability for grain yield for ten cultivars studied between 2002 and 2003; yield (¨), height (D), 1,000-kernel weight (›), and sedimentation (·) .

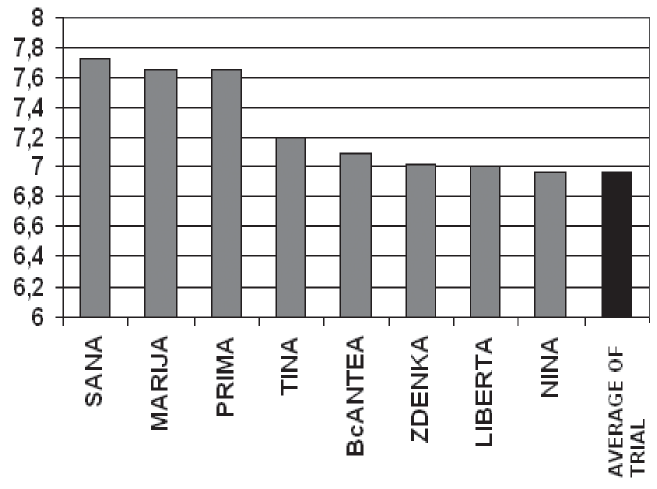

Fig. 3. The results of average yields of the Bc winter wheat cultivars in macro-trial at Belje d.d. in 2000–04, t/ha.

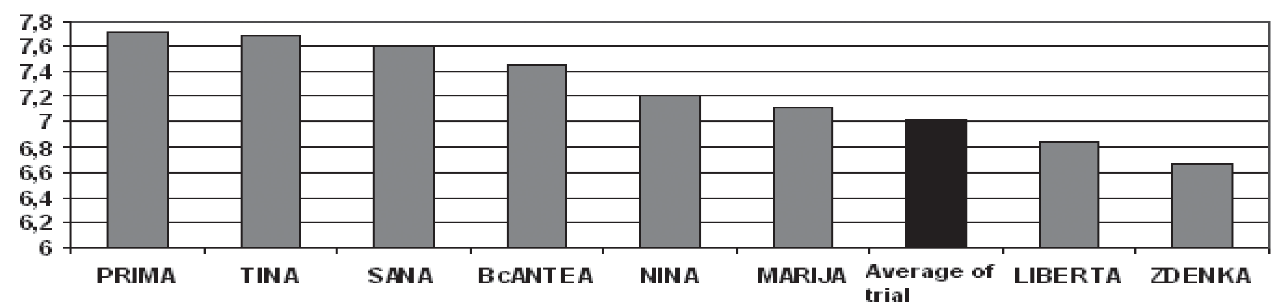

Fig. 4. The results of average yields of the Bc winter wheat cultivars in macro-trial PIK Vinkovci d.d. 2000–04, t /ha.

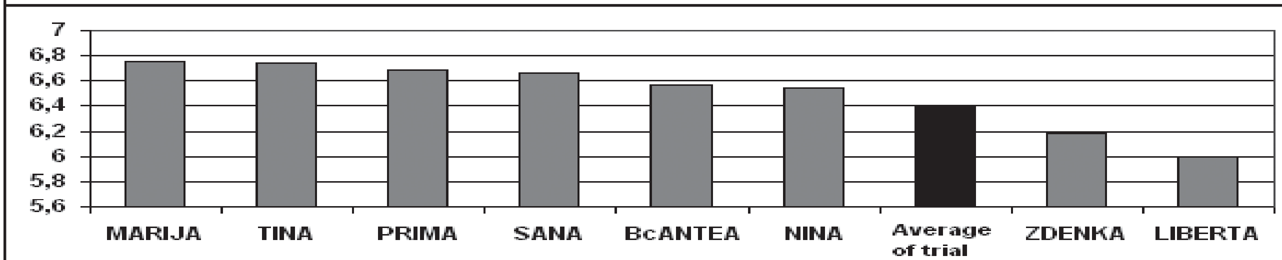

Fig. 5. The results of average yields of the Bc winter wheat cultivars in macro-trial PG-a –Koprivnica 2000–04, t/ha.

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http://genbank.vurv.cz/ewdb

Evaluation of selected genetic resources of Triticum aestivum subsp. aestivum, T. turgidum subsp. durum and dicoccum, and T. monococcum subsp. monococcum.

Z. Stehno and M. Trcková.

Four wheat species represented by spring cultivars or other genotypes listed in Table 1 were evaluated in 2004 in the Research Institute of Crop Production in Prague. Differences among species *T. aestivum* subsp. *aestivum, T. turgidum* subsp. *durum and dicoccum,* and *T. monococcum* subsp. *monococcum* were tested by analysis of variance completed with Tuckey HSD test (homologous groups) at P = 0.05.

Table 1. A survey of tested cultivars and other genetic resources. Country codes are Albania (ALB), Argentina (ARG), Austria (AUT), Azerbaijan (AZE), Canada (CAN), Czech Republic (CSK), Denmark (DNK), France (FRA), Georgia (GEO), Germany (DEU), Hungary (HUN), Italy (ITA), Mexico (MEX), Poland (POL), Portugal (PRT), Russian Federation (RUS), Spain (ESP), Switzerland (CHE), Ukraine (UKR), and Yugoslavia (YUG).

Cultivar	Origin	Cultivar	Origin	Cultivar	Origin
Triticum aestivum* subsp. *aestivum		***Triticum turgidum* subsp. *dicoccum***		***Triticum turgidum* subsp. *durum***	
Munk	DEU	*T. dicoccum* (Kromeriz)	CZE	Zenit	ITA
Sandra	CZE	*T. dicoccum* (Ruzyne)	CZE	Marmilla	ITA
Roxo	PRT	Kahler Emmer	DEU	Valbelice	ITA
Buck Yapeyu	ARG	May-Emmer	CHE	Mojo 2	MEX
Strela	RUS	Weisser Sommer	DEU	Saadi	FRA
Pacific	CAN	*T. dicoccum* (Tapioszele)	HUN	Kharkovskaya 21	UKR
Saratovskaya 46	RUS	Krajova-Podbranc (Toman)	CZE	Auroc	FRA
AC Reed	CAN	Poering Jaarma (Nachitch.)	AZE	Olinto	ITA
Kommissar	AUT	*T. dicoccum* (Balkan)	YUG	Kievlanka	FRA
Broma	POL	*T. dicoccum* (Brno)	CZE	Lyudmila	RUS
Triticum monococcum* subsp. *monococcum					
T. monococcum (Leningr.)	RUS	Escana	ESP	*T. monococcum*	GEO
T. monococcum	ALB	*T. monococcum* (Tabor)	CZE	*T. monococcum* No. 8910	DNK

Average plant height of durum wheat (86.5 cm) was significantly different (Table 2, p. 28) from emmer (115.0 cm). Beard wheat cultivars and einkorn genotypes did not differ each from other neither from the species mentioned above. The number of days from sowing to heading for bred and cultivated species and durum and bread wheat (57.8 and 60.4 days-to-heading, respectively) differed from that of emmer and einkorn hulled wheats (72.0 and 79.3 days, respectively). A similar situation was recorded at flowering, which started 6.2 (*T. aestivum* subsp. *aestivum*) to 7.5 (*T. turgidum* subsp. *durum*) days after heading. The sequence of species and significant differences were the same as for heading. Because a very similar situation was observed in wax ripeness, we can assume that intervals between particular stages are quite similar in tested wheat species.

An important period for assimilate transfer from photosynthetic active organs into grain is the parallel existence of photosynthetic active area and developing grain capacity that is period from flowering to total chlorophyll decomposi-

Table 2. Significant differences among wheat species for various agronomic characteristics (groups significant at P = 0.05).

Species	Average	Group	Species	Average	Group
Plant height (cm)			**Number of kernels/spikelet**		
T. durum	86.5	a	*T. monococcum*	0.8	a
T. aestivum	98.8	ab	*T. dicoccum*	1.1	a
T. monococcum	101.7	ab	*T. aestivum*	2.1	b
T. dicoccum	115.0	b	*T. durum*	2.1	b
Number of days from sowing to heading			**Grain weight/spike**		
T. durum	57.8	a	*T. monococcum*	0.39	a
T. aestivum	60.4	a	*T. dicoccum*	0.58	a
T. dicoccum	72.0	b	*T. aestivum*	1.43	b
T. monococcum	79.3	c	*T. durum*	1.45	b
Number of days from sowing to flowering			**1,000-kernel weight (g)**		
T. durum	65.3	a	*T. monococcum*	22.26	a
T. aestivum	66.6	a	*T. dicoccum*	27.89	b
T. dicoccum	78.3	b	*T. aestivum*	38.15	c
T. monococcum	86.2	c	*T. durum*	47.02	d
Number of days from sowing to wax ripeness			**Harvest index (HI)**		
T. durum	105.8	a	*T. monococcum*	0.29	a
T. aestivum	106.7	a	*T. dicoccum*	0.36	b
T. dicoccum	109.8	b	*T. aestivum*	0.46	c
T. monococcum	112.7	c	*T. durum*	0.47	c
Number of days, sowing to chlorophyll decomposition			**Crude protein content (%)**		
T. durum	104.1	a	*T. aestivum*	14.34	a
T. aestivum	105.3	ab	*T. durum*	14.70	a
T. dicoccum	107.3	bc	*T. dicoccum*	19.32	b
T. monococcum	109.7	c	*T. monococcum*	19.80	b
Number of days, flowering to chlorophyll decomposition			**Sedimentation by Zeleny (ml)**		
T. monococcum	23.5	a	*T. dicoccum*	23.80	a
T. dicoccum	29.0	b	*T. monococcum*	24.33	a
T. aestivum	38.7	c	*T. durum*	25.60	a
T. durum	38.8	c	*T. aestivum*	40.50	b
Spike length (cm)			**Wet-gluten content (%)**		
T. monococcum	5.4	a	*T. monococcum*	18.10	a
T. durum	6.6	a	*T. durum*	20.87	a
T. dicoccum	6.9	a	*T. aestivum*	27.11	a
T. aestivum	10.0	b	*T. dicoccum*	34.70	a
Number of spikelets/spike			**Gluten index (GI)**		
T. durum	14.8	a	*T. dicoccum*	19.87	a
T. aestivum	17.9	b	*T. monococcum*	20.19	a
T. dicoccum	19.8	bc	*T. aestivum*	38.39	a
T. monococcum	22.2	c	*T. durum*	47.08	a
Number of kernels/spike					
T. monococcum	17.4	a			
T. dicoccum	21.2	a			
T. durum	31.0	b			
T. aestivum	37.6	c			

tion. For this trait, cultivated species were very similar; bread wheat 38.7 days and durum wheat 38.8 days. They differed significantly from emmer (29.0 days) and especially from einkorn (23.5 days). Significantly longer spikes were recorded in bread wheat (10.0 cm) in comparison to other species (5.4–6.8 cm). Spike length was not related to the number of spikelets/spike. The lowest number of spikelets/spike, in durum wheat, was significantly different from all other species. For the number of kernels/spike, einkorn and emmer were quit similar (17.4 and 21.2 kernels, respectively) and differed significantly from durum wheat (31.0) and bread wheat (37.6). The number of kernels/spikelet corresponded with number of kernels/spike. Cultivated species did not differ from each other (both 2.1 kernels/spikelet). Nearly one kernel/spikelet was observed in emmer and 0.79 kernels per spike in einkorn.

Grain weight per spike results from number of kernels in spike and average weight of one kernel evaluated as 1,000-kernel weight. Cultivated species (durum wheat 1.45 g and bread wheat 1.43 g) were significantly different from hulled species (emmer 0.58 g and einkorn 0.39 g). All tested species differed in 1,000-kernel weight each from others that was caused by deep differences in this trait (from 22.26 g in einkorn to 47.02 g in durum wheat). Harvest index (HI) also was very different, ranging from 0.29 (einkorn) to 0.47 (durum wheat).

The hulled wheat species (*T. turgidum* subsp. *dicoccum* and *T. monococcum* subsp. *monococcum*) were lower in production comparison to bread and durum wheat had significantly higher crude protein content. Standard crude protein content in bread wheat (14.34 %) and durum wheat (14.70 %) was significantly overcome by emmer (19.32 %) and einkorn (19.80 %). High sedimentation value by Zeleny was characteristic for bread wheat (40.5 ml) confirming suitability of the tested species representatives for backing purposes. All other three species with low sedimentation (23.8–25.6 ml) can be considered as suitable for other utilization (pasta and biscuits). Nonsignificant differences in the last two quality characters (wet gluten content and gluten index) were caused by high intraspecies variability.

Acknowledgment. The research was supported by Grant No. 521/02/0479 from the Grant Agency of the Czech Republic.

ITEMS FROM ESTONIA

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Chromosome location of genes for powdery mildew resistance in the common wheat cultivar Helle.

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Abstract. Chromosomal localization of a powdery mildew-resistance gene was conducted in the resistant wheat cultivar Helle employing the susceptible set of 21 Chinese Spring monosomic lines. Monosomic F_1 plants were allowed to self-pollinate and to produce F_2 seeds. Seedlings of F_2 and F_3 plants, and their parents, were inoculated with isolate number 6 of *Blumeria graminis* f.sp. *tritici*. The monosomic analysis results revealed that one dominant gene conferring resistance is located on chromosome 3D.

Introduction. Powdery mildew is an important leaf disease of common wheat in temperate climate of Baltic region. Breeding of resistant cultivars is the most economical and environmentally safe method to eliminate the use of fungicides and to reduce crop losses due to this disease. To date, 32 major gene loci conferring resistance to wheat powdery mildew have been located on specific chromosomes (McIntosh et al. 1998, 2003; Hsam and Zeller 2002; Hsam et al. 2003). Nine resistance genes/alleles, *Pm1, Pm2, Pm3c, Pm3d, Pm4b, Pm5, Pm6, Pm8,* and *Pm9,* are currently in use in Europe. In Scandinavian countries and in Estonia, some wheat cultivars possess the resistance gene *Pm4b* (Peusha et al. 1996; Enno et al. 2002). Because of the coevolution of host and pathogen, race-specific resistance genes can be overcome by new races of the pathogen possessing corresponding virulence genes. Therefore, searching for new sources of powdery mildew resistance in wheat genotypes is a necessity. Our objective was to characterize the resistance genes involved in cultivar Helle and to determine their location on specific chromosomes by monosomic analysis.

Materials and Methods. Seeds of the spring wheat cultivar Helle were obtained from the Jõgeva Plant Breeding Institute, Estonia. The pedigree of Helle is 'WW 24042/Polkka//SV70415/Snabbe//Norröna/KärnII//Bor/Hja 25115'.

The Chinese Spring monosomic series used for locating the resistance gene were kindly supplied by F.J. Zeller, Technische Universität München, Institut für Pflanzenbau und Pflanzenzüchtung, Freising-Weihenstephan, Germany. The set of CS monosomic lines was used as female parent in crosses with cv. Helle. Cytologically verified monosomic plants F_1 of each cross were grown in greenhouse and selfed to obtain F_2 generation. Mitotic chromosome counts of all parental lines and F_1 plants of all cross combinations were made from squashes of root-tip cells using Feulgen staining procedures.

B. graminis f.sp. tritici (Bgt) isolate no. 6 was used to test segregation in F_2 and F_3 populations. Avirulent to Helle, isolate number 6 was kindly provided by F. Felsenstein, Technische Universität München, Freising, Weinstephan, Germany. The test for mildew disease resistance was conducted on primary leaves from 10-day-old seedlings cultured on 6 g/l of agar and 35 mg/l benzimidazole in plastic boxes. The expression of resistance was scored at the 10-day stage. The methods of inoculation and the conditions of incubation and disease assessment were according to the detached leaf segment method described by Hsam and Zeller (1997). Three main classes of host reaction were distinguished: r = resistant (0–20 % infection relative to susceptible cultivar Kanzler); i = intermediate (30–50 % infection); s = susceptible (> 50 % infection). In monosomic analysis, the 0 to 4 infection-type scale of Stakman et al. (1962) also was used to clearly separate the tested individuals into two categories, either resistant or susceptible. Chi-square tests for goodness-of-fit were used to test for deviation of the observed data from the theoretical expected segregation.

Table 1. F_2 segregation for seedling reaction to *Blumeria graminis* f.sp. *tritici* isolate number 6 in progenies of monosomic F_1 plants from crosses of 21 Chinese Spring monosomic lines with the cultivar Helle (* P < 0.01).

Chromosome	# of plants	Observed segregation to isolate no. 6 Resistant	Susceptible	$X^2 \leq$ 3:1
1A	142	105	37	0.08
2A	120	96	24	1.60
3A	132	102	30	0.36
4A	89	68	21	0.09
5A	150	114	36	0.08
6A	147	112	35	0.10
7A	107	79	28	0.07
1B	157	117	40	0.01
2B	146	112	34	0.22
3B	57	44	13	0.14
4B	103	78	25	0.06
5B	120	92	28	0.17
6B	142	107	35	0.01
7B	89	66	23	0.002
1D	109	79	30	0.27
2D	119	88	31	0.07
3D	234	202	32	16.00*
4D	138	100	38	0.47
5D	133	103	30	0.52
6D	150	118	32	1.03
7D	91	68	23	0.002
CS/Helle	165	120	45	0.45
Total without CS M3D/Helle	2,441	1,848	593	0.65

Results and Discussion. The F_2 populations from crosses of the 21 CS monosomic lines susceptible to powdery mildew and the mildew-resistant Helle were tested with *Bgt* isolate no. 6. All of the F_2 populations, except the crosses involving chromosome 3D, segregated in a ratio of 3 resistant : 1 susceptible, conforming to a dominant monogenic inheritance (Table 1). The F_2 hybrids from the crosses 'CS M3D/Helle' were tested against *Bgt* isolate no. 6 and segregated into 202 resistant : 32 susceptible progenies ($X^2 = 16$, P < 0.01). Such great deviation from Mendelian ratio of segregation with significant decrease of the susceptible plants amount indicates the location of the dominant resistance gene on the critical chromosome 3D.

Additional tests with *Bgt* isolate no. 6 involving six F_3 families of resistant F_2 plants from the critical crosses of 'CS M3D/Hell'e was also made to confirm results of the F_2 monosomic analysis. No susceptible plants was observed in the five families of F_3 'CS M3D/Helle' after inoculation with the *Bgt* isolate, confirming the location of the resistance gene on chromosome 3D. Very few susceptible plants were found in only one F_3 family of the respective crosses. These plants were expected to be nullisomic (2n = 40) derived from monosomics F_2 plants. Thus, the available evidence obtained from disease reaction assessment of the F_2 and F3 populations indicated that cultivar Helle possessed the dominant powdery mildew resistance gene located on chromosome 3D. Because no wheat mildew resistance gene is known on chromosome 3D, we propose that this new resistance gene in cultivar Helle be designated *Mlhl*.

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ITEMS FROM GERMANY

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Assessment of SNP haplotypes of the puroindoline b gene for grain hardness in European wheat varieties by Pyrosequencing.

X.Q. Huang and M.S. Röder.

Grain hardness is one of the most important quality characteristics of bread wheat and has a profound effect on milling, baking and the quality of the end product. Grain hardness is reported to result from either a failure to express puroindoline a (*Pina*) or single nucleotide mutations in puroindoline b (*Pinb*). For the first time, we have developed two SNP assays for identification of the seven *Pinb* alleles using Pyrosequencing technology (Huang and Röder 2005). The hardness genotypes of German wheat cultivars available confirmed the reliability and validation of the SNP assays developed for the *Pinb* locus. SNP haplotypes for 493 European wheat cultivars at the *Pinb* gene locus are presented at http://pgrc.ipk-gatersleben.de/puroindoline.

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Dissection of QTL for grain weight into single Mendelian genes.

M.S. Röder and X.Q. Huang.

In previous research, the advanced backcross strategy was applied for the first time in wheat in order to introduce and map QTL from unadapted germ plasm via synthetic wheat lines. In the BC_2F_2 winter wheat population 'Prinz/W-7984', a total of 40 putative QTL for agronomic and plant morphologic characters were mapped (Huang et al. 2003). In the BC_2F_2 winter wheat population' Flair/XX86', a total of 57 putative QTL were identified and mapped (Huang et al. 2004). In order to test the stability of the detected QTL, the BC_2 population 'Prinz/W-7984' was advanced to BC_3 and reëvaluated in the field for QTL. Among the characters, total grain yield, heading date, plant height, number of tillers (spikes)/area, and 1,000-kernel weight, the 1,000-kernel weight turned out to be the most stable character. Of eight QTL for 1,000-kernel weight detected in the BC_2 of 'Prinz/W-7984', five QTL were detected in the BC_3 at similar mapping positions on chromosomes 2D, 4D, 7B (two QTL), and 7D. Coinciding mapping positions of QTL for 1,000-kernel weight among the two BC_2 populations 'Prinz/W-7984' and 'Flair/XX86' were detected for chromosomes 2A, 2D, and 7D. For further verification and fine mapping of the respective QTL, both mapping populations were advanced to BC_4, and the resulting NILs currently are being used to develop segregating F_2-populations.

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Salt tolerance.

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Fifty-four winter and 32 spring bread wheat and 18 different tetraploid accessions (*T. durum* subsp. *dicoccum* and subsp. *polonicum*) from Georgia were tested for salt tolerance at the germination stage. In addition, several Georgian endemics were investigated under salt-stress conditions, among them 25 hexaploid (*T. aestivum* subsp. *macha* and *T. zhukovskyi*) and 16 tetraploid (*T. turgidum* subsp. *carthlicum*, *T. karamyschevii*, and *T. timopheevii* subsp. *timopheevii*) accessions. Tests were made with three different sodium chloride solutions (1 %, 1.5 %, and 2 %) and distilled water as control.

In general the hexaploid species showed a higher salt tolerance compared to the tetraploids. The Georgian endemic winter wheat *T. aestivum* subsp. *macha* exhibited a better tolerance under salt stress conditions than both winter and summer *T. aestivum* accessions. Because of an increased inability to elongate shoots in 2 % sodium chloride, the hexaploid wheats from Georgia were considered as moderately salt tolerant.

Within the tetraploid accessions, no large differences with respect to salt tolerance were observed. Compared to *T. turgidum* subsp. *dicoccum* and *T. turgidum* subsp. *durum,* the endemic *T. turgidum* subsp. *carthlicum* accessions showed the best development under salt-stress conditions.

Copper tolerance.

Using different genetic stocks, loci for copper tolerance were mapped on the homoeologous group 5 of wheat.

Chromosome 5A. Single-chromosome, recombinant inbred lines for chromosome 5A, originating from a cross between the substitution lines Chinese Spring/*T. aestivum* subsp. *spelta* 5A and Chinese Spring/Cheyenne 5A, were mapped using microsatellite markers and screened in the greenhouse for copper tolerance. A region influencing Cu tolerance was found on the long arm of chromosome 5A. The role of this region was reinforced by screening Chinese Spring homozygous deletion lines for chromosome 5AL.

Chromosome 5B. Single-chromosome, recombinant inbred lines for chromosome 5B, originating from a cross between Chinese Spring and a Chinese Spring/Cheyenne 5B substitution line, were mapped using microsatellite markers and screened in the greenhouse for copper tolerance. A minor QTL affecting Cu-tolerance was identified on the long arm of chromosome 5B close to the centromere, which was nearly in the same position as the the QTL influencing Cu tolerance mapped earlier in the ITMI mapping population.

Chromosome 5D. Screening Chinese Spring 5DL homozygous deletion lines for copper tolerance, the locus affecting Cu tolerance was mapped on the telomeric end of chromosome 5DL. In the ITMI mapping population, the greatest effect for Cu tolerance was found in another region of chromosome 5D, however, the deletions used for this analysis are far from this region and, therefore, not suitable to find effects located there.

Preharvest sprouting/dormancy.

A set of 85 *Triticum aestivum* cultivar Chinese Spring–*Ae. tauschii* introgression lines developed at IPK Gatersleben was cultivated under greenhouse conditions in 2004. The lines were evaluated for the domestication traits preharvest sprouting and dormancy (germination) in order to discover the influence of the D genome on these traits. Single-chromosome introgression lines offer the study of QTL specific for individual chromosomes. From the results of other mapping populations, no indication was evident for an influence of the D genome. However, a major QTL could be found for dormancy on the long arm of chromosome 6D and additionally a minor QTL on the short arm of chromosome 6D. No QTL could be localized for preharvest sprouting. To verify the detected QTL, a replication of the tests will be done under field conditions in 2005.

Geographical mapping of morphological/color traits.

Using the morphological classification system applied in the Gatersleben genebank for hexaploid wheat, it became possible to divide the collection in respect to the presence or absence of single morphological traits. The characters presence/absence of awns, awn color, glume color, presence/absence of hairs on glumes, presence/absence of inflate spike type, spike density, grain color, stem filling, and presence/absence of ligules were considered. Combining the morphological data with the data of the countries of origin the global distributions of the traits were estimated. Whereas some traits (presence/absence of awns, awn color, glume color, presence/absence of hairs on glumes, and stem filling) occur preferentially in certain geographical regions, others (presence/absence of inflate spike type, spike density, grain color, and presence/absence of ligules) seem to be randomly distributed.

Classification of tetraploid wheat.

A total of 99 accessions belonging to 13 tetraploid wheat species were analyzed together with Kamut wheat using 28 wheat microsatellite markers (WMS) mapped on the A and B genomes of hexaploid wheat (two/chromosome). In total, 453 alleles were detected. The average PIC value was 0.80. Genetic similarity values between accessions were used to produce a dendrogram. Major groups of accessions reflecting taxonomical groups were distinguishable. Kamut wheats were found in one cluster together with three accessions of *T. turgidum* subsp. *polonicum* and three accessions of *T. turgidum* subsp. *durum*, which were originated from Turkey, Iraq, Iran, and Israel. We concluded that Kamut is a product of a hybridization between *T. turgidum subsp. durum* and *T. turgidum* subsp. *polonicum* which took place in the area of the Fertile Crescent.

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ITEMS FROM HUNGARY

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Wheat season. Due to the mild winter, the cereals overwintered without damage. The spring, which was cooler and wetter than usual, favored the development of wheat, and the hot weather characteristic of July did not prevent grain filling. Thanks to the extremely favorable weather, the wheat yield average was higher than expected (5.1 t/ha).

Breeding.

Z. Bedö, L. Láng, O. Veisz, G. Vida, I. Karsai, K. Mészáros, and M. Rakszegi.

Breeding. Four new winter wheat cultivars were registered in 2004.

Mv Regiment (Mv 05-02), an early maturing, high-yielding cultivar with good abiotic stress resistance, was selected from the cross 'GA901273-46-I/F6038W12-1'. This cultivar has good frost resistance and tolerates high temperature during the grain filling period. Mv Regiment is resistant to powdery mildew, moderately susceptible to the local races of leaf rust, and susceptible to yellow rust. Mv Regiment is a medium-quality, soft wheat.

Mv Hombár (Mv 06-02) is an early maturing cultivar with high yield potential and good yield stability. The cultivar has the parentage 'GA90078-I/MV-Matador'. Mv Hombár has good resistance to frost and powdery mildew and is moderately resistant to leaf rust and yellow rust. The cultivar has a soft kernel type, with extremely high wet gluten (37–39 %) and higher than average protein content. The rheological quality measured by a Farinograph is poor.

Mv Táltos (Mv 07-02, F4549W2-1/FATIMA) is an average quality bread wheat with competitive yield potential. The average gluten content is 30 %, and the gluten is strong and elastic, resulting in good B1–A2 Farinograph quality. Mv Táltos is not sensitive to sprouting and has good quality stability. Mv Táltos matures early and has reliable winter hardiness. Drought tolerance has been proved in very dry seasons.

Mv Kemence, (Mv 10-02), a good quality, hard-kernel bread wheat, was selected from the cross 'F885K4-1/MV Magdalena'. The wet gluten content varies between 30–34 %, and the farinograph quality is typically A2, rarely B1. Mv Kemence is agronomic characters are favorable, and reliable winter hardiness is associated with good lodging resistance. The cultivar is moderately resistant to powdery mildew and leaf and yellow rusts.

Kernel-hardness studies. We established that not only the hexaploid species, but also the diploid species studied all contained genes for puroindoline-a and puroindoline-b. Among the hexaploid cultivars tested, a Gly (46)–Ser (46) mutation was detected in the Bánkúti 1201 population. The glycine–serine sequence exchange influences grain hardness by inducing a reduction in hydrophobicity. Two genotypes with hard grains were found among the diploid species. In the tetraploid group of species, three soft-grained genotypes were detected containing puroindoline genes, despite the fact that they had no D genome. In the tetraploid species, deletions or point mutations were detected in the puroindoline-b sequence, resulting in a lack of protein expression or in changes in the structure and lipid-binding ability of the puroindoline proteins. As a result, the endosperm structure is hard. The analysis indicated that a deletion is to be found in the puroindoline-b gene of the tetraploid *T. turgidum* subsp. *petropavlovsky* (AB), as the result of which, no protein is expressed, so the grain type is hard. These lines can be used to increase the genetic diversity of wheat.

Cultivar identification by microsatellite markers. A total of 96 winter wheat cultivars registered in Hungary were analyzed using microsatellite markers. All the markers identified using SSR primers were located not only on different chromosomes but on different chromosome arms. Fifteen primers were tested on the complete cultivar collection. A total of 91 amplified fragments were obtained with sizes ranging from 123–239 bp. The largest number of alleles was recorded for primer pair GWM219 (11) and the smallest for primer pairs GWM664 and GWM415 (2). Several reactions included allele sizes characteristic of a single or a small number of varieties. The 96 cultivars could be distinguished using a maximum of nine markers.

Disease-resistance studies. An artificially inoculated nursery was studies for the degree of infection of genotypes with known stem rust-resistance genes. We found that cultivars with the *Sr36* gene continued to be free of stem rust infection in 2004. Resistant infection type, combined with less than 20 % severity, was observed for genotypes with the genes *Sr9d, Sr11, Sr30, Sr31,* and *SrDr*, and for the gene combination *Sr5+Sr6+Sr8+Sr17*.

Within the framework of international (Bioexploit-EU FP6) and Hungarian (NKTH) projects, leaf rust-resistance genes that can be traced with PCR-based markers in molecular marker-assisted selection (*Lr9, Lr19, Lr24, Lr25, Lr29, Lr35, Lr 37,* and *Lr47*) are identified and traced in the progeny populations of crosses between four Martonvásár cultivars and sources carrying these resistance genes. Phenotypic analysis has commenced for 16 populations in the artificially inoculated nursery.

Powdery mildew isolates collected in the neighborhood of Martonvásár are used to determine the race composition of the pathogen population, the level of virulence and the efficiency of known resistance genes. The dominant wheat powdery mildew races (and their frequency) in 2004 were 51 (25.5 %), 72 (17.2 %), 90 (11.5 %), 76 (10.4 %), and 63 (6.8%). The number of virulence genes in the pathogen populations averaged 5.71. Almost complete resistance to the tested wheat powdery mildew isolates was provided by resistance gene *Pm4a*. In addition, the virulence in the pathogen population was less than 20 % on cultivars with genes *Pm1+Pm2+Pm9, Pm3b,* and *Pm3d*.

The field resistance of Martonvásár wheat cultivars and breeding lines, and of potential resistance sources, to FHB was examined under artificially inoculated conditions in an irrigated nursery. Among the winter wheat cultivars, the resistance of Martonvasari 4, Mv Magdalena, and Mv Emese was better than the average of the tested cultivars.

The resistance of a number of cultivars and breeding lines to the fungus species *P. tritici-repentis*, which causes tan spot on *Gramineae*, and *Phaeosphaeria nodorum*, responsible for leaf and glume blotch in wheat, was determined after artificial inoculation in the seedling and adult-plant stages. Results so far suggest that there are significant differences between the cultivars in susceptibility to both diseases.

Abiotic stress resistance studies. The individual effects and interactions of climatic extremes, soil, water, and temperature on plants were investigated in experiments set up in an artificial environment system as part of the meteorological research involved in the Agroecological Program. Drought stress was applied in five different stages of development to determine its effect on the yield components of the wheat cultivars Mv Emma and Mv Martina. On the basis of phenological data and yield, the plants are most sensitive to drought from flowering to milky ripeness, very sensitive between booting and heading, and moderately sensitive from shooting to booting, especially if the length of each stage is considered. We found that drought stress during the sensitive period may cause yield losses as great as those caused by permanent water deficiency.

Studies were also made on the relationship between abiotic stress factors (drought) and pathogen infection (*P. tritici-repentis*) and on the phenomenon of cross-tolerance to abiotic and biotic stress factors. We concluded from the results that the biomass production of the plants declined linearly as the concentration of the PEG-6000 solution increased. As the result of infection with the pathogen, there was a further decrease in biomass production. Genotypes susceptible to the pathogen were infected to a significantly lower extent than the control plants after treatment with 5 and 10 % PEG, thus confirming the existence of cross-tolerance.

Within the framework of environment protection research involving the effects of global climate change, investigations were made on how interactions between nitrogen supplies, heat stress during ripening and increased atmospheric CO_2 level affected the development and yield of winter wheat cultivars. Heat stress was found to result in forced ripening, resulting in reduced biomass and yield, and poorer dough quality. The yield-reducing effect of heat stress was relatively greater at high nitrogen supply levels than with more modest nutrient supplies. An increased level of atmospheric CO_2 was able to counteract, totally or in part, the reductions in biomass and yield caused by heat stress. With low nitrogen supplies, the biomass and yield-increasing effect of a rise in the atmospheric CO_2 level was observed to a lesser extent, if at all.

Studies were made on the effects of soil nitrogen and phosphorus supplies and of the doubled atmospheric CO_2 level on winter wheat cultivars. Plants ripen early in the case of nutrient deficiencies, and the doubled CO_2 level caused them to ripen even earlier. At high nutrient levels the number of grains increased, but their size remained the same or decreased. The yield quality, however, was determined to a greater extent by variety traits than by the quantity of nutrients. At twice the normal CO_2 concentration, there was generally a deterioration in yield quality, but this was only pronounced in the case of poor nutrient supplies. Phosphorus deficiency combined with high levels of soil nitrogen prevented an increase in the protein and gluten contents of the grain.

Durum wheat breeding. One new winter durum cultivar was registered in 2004.

Mv Gyémánt (Mv22-01, GK Basa/DF33//Krisztall2/3/Parusz/4/DF623/5/GKD11-12) is a winter-hardy, high-yielding, winter durum wheat with good pasta-making quality. Mv Gyémánt had one of the best values of cold tolerance of all the breeding lines tested, with a survival rate in the phytotron at –15°C of over 80 %, which is an outstanding achievement for a winter durum wheat genotype. This level of cold tolerance is combined with high yellow pigment and protein content.

Durum quality. The elaboration of a marker-assisted method to improve the efficiency of selection for yellow pigment content in durum wheat was continued in 2004. Several polymorphic RAPD and SSR markers have been identified in tests on previously developed recombinant lines and on the parental varieties of these populations.

Studies were made on the yellow index values of 198 lines originating from the 'MvTD10-98/PWD1216' combination of winter durum wheat. The difference in the yellow index values of the two parents considerably exceeded the $LSD_{5\%}$ value. The Minolta 'b' value of the parent with the lower yellow pigment content (MvTD10-98) was 18.46 in 2002 and 21.19 in 2004, and no values lower than this were recorded for any of the lines, but nor were any lines found with values higher than that of the parent with the higher yellow index (PWD1216 = 25.98). The yellow index of five lines did not differ significantly from that of the better parent. The yellow index also was significantly influenced by the year, but there was no substantial difference over the years for the order of progeny with values close to the parental values. Efficient selection for both positive and negative values of yellow pigment can be carried out in early progeny generations.

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Cell Biology Department

B. Barnabás, M. Molnár-Láng, É. Darkó, É. Szakács, and I. Takács.

Effect of cyanobacterial and microalgal biomass on anther culture response of wheat. We investigated the influence of media supplemented with a biomass of four terrestrial and freshwater microalgal and cyanobacterial strains (1-2 g/l) on the androgenic response, frequency of microspore-derived embryo-like structures, and their regeneration capacity in anther cultures of wheat. The addition of 1 g/l of cyanobacterium biomass MACC 643 to induction and regeneration media significantly improved the androgenic response by 50 % in the genotype Mv Pálma and reduced the requirement for the synthetic auxin 2,4-D.

Regeneration of haploid plants from activated egg cells of wheat via zygote rescue. Haploid wheat plants were produced by a new method of zygote rescue carried out after distant pollination. Wheat stigmas were pollinated with maize pollen and subsequently the activated egg cells from the elongated ovaries were rescued for *in vitro* plant development in single cell culture. As a control, older embryos also were dissected and subsequently cultured. The efficiency was comparable with both the techniques applied. Taking into consideration that the lack of a normal endosperm hampers embryo development even in the early stages, early zygote rescue after distant pollination may represent a more efficient way of producing DH plants in cultivars which are recalcitrant in androgenic cultures, after further optimization of the *in vitro* culture of isolated single cells.

Identification of a new class of recombinant prolamin genes in wheat. A novel storage-protein gene with obvious chimeric structure was isolated from an immature kernel-specific cDNA library prepared from the old Hungarian cultivar Bánkúti 1201. This clone contains γ-gliadin sequences on the 5’ region and LMW-glutenin sequences on the 3’ end. A frameshift mutation also was introduced by the putative recombination event, thus, the amino acid sequence of the Cterminal region was transformed to a completely new polypeptide. Based on this finding, seven additional recombinant prolamin genes of similar structure were isolated with specific PCR primers. The eight chimeric clones seem to be derived from four individual γ-gliadin and three LMW-glutenin sequences. These genes show remarkable diversity in terms of size, gliadin/glutenin ratio, frameshift mutations, and sulphur content as well. The putative functional characteristics of the chimeric polypeptides and problems related to the origin of the encoding genes are discussed.

Detection of the T1A·1R wheat/rye translocation in new Martonvásár wheat cultivars and advanced lines using in situ hybridization. Several types of rye translocation carrying major resistance genes are to be found in the foreign and Hungarian wheat varieties currently under cultivation. The T1B·1R translocation involving the 1RS chromosome arm from the rye cultivar Petkus can be detected in many of the Martonvásár wheat cultivars registered in earlier years. The presence of the T1A·1R translocation was first detected by C-banding in the Mv Dalma. Recently, 13 new Martonvásár cultivars and advanced lines were tested to discover whether they carried this rye chromosome segment. The presence of rye translocations was demonstrated using GISH, whereas the chromosomes were identified by means of FISH. The DNA probe used in FISH was the pSc119.2 repetitive sequence, which exhibits a specific hybridization pattern on the long arm of chromosomes 1A and 1B, allowing the two types of rye translocation to be identified unambiguously. We demonstrated that, of the genotypes examined, Mv Táltos, Mv 07-03, Mv 08-03, and Mv 12-04 contained the T1B·1R translocation, whereas Mv Gorsium and Mv Walzer carried the T1B·1R translocation. Pedigree analysis on the tested cultivars indicated that the sources of the T1A·1R translocation in the Martonvásár wheat breeding program were the wheat lines GA90078-I, F4549-W2-1, and F4831, which can all be traced back to the wheat cultivar Amigo.

Physiological and morphological responses to water stress in *Ae. biuncialis* and *T. aestivum* genotypes with differing tolerance to drought. The physiological and morphological responses to water stress induced by PEG or by withholding water were investigated in *Ae. biuncialis* genotypes differing in the annual rainfall of their habitat (1,050, 550, and 225 mm/year) and in *T. aestivum* wheat genotypes differing in drought tolerance, in order to find *Ae. biuncialis* accessions suitable for improving drought tolerance in wheat through intergeneric crossing. A decrease in the osmotic pressure of the nutrient solution from –0.027 MPa to –1.8 MPa resulted in intense water loss, a low extent of stomatal closure, and a decrease in the intercellular CO_2 concentration (C_i) in *Aegilops* genotypes originating from dry habitats, whereas in wheat genotypes, high osmotic stress induced increased stomatal closure, resulting in a low level of water loss and high C_i. Nevertheless, under saturating light at a normal atmospheric CO_2 level, the rate of CO_2 assimilation was higher for the *Aegilops* accessions under strong osmotic stress than for the wheats. Moreover, in the wheat genotypes, CO_2 assimilation exhibited less or no O_2 sensitivity. These physiological responses were manifested in changes in the growth rate and biomass production, because *Aegilops* genotypes (*Ae*550 and *Ae*225) retained a higher growth rate (especially in the roots), biomass production and yield formation after drought stress than wheat.

On the basis of these results, *Aegilops* genotypes originating from a dry habitat seem to have better drought tolerance than wheat, making them good candidates for improving the drought tolerance of wheat through intergeneric crossing.

Changes in the meiotic pairing behavior of a winter wheat–winter barley hybrid maintained for a long period in tissue culture and tracing the barley chromatin in the progenies using GISH and SSR markers. Our aim was to produce backcross progenies in a new 'winter wheat (Asakaze komugi) / 6-row winter barley (Manas)' hybrid produced in Martonvásár. Because no backcross seeds were obtained on the initial hybrids, young inflorescences of the hybrids were used for *in vitro* multiplication in three consecutive cycles until a backcross progeny was developed. The chromosome constitution of the regenerated hybrids was analyzed using GISH after each *in vitro* multiplication cycle. The seven barley chromosomes were present even after the third *in vitro* multiplication cycle, but abnormalities were observed. Sixteen BC_2 plants shown by GISH analysis to contain one to three complete barley chromosomes, two deletion barley chromosomes, and a dicentric wheat–barley translocation were grown to maturity from the single backcross progeny. The barley chromatin was identified using 20 chromosome-specific barley SSR markers. All seven barley chromosomes were represented in the BC_2 plants. A deletion breakpoint at FL ±0.3 on the 5HL chromosome arm facilitated the physical localization of microsatellite markers.

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Genetic and physiological studies.

G. Galiba, G. Kocsy, T. Janda, G. Kovács, E. Páldi, G. Szalai, A. Vágújfalvi, B. Tóth, E. Horváth, and M. Pál.

Stress-induced antioxidant responses. In the following experiments, changes induced by cold treatment and drought stress in the activity of the antioxidant enzyme system were investigated in the wheat cultivars Cheyenne (frost resistant) and Chinese Spring (frost sensitive). In Cheyenne, both drought and cold treatment caused a significant increase in the activity of catalase, ascorbate peroxidase, and guaiacol peroxidase. In Chinese Spring, however, only drought stress led to an increase in activity in the case of catalase and ascorbate peroxidase. No significant change in the glutathione reductase activity were observed either after 2 days of cold hardening at 5°C or after 1 day of drought stress in either genotype. Salicylic acid did not increase the stress tolerance of wheat; it diminished the frost resistance of the winter wheat Cheyenne and the drought tolerance of the spring wheat Chinese Spring despite stimulating the activity of the guaiacol peroxidase and ascorbate peroxidase enzymes. The ability of p-hydroxybenzoic acid to improve abiotic stress tolerance was demonstrated for the first time; it was found to increase drought tolerance in Cheyenne and frost resistance in Chinese Spring. The increase in catalase activity could be responsible for the induction of drought tolerance. The frost resistance of Cheyenne increased as the result of drought stress, especially after preliminary treatment with p-hydroxybenzoic acid. In Chinese Spring, the effect of drought stress on frost resistance was ambiguous. Although it reduced damage to the photosynthetic system in the course of frost stress, the plants suffered substantial membrane damage.

Genetic resources. The growing interest in hulled wheat cultivation has no doubt been stimulated by the increasing demand for traditional foods with an image of naturalness, especially on the organic market. The new economic situation could stimulate the breeding and production of emmer and einkorn as the source of an especially valuable foodstuff. Based on the intensively growing market needs, the establishment of organic breeding procedures has been initiated in the case of einkorn and emmer. Several hundreds of genebank accessions from these two species have been characterized in recent years. The results suggest that their direct use in breeding is greatly hindered, however, by the fact that the lots stored in the genebank are very heterogeneous populations. In recent years, several pure lines have been produced using the single seed descent method, and the lines obtained have been agronomically described. The genetically extreme genotypes were crossed to produce mapping populations for further molecular studies. The best lines were used in organic breeding. In the case of einkorn, the lines obtained were tested under low-input conditions and their yielding capacity has found to be already higher than 3 t/ha. During the einkorn improvement procedure, a new semidwarf genotype was identified and genetically analyzed. According to the results of a recent experiment, this genotype carries a recessive monogenic dwarf gene, which should be highly useful in producing semidwarf einkorn cultivars.

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Breeding activity.

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During the past 4 years, 21 new winter wheat cultivars have been released for Hungary. The released cultivars with the full parentage are given in Table 1. Some of the released cultivars have achieved a significant acreage in Hungary and have special agronomic and breeding value.

Table 1. Pedigree information of the recently release cultivars from the Cereal Research Non-Profit Company, Szeged, Hungary.

Cultivar	Year of release	Pedigree
GK Bagoly	2000	Mv16 / Zg241
GK Sas	2000	Mv16 / Zg241
GK Szivarvany	2000	Zg241 / Othalom // Mv17 / Othalom
GK Szalka	2000	Garaboly / Mv 22
GK Raba	2000	Bucsanyi 20 / HE 82
GK Csongrad	2001	Kincso / 2*Mini Mano // Kincso / Istvan
GK Heja	2001	Mv16 / Zugoly
GK Hollo	2001	Mv16 / Zugoly C.12
GK Tunder	2001	Zugoly / 85.50
GK Ati	2001	2*Mv4 /3/ Jkm / Rna2 // Gm / D1 /4/ Mini Mano
GK Margit	2001	Ck983 / Gb // Mini Mano / Reka
GK Jutka	2001	Ck983 / Gb // Mini Mano / Reka
GK Hattyu	2002	Gobe / Othalom / Mini Mano
GK Cinege	2002	Zugoly / Élet
GK Smaragd	2002	2*Istvan / Gobe
GK Rubintos	2002	2*Mv4 /3/ Jkm /Rna2 // Gm / D1 /4/ Mini Mano
GK Ledava	2002	E34 / 76.1.142 // Zg5007 / GK020684
GK Tisza 1	2003	Tiszataj / Zombor
GK Kapos	2003	GKT5 // Sz1500 / Ttj /3/ 4470
GK Piacos	2003	Mv15 / BLFA8
GK Hargita	2003	David / Kalasz

GK Ati is a premium quality wheat, comparable to Canadian hard red wheats. This cultivar has a gluten content of approximately 40 per cent with excellent gluten quality and a hard endosperm, short straw, an average yield potential, but moderate winter hardiness. One special characteristic is better tolerance to *Olemma melanopus* than all other cultivars in Hungary.

GK Bagoly is an early cultivar with a high yield potential and good resistance to leaf and stem rust. In addition to a high gluten content (33–35 %) and acceptable baking quality, GK Bagoly has the hardest kernel endosperm structure among the GK cultivars.

GK Cinege is a very early cultivar with good baking quality with brown glumes.

GK Csongrad is an early ripening cultivar and one of the firsts in yielding ability in Hungary. In the past dry years, it was one of the best in drought tolerance. The cultivar is resistant to stem rust (carries *Sr36*) and moderately susceptible to leaf rust and powdery mildew. Wet gluten content (33–35 %) and the bread making quality also are high.

GK Hargita is an early, awnless cultivar with a high yield potential. The wet gluten content is 32–34 %, the Farinograf quality 68–86. GK Hargita has good resistance to leaf rust, yellow rust, and leaf spots.

GK Hattyu is one of the standard cultivars of the intermediate-maturity group, with a very attractive plant type (strong straw, white head, and good stand). Baking quality is moderate.

GK Hollo is the standard cultivar of the late-maturity group in Hungary. In addition to a high yield potential, GH Hollo has a strong resistance to all the foliar diseases in Hungary, a gluten content of 35–38, and good baking quality but intermediate kernel hardness. Because of its tall straw, this cultivar is capable to lodging under high-input conditions.

GK Tisza is a new premium quality wheat with an average yield potential.

During the past 5 years, two new winter durum wheat cultivars (GK Selyemdur and GK Diadur) have been released for Hungary.

GK Betadur is the leading standard durum cultivar in the Hungarian production (with an 80 % acreage of the total durum fields), because of its excellent milling and pasta quality. This cultivar was registered in Serbia-Montenegro and has a license in Romania.

GK Selyemdur (registered in 2001) has the same quality as GK Betadur but with an improved yield potential. The acreage is increasing and in 2004 it reached the 10 % of the total durum area.

Multi location yield tests are set for testing the adaptability of our advanced lines. Adaptability, which is highly dependent on drought, winter tolerance, and sink-source capacity, is a crucial characteristic in wheat. Our tests are usually planted at ten locations under different conditions (soil type, altitude, precipitation, lowest temperature in winter, high and low input, and sowing time). At any location, 40–60 genotypes in four replications are tested excluding the check cultivars. Yield and yield components such as 1,000-kernel weight and some agronomic parameters are evaluated to find the best yielding cultivar that are adaptable to abiotic stresses.

Advances lines also were tested for frost resistance in a growth chamber. At flowering time, experiments estimating sink and source capacity were executed. Some of the most important quality parameters of the sample of each location, such as gluten content and hardiness index also were measured by MININFRA (NIR method on full seeds) to measure the stability of these parameters. Year by year, the multilocation trials are the basis of the development of our new winter wheat and winter durum wheat cultivars.

Abiotic stress resistance studies.

L. Cseuz.

Within the framework of Wheat Consortium on Research supported by the Hungarian Ministry of Education, our advanced wheat lines were tested for drought tolerance as a selection tool in our breeding system.

Water retention ability (WRA) was determined from the fresh mass of three excised leaves of 70 genotypes (registered cultivars and candidates) harvested from the field early in the morning. After maintaining in Petri dishes on wet filter paper for 24 h, the turgid mass was measured, and the leaves desiccated for 8 hrs in controlled conditions (65 % relative humidity and 24°C). After measuring their desiccated mass, the dry mass of the flag leaf was determined after a total desiccation. From these data, the initial relative water content (RWCi) and the desiccated relative water content (RWCd) were calculated. WRA was evaluated by comparing the reduction of RWC among the genotypes tested: (RWCd/RWCi) x 100 (%). We found a 40–90 % variation in the relative water content of the excised leaves after 8 hr desiccation in the year 2002 and 20–78 % water loss in 2003. The initial relative water content of flag leaves at dawn was between 69–96 % and 83–99 % among the 70/100 genotypes tested. On average, flag leaves could take up ~ 20 % in 2002 and 7 % water, to the initial RWC. After the 8 h desiccation, the flag leaves could retain 55 % and 37 % of their initial RWC on average. Genotypes with the best WRA could retain 80 % of their initial RWC, whereas the poor genotypes could only retain 21 %. In 2003, genotypes with higher WRA retained 67.85 %, whereas those with the lowest WRA value only retained 16.73 % of their initial RWC.

Chemical desiccation tests were made to evaluate the translocation ability of the stem reserves in 100 genotypes. Each entry was sprayed with a desiccant (2 % $NaClO_3$ solution) 14 days after anthesis. Kernel weight reductions due to the postanthesis stress were assessed by comparing treated and control plots for each entry. Wheat cultivars differed between 16.7–55 % in reduction of kernel mass, and this response was correlated with the response to the late season drought among the genotypes tested. In 2002, kernel mass was reduced by 34.6 % on average in the tested genotypes. The desiccant treatment caused expressive depression in kernel mass, and significant differences were found among the 70 entries. Hundreds of lines can be evaluated relatively fast and easy with these tests. In 2003, the depression of kernel mass was 38.9 %, and a great variation were found among the 100 tested genotypes (12.4–43 %).

Remote measurements of canopy temperature were done with a hand-held infrared thermometer (Crop Trak IR Thermometer Spectrum Inc.). In the nonstressed experiment, canopy temperatures were measured in three repetitions 2 to 5 days after each irrigation. Measurements were done at midday, under sunny, windless conditions at heading stage in a stressed (rainfed) and in an irrigated trial. Three repetitions and check cultivars established the right calibration. The thermometer was pointed down from a distance of 1 m to avoid the influence of soil exposure. In 2002, canopy temperature was 23.6˚C, varying between 22.2 and 25.1°C, whereas the air temperature was 32°C. No significant difference was detected between the stressed and irrigated plots in canopy temperature under heat and drought stress. In 2003, the spring also was dry and hot. The drought continued until June, and irrigation treatments significantly affected plant growth and production. The average canopy temperature of the plots in the nonstressed environment (irrigated) was 22.85°C, whereas it was 26.47°C under stressed conditions. Extreme values in the irrigated treatment had less of a difference (20.1–25.0°C) than in the control plots (25.07–31.07°C). On average, drought increased the temperature of canopy surface by 3.61°C, which equals 13.61 %.

Haploid biotechnology and genetic transformation.

C. Lantos, E.F. Juhasz, R. Mihaly, A. Mesterhazy, L. Cseuz, M. Csösz, D. Dudits, and J. Pauk.

Wheat anther culture. Doubled haploid wheat lines were produced by anther culture, and these lines have been integrated into breeding programs. For genetic research, mapping populations have been generated by anther culture to study the genetic background of drought tolerance and FHB and *Dreschlera* resistance. DH lines were induced from a segregating F_2 population using sensitive and resistant parents in crosses. The size of mapping populations are designed for about 160–160 DH individuals.

Isolated microspore culture. Isolated microspore culture is a special field of haploid technology. Intensive research has been cone on isolated microspore culture of wheat, triticale, and rice. The effect of different media were studied on induction of androgenesis. Different basic media and hormonal combinations were tested and compared. The best results were shown by a modified W14 medium supplemented by 0.5–0.5 mg/l 2.4-D and kinetin. Ten elite genotypes were tested in isolated microspore culture. All ten genotypes were responsive and able to product embryo-like structures. Green plants were regenerated from microspore derived embryos in case of seven varieties. To date, the bottleneck of microspore culture of cereals is the green plant regeneration.

Anther and microspore culture based haploid technology have been applied for *in vitro* selection of segregated transgenic populations at cell level. Stability of inheritance of the *bar* gene was studied in anther culture and *in vitro* microspore culture. Finally, DH transgenic wheat lines (TDH) were selected and generated using haploid-induction methods.

Genetic transformation (ALR). Climatic changes indicated some years ago that new molecular-genetic research was needed for the hunt for drought-resistance genes and gene-regulating elements. Without doubt, any agronomically important crops are expressing enhanced oxidative stress tolerance would be of great commercial value, because many limiting factors for plant performance involve oxidative stress.

The aldose reductase (ALR) gene was isolated from alfalfa (MsALR) and constructed into a plant expression vector (pAHC25) named pAHALR. Young embryos were bombarded with this plasmid. The transformed calli were cultured and selected on medium containing 20 mg/l ppt as selective agent. For the molecular analysis of transgenic samples, PCR and Western hybridizations were made. The activity of ALR also was investigated on the transgenic plants by biochemical and physiological analysis.

Use of molecular markers in the resistance breeding to rust diseases and Fusarium head blight in wheat.

L. Purnhauser, M. Tar, G. Kaszony, M. Csösz, and A. Mesterhazy.

The NILs of *Lr20* and *Lr52* and its recurrent parent *Thatcher*, were used to identify AFLP, RAPD, and SSR markers linked to *Lr20* and *Lr52*. An F_2 populations from a cross between the resistant NIL *Lr20, NIL Lr52,* and the susceptible cultivar GK Deliba were used to map the linked markers. Segregation of *Lr20* and *Lr52* for resistance was evaluated using artificial infection. Out of 135 AFLP primer combinations tested, 32 showed polymorphism between the *NIL Lr20* and GK Delibab. However, no linkage was found between these bands and the resistant phenotype. In addition, 15 microsatellite primers between the *NIL Lr20* and GK Delibab also were tested. Three were polymorphic, but only one of them was linked to the *Lr20*. RAPD and SSR primers were tested between the *NIL Lr52* and *GK Delibab*. *Lr29,* for which we previously found linked RAPD marker, a new S-SAP marker and several microsatellite markers also linked to *Lr29* were identified. Marker-assisted selection was initiated to transfer *Lr1, Lr19, Lr20, Lr29, Lr24,* and *Lr37,* and *Sr36* genes to six Hungarian wheat cultivars.

In our *Fusarium*-resistance project, some exotic resistance sources (including Sumai 3, Nobeoka bozu, and Ringo Star) are used to transfer FHB tolerance to the agronomically better, but susceptible Hungarian wheat cultivars. The objective of this study was to characterize the wheat lines for FHB tolerance by the use of several microsatellite markers specific for FHB QTL (identified in Sumai 3) at chromosomes 2BS, 3BS, 5A, and 6BS, and to evaluate the correlation between the FHB tolerance and the presence of markers in wheat lines developed in the FHB-resistance program. The results showed that the level of tolerance in some new lines reached that of the resistance sources. The presence of markers showed a fairly good association with the phenotipic tolerance data especially for markers specific for 3BS chromosome. These markers are used in our MAS program for FHB tolerance.

Acknowledgement. This research was supported by a postdoctoral OTKA grant D38486.

Role of free phenols in resistance to cereal leaf beetle and bird cherry oat aphid in winter wheat leaves.

M. Papp, M. Varga, T. Bartok, A Mesterhazy, Z. Kertesz, and J. Matuz.

Resistance to the cereal leaf beetle and bird cherry-oat aphid was tested in 2000–03 on 30 winter wheat cultivars by means of an artificial infestation in field cages covered by insect nets. Highly significant differences were found between cultivars in leaf-feeding damage by *O. melanopus*, infestation severity by *R. padi,* and reduction of yield and 1,000-kernel weight.

The most resistant cultivar had 29 % leaf-feeding damage by *O. melanopus*, and the most susceptible 77 %. The average yield decrease caused by *O. melanopus* was 42 %, with extremes of 24 and 54 %. The correlation between the leaf-feeding damage by *O. melanopus* and the yield loss was significant (r = 0,8208; P < 0,001). Values of infestation by *R. padi* varied between 25 and 47 %. The average yield reduction caused by *R. padi* was 33 %. Yield of the most tolerant cultivar was reduced by 21 %, whereas the most susceptible one was reduced by 51 %. A highly significant correlation was found between infestation severity by *R. padi* and yield reduction (r = 0,8368; P < 0,001). Among the examined cultivars, our new cultivar GK Ati, had significant resistance to *O. melanopus*. Released in 2001, GK Ati was patented in 2004. GK Bagoly and GK Cinege had medium to good resistance to *R. padi*.

The qualitative and quantitative chromatographic analyses of the free phenols and phenolic acids were made from leaf extracts of 26 wheat cultivars collected at booting, heading and milk-ripening. The highest amount of phenols and phenolic acids was detected in wheat leaves at boot stage. At heading and milk-ripening, their quantity was more than 50 % less. Of the phenolic acids, the high concentration of vanillic acid and ferulic acid contents seem to be resistance factors to *O. melanopus*, whereas resistance to *R. padi* correlated closely with the high protocatechuic, ferulic, and caffeic acid concentrations.

Acknowledgement. This work was supported by OTKA Foundation grant No. T°32538.

Genetic variability of Fusarium species pathogenic to wheat in Hungary.

B. Toth, A. Mesterhazy, T. Bartok, and J. Varga.

Fusarium head blight is economically one of the most important fungal diseases of wheat throughout the world. Contamination of wheat by the mycotoxins produced by *F. graminearum* and *F. culmorum* is the most serious effect of FHB, because these mycotoxins, including various trichothecenes (DON and NIV) and zearalenone, are harmful both to humans and animals. We examined the genetic variability of Hungarian populations of *F. graminearum sensu lato* and *F. culmorum* by various molecular and analytical methods. All Hungarian isolates were found to belong to mycotoxin chemotype I, producing DON and/or its acetylated derivatives (predominantly 15-acetyl-DON). The genetic variability of *F. graminearum* isolates was much higher than that of *F. culmorum* isolates during RAPD and IGS-RFLP analyses. Phylogenetic analysis of putative reductase gene sequences let us cluster the *F. culmorum* isolates into three main groups corresponding to European, North American, and Hungarian isolates. For *F. graminearum*, representatives of species other than *F. graminearum sensu stricto* (*F. boothii* and *F. vorosii*) also have been identified in Hungary. Formal description of *F. vorosii* is in progress. Mycoviruses also have been identified in five *F. culmorum* and one *F. graminearum* isolates. A real-time PCR method has been developed to detect Fusaria in wheat. We also identified 16 polyketide synthase (PKS) and 15 nonribosomal peptide synthetase (NRPS) genes in a *F. graminearum* genomic database. Two of these NRPS genes were found to be closely related to peptide synthetases of various fungi taking part in psiderophore biosynthesis. Further studies are in progress to clarify the role of some of the identified PKS and NRPS in pathogenesis..

Acknowledgments. This research was supported by a postdoctoral OTKA grant (D38486). We also thank the NKFP (4/038/2001) and EU (QLK1-CT-1999-01380) for supporting aspects of this work.

Estimating occurrence of the necrotrophic pathogens in Hungary.

M. Csösz.

We started a new project to receive data about the change of occurrence of the necrotrophic pathogens in Szeged in 2000. More than 10.000 leaf samples from 8–13 locations were collected for analysis in March, April, May, and June 2000–04. The previous crop was different at each field (canola, winter canola, peas, mustard, red pepper, sunflower peas black soil, onion, sugar beet, and winter wheat (only 1 place)). The samples were incubated in Petri dishes on wet filter-paper at 20°C for 48–72 h. The necrotrophic fungi (*B. sorokiniana*, *D. tritici-repentis*, *S. tritici*, and *S. nodorum*) were then subject to microscopic identification. Epidemiologically the four diseases have different patterns. The *D. tritici-repentis* and the *S. nodorum* were highest in June, *S. tritici* in April, and *B. sorokiniana* similar in each month, but the measure of the occurrence was not higher than 20 % as an average of 5 years (Table 2). Presence of necrotrophic pathogens was lowest in 2003. We observed significant differences in composition and occurrence of pathogens among the locations and years.

Table 2. Changing of occurrence of necrotrophic pathogens (%) in Hungary between 2000–04.

Month	Year (occurrence (%))					5-year average
	2000	2001	2002	2003	2004	
Drechslera tritici-repentis						
March	—	8.01	1.18	0.00	0.00	2.30
April	0.21	14.53	3.24	0.16	1.21	3.87
May	7.04	8.05	6.03	4.75	17.87	8.75
June	24.67	18.72	6.47	5.06	18.59	14.70
Septoria tritici						
March	—	28.85	1.18	0.00	0.00	7.51
April	22.01	19.80	1.76	0.32	3.33	9.44
May	6.11	11.72	3.38	0.00	11.73	6.59
June	5.98	2.31	2.79	0.47	19.77	6.26
Septoria nodorum						
March	—	11.54	1.03	0.00	0.00	3.14
April	2.73	9.40	1.32	0.00	0.45	2.78
May	5.07	5.13	6.62	0.63	0.80	3.65
June	20.37	31.79	6.47	4.91	22.50	17.21
Bipolaris sorokiniana						
March	—	0.48	0.15	0.00	0.00	0.16
April	4.40	1.00	0.15	0.16	0.00	1.14
May	7.15	1.10	0.00	0.16	0.53	1.79
June	4.30	0.26	0.29	0.47	6.46	2.36

New diabetic cereal products: diabetic powder mixtures for producing diabetic rolls and breads.

E. Acs and Zs. Kovacs.

DIABET-MIX powder mixture is an additional powder containing vegetable protein that can be used for producing diabetic bakery products. The carbohydrate content of rolls and breads baked by using this powder is 30 % less than that of regular baking products and 10 % of the carbohydrate components left in the products is a hardly digestible polysaccharide. This product could be used in a diabetic diet. Using these new products, 50 % or more could be consumed in the diet with the blood glucose level remaining at 30 % or less because of the favorable physiological effects of the powder's polysaccharide content. The effect is clinically tested. These products can be applied to a fat-reducing diet as well, because of slight absorption. Some characteristic data of the diabetic bread and roll include carbohydrates, 37.9 %; protein, 16.6 %; and energy, 948 KJ/100 g. The DIABET-MIX product family and the production technology of items baked using it are under patent.

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Our efforts in wheat breeding continue. Our recent release is **Kg Széphalom**, a high-yielding, semidwarf cultivar with excellent winter hardiness and quality. We started the multiplication of seed. The cultivars registered earlier, Alex (1999), Róna (1998), Hunor (1998), Kg Kunhalom (2002), and Kg Magor (2002), gained in area planted and used more and more widely, especially in the dry plain area.

Because breeding has to meet the requirements of the society, farming, and market, we have to take into consideration of the challenge of the present days. In order to meet the farmer's and market needs and requirements, our breeding strategy based on selection under low-input management and is associated with the tillering capacity, adaptation to the low-input production, and stable yield.

Our strategy involves the increase of biological yield and the improvement of harvest index and good reaction to the fertilizers especially for nitrogen. For this reason, we studied a group of cultivars to learn the genetic advances during the last century. We set up a trial with the leading cultivars of the first half of the 20th century, so-called extensive types. We studied the most widely used cultivars of the second half of the century and, finally, some newer releases.

The cultivars can be grouped according to their yield potential (Table 1). The extensive types of the cultivars produced on average 4.83 t/ha. We took this as 100.00 %. The next generation produced 7.30 t/ha, which means 151.14 % over the previous group. The next group yielded 8.71 t/ha, 180.33 %. These are the leading cultivars at present. The next group of cultivars produced 9.53 t/ha and 197.31 %. The newest cultivar, Kg Kunhalom, was on the top with 10.06 t/ha and 208.33 %. The candidate cultivar Gloria was on the same level and ranked second.

We need to emphasize that the cultural conditions were excellent in 2003–04 crop year.

Table 1. Yield potential of leading cultivars from the 20th century. The percent increase is based on the average for Bánkúti 1201 (for cultivars from the first half of the 20th century, A %), Bezosztája 1 (for cultivars from the second half of the 20th century, B %), and Mv Magdaléna (for the newer releases, C %).

Cultivar	Year of registration	Yield (t/ha)	A %	B %	C %
KG Kunhalom	2002	10.09	230.10	142.92	113.95
Glória	fj.	10.04	228.85	142.14	113.33
Buzogány	1998	9.73	221.89	137.82	109.88
GK Cipó	1998	9.64	219.73	136.47	108.81
Róna	1998	9.60	218.81	135.91	108.36
Alex	1999	9.42	214.71	133.36	106.32
Gaspard	1992	9.41	214.48	133.22	106.21
GK Öthalom	1985	9.39	214.03	132.93	105.99
F 98039 G-51	fj.	9.06	206.61	128.33	102.32
MV 15	1985	8.93	203.53	126.42	100.79
KG Magor	2002	8.92	203.31	126.27	100.68
Mv Pálma	1994	8.91	203.08	126.13	100.56
Mv Magdaléna	1996	8.86	201.94	125.42	**100.00**
Mv Csárdás	1999	8.76	199.66	124.01	98.87
Hunor	1998	8.70	198.40	123.23	98.25
Fatima 2	1992	8.65	197.15	122.45	97.63
Mv Palotás	2000	8.38	190.99	118.63	94.58
GK Élet	1996	8.34	190.08	118.06	94.13
Boema	fj.	8.05	183.47	113.95	90.85
MV 23	1991	7.94	180.96	112.39	89.61
MV 4	1974	7.21	164.31	102.05	81.37
Mv Magvas	1998	7.16	163.17	101.35	80.80
Jubilejnaja 50	1970	7.14	162.83	101.13	80.63
Bezosztája 1	1960	7.06	161.00	**100.00**	**79.73**
Tiszavidéki	—	5.30	120.75	75.00	59.80
FertQdi 293	1960	5.27	120.07	74.58	59.46
Fleischmann	1924	4.70	107.07	66.50	53.02
Bánkúti új	1929	4.51	102.85	63.88	50.93
Bánkúti 1201	1929	4.39	**100.00**	62.11	49.52
$SD_{5\ \%}$		0.75			

We planted at the proper time, which lead to a good tillering and stand establishment. The spring was cool, and the distribution of precipitation unusually excellent. One-hundred thirty kilograms of N fertilizer was applied, so the different yield can be contributed to the genetic yield potential of the cultivars. These data also show the genetic advance in wheat breeding during the last 50 years in Hungary, which is approximately 100 % or more.

The major goal of the breeding at the moment is to enhance the economic viability and competitiveness of the Hungarian wheat production maintaining the quality and marketability meeting the consumer needs, while developing environmentally friendly and efficient processing concepts.

ITEMS FROM INDIA

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Combining quality with durable rust resistance and molecular studies in Indian wheat.

B.K. Das, A. Saini, Ruchi Rai, and S.G. Bhagwat (Nuclear Agriculture & Biotechnology Division) and N. Jawali (Molecular Biology Division).

Genetic improvement of wheat for quality and rust resistance is being continued. HMW-glutenin subunits are being used as a criterion for selection. Rust resistance genes such as *Sr 31* and *Sr24/Lr 24* are being combined with high-yielding ability. Selections made on the basis of good agronomic characters are being advanced.

A SCAR marker ($SCAR30R_{580bp}$) for *Sr31* gene has been developed. A 1,100-bp band was found associated with the susceptible allele, which also was converted into a SCAR ($SCAR\ 26L_{1100\ bp}$) marker. The two-marker system is expected to enable identification of homozygous resistant plants in early generation.

Genetic map of bread wheat.

E. Nalini and N. Jawali (Molecular Biology Division), and S.G. Bhagwat (Nuclear Agriculture and Biotechnology Division).

Development of a genetic map of bread wheat based on a population derived from an intervarietal cross is being continued. AFLPs were used to screen the parents and the derived F_2. A total of 96 AFLP primer-pair combinations were screened for polymorphism between the parents. All the primer combinations detected polymorphism between the parents with the number of polymorphic bands ranging from 2 to 16. Among these, 14 pair combinations that yielded eight or more number of polymorphic bands in the parents have been used for analyzing the mapping population. In all, 154 polymorphic bands were obtained from 14 primer combinations. These AFLP loci will be integrated in to a map based on STMS, RAPD, and other markers.

Thermotolerance in wheat.

Suman Sud, B.K. Das, and S.G. Bhagwat (Nuclear Agriculture and Biotechnology Division).

Heat stress affects performance of wheat plant at early stage and also at the grain-filling stage. Work has been initiated to assess thermotolerance at seedling stage using membrane-stability and cell-viability assays. Over 50 commonly grown cultivars have been tested in both the assays. We found a positive correlation (r = 0.58) between the two assays. Cultivars NIAW-34, PBN-4135-1, and Ajantha were relatively more thermotolerant.

A radiation-induced mutant in wheat.

S.G. Bhagwat (Nuclear Agriculture and Biotechnology Division).

A genetic stock carrying the sphaerococcum character was irradiated with gamma rays, and a lax spike mutant was isolated. The mutant also showed alteration in grain appearance, culm length, and flag leaf blade size (Fig. 1). An F_2 population from a cross between the two was grown in the field. Flag leaf blade area on main tiller and stomatal frequency on the upper surface were estimated. The entire F_2 showed negative correlation as expected. Parental and mutant types were identified on the basis of spike character. These results indicate that the mutant may have stomatal frequency lower than expected as compared to the parent. Because the mutant has alteration in various characters, a large deletion or a mutation with pleiotropic effect may be present.

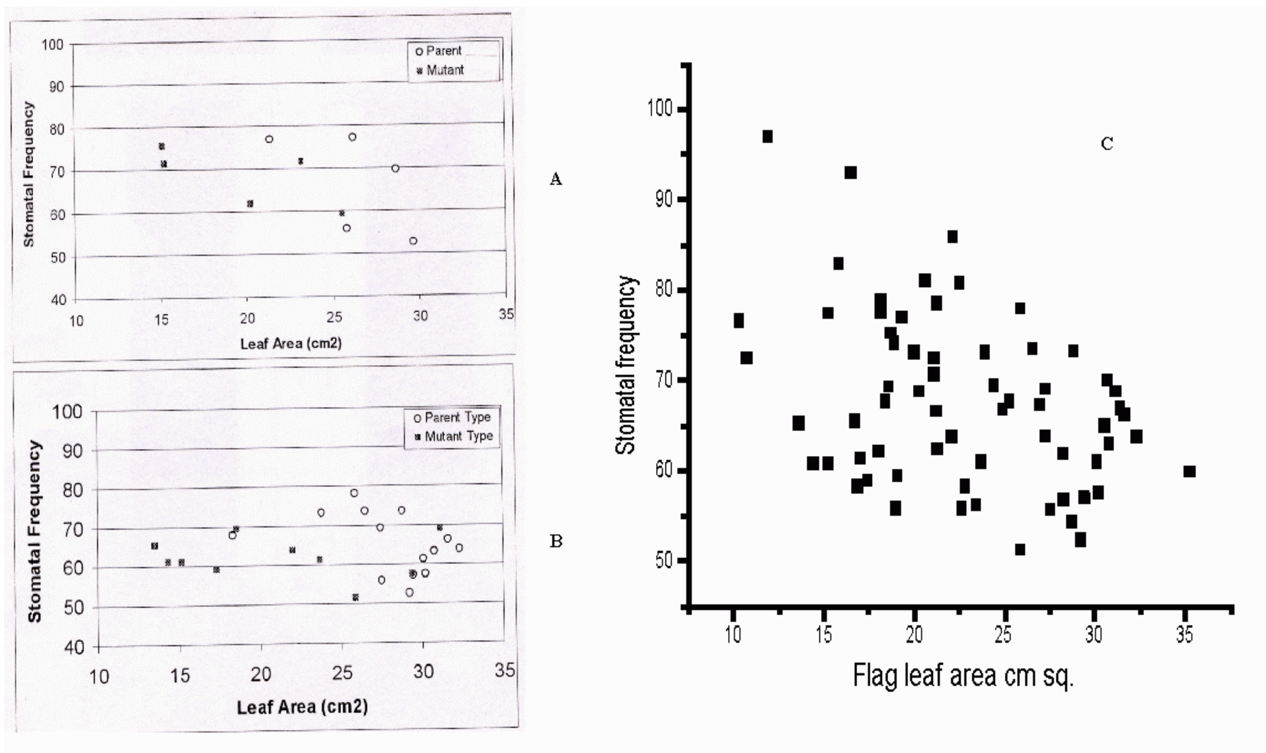

Fig. 1. A, Relationship between leaf area (cm^2) and stomata/mm^2 in the parent and the mutant; B, Relationship between leaf area (cm^2) and stomata/mm^2 in the parent and mutant type from F_2; and C, Relationship between leaf area (cm^2) and stomatal frequency in the F_2 between parent and mutant.

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Quality analysis of some Indian hexaploid wheat cultivars.

K. Gajalakshimi and V.R.K. Reddy.

Various physical properties of wheat grain (grain weight, test weight, moisture content, pearling index, particle size index, and grain appearance score), chemical properties of wheat flour (protein, fat, ash, total sugar, damaged starch, and sedimentation value), rheological properties of wheat dough (Farinograph water absorption, dough-development time, stability time, Farinographic resistance, mixing tolerance index, and resistance to extension, extensibility and area of the Extensographic curve), and glutenin quality of seed proteins were evaluated in 50 Indian hexaploid wheat cultivars obtained from various parts of the India in order to assess their suitability for different types of baking and pasta products.

Wheat grains from 44 wheat cultivars showed high to medium physical properties and different chemical constituents. The seeds of these wheat cultivars are semihard to hard in nature, they had higher percentages of protein, total sugar, wet gluten, damaged starch content, and SDS-sedimentation values with lower percentages of fat and ash. These wheat cultivars were recommended for all-purpose use (blending, baking, and pasta making). Grains of the remaining six wheat cultivars showed poor physical properties coupled with lower percentages of protein, total sugar, wet gluten, damaged starch content, and SDS-sedimentation values with higher percentages of fat and ash. These wheat cultivars were recommended for biscuit-making quality.

Rheological properties of wheat dough are recorded using Farinographic and extensographic meters by the Naga Research Institute, Dindigal, Tamil Nadu, India. Wheat dough from 18 wheat cultivars with high dough-development times, stability times, and an area with medium extensibility and low mixing tolerance index values that give high resistance are strong-type wheat doughs. Dough from six wheat cultivars having lower dough-development times, stability times, and area with higher extensibility and mixing tolerance index values are weak-type wheat doughs. Twenty-six wheat cultivars have medium-strong type wheat doughs.

All 50 wheat cultivars also were analyzed for their allelic variations of HMW-glutenin subunit proteins by SDS–PAGE. A total of 11 alleles were identified; three (a, b, and c) at the *Glu-A1* locus, five (a, b, c, d, and e) at the *Glu-B1* locus, and three (a, b, and d) at the *Glu-D1* locus. The most frequent HMW-glutenin subunits were 1 and 2* at *Glu-A1*, 17+18 at *Glu-B1*, and 5+10 at *Glu-D1*. The most frequent protein combinations are 2*, 7+8, 2+12, and 2*, 7, 5+10. The *Glu-1* quality score ranged from 5–10. A *Glu-1* quality score of 8 is present in large number of the cultivars. We predict that the cultivars that possess high *Glu*-1 scores, i.e., 9 or above, have the higher glutenin strength needed for blending purposes (mixing with weak quality flour). Cultivars with a *Glu-1* score of 8 have good bread-making quality. *Glu-1* score below 6 have very good biscuit-making quality. Correlation between the *Glu-1* quality score and quality parameters, such as physical, chemical, and rheological parameters, were studied. Significant, positive correlations ($p < 0.05$) was observed between the *Glu-1* score and test weight, sedimentation value, wet gluten, Farinographic parameters, and extensographic parameters (area and resistance) were observed. A negative correlation was found between the *Glu-1* score and protein content, mixing tolerance index (degree of softening), extensibility, and the Resistance/Extensibility ratio. Significant positive correlation was found between wet gluten and protein content, sedimentation value, Farinographic parameters and extensographic parameters (except MTI). Significant negative correlation was found between wet gluten and test weight and mixing tolerance index.

Based on the results of physical properties of the grain, chemical properties of flour, rheological properties of dough, and glutenin-subunit composition of seed proteins in the 50 Indian hexaploid wheats, the cultivars were ordered into five groups: high, medium-high, medium, medium-low, and low quality wheats. Among the 50 wheat cultivars, 13 were high quality, five were medium-high, 22 were medium, 4 were medium-low, and 6 were low quality.

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Development and use of molecular markers for wheat genomics.

QTL analysis for different traits using trait-specific, intervarietal mapping populations.

QTL analysis for preharvest sprouting tolerance (PHST) using trait-specific, intervarietal mapping populations. QTL analysis for PHST in bread wheat was earlier conducted by us following single locus composite interval mapping (CIM) and two locus analysis (QTLMapper), using an International Triticeae Mapping Initiative population (ITMI*pop*). In this study, an intervarietal mapping population in the form of RILs developed from a cross between the genotypes, SPR8198 (PHS tolerant) and HD2329 (PHS susceptible) was used for single-locus CIM. The parents and the RIL population were grown in six different environments, and the data on PHS were recorded on a scale of 1–9 with a score of 1 for genotypes with complete resistance to PHST and a score of 9 for the genotypes with complete sprouting in each case. A framework linkage map of chromosome 3A with 13 markers was prepared and used for QTL analysis. A major QTL (*QPhs.ccsu-3A.1*) was identified on 3AL explaining 24.68 % to 35.21 % of the variation in an individual environ-

Table 1. Summary of composite interval mapping for 18 metric traits in three mapping populations (PHS, preharvest sprouting; GW, grain weight; and GPC, grain-protein content).

Population	Trait	No. of QTL detected	No. of definitive QTL*	LOD score range	PVE (%) range
HD2329/SPR8198 (PHS)	Preharvest-sprouting tolerant	1	1	4.86–6.81	24.68–35.21
CS/RS111 (GW)	Tillers/plant	5	2	2.19–3.35	7.73–20.53
	Grain yield	5	1	2.24–3.66	8.77–14.24
	Grains/spike	4	2	2.08–3.97	11.13–19.02
	Grain weight	3	3	2.24–4.46	9.00–19.80
WL711/PH132 (GPC)	(i) *Growth-related traits.*				
	Days-to-heading	21	8	2.03–6.13	5.82–50.08
	Days-to-maturity	20	8	2.01–9.92	6.34–47.10
	Early growth habit	16	3	2.06–5.78	6.04–31.61
	Plant height	7	2	2.12–5.43	7.41–18.16
	(ii) *Yield and yield-contributing traits.*				
	Tillers/plant	13	3	2.00–3.74	6.17–17.13
	Biological yield	12	2	2.14–6.95	6.02–21.25
	Grain yield	17	6	2.00–5.12	6.53–47.38
	Harvest index	11	3	2.12–4.74	8.12–39.42
	Spike length	10	3	2.07–5.98	7.48–19.23
	Spikelets/spike	9	4	2.00–4.48	7.18–15.81
	Grains/spike	13	4	2.08–4.01	6.74–17.61
	Grain weight	7	1	2.07–3.85	8.52–14.80

* QTL detected above threshold LOD score.

ment (for details, see Table 1, p. 51). When PHST data from six environments was pooled, the QTL explained 78.03 % variation. The results obtained here are significant, because the QTL detected seems to be new and was present in all the environments and also with the pooled data, a rather rare event in QTL analysis. The positive additive effects in the present study suggest that a superior allele of the QTL is available in the superior parent (SPR8198), which can be used for MAS for the transfer of this QTL allele to elite strains with to obtain superior progeny. This work has been submitted for publication in Plant Science, and is currently under review.

QTL analysis for yield and its component traits, using a trait-specific, intervarietal mapping population for grain weight (GW).
QTL analysis for yield and its four component traits (tillers per plant, grain yield, grains/spike, and GW) in bread wheat was conducted following CIM and using an intervarietal mapping population for grain weight in the form of RILs developed from a cross between Rye Selection 111 (high GW) and Chinese Spring (low GW). The parents and the RIL population were grown in six different environments, and the data on the four traits were recorded. For QTL interval mapping, framework linkage maps were prepared for chromosomes 1A, 2A, 2B, and 7A using 68 markers, including SSRs, AFLP, and SAMPL. For four different yield and component traits, the number of QTL ranged from three for grain weight to five each for tillers/plant and grain yield. A total of 17 QTL were identified. Of 17 QTL, only five were considered as consistent QTL, because they were detected in more than three environments in this study (for details, see Table 1). Of these five QTL, three for GW were detected, one each on 1A, 2B, and 7A, whereas one each for grain yield and grains/spike was detected, both on chromosome 2B. No consistent QTL was detected for tillers/plant.

QTL analysis for agronomically important traits using a trait specific intervarietal mapping population for grain protein content (GPC).
<u>QTL analysis for growth related traits.</u> QTL interval mapping for four growth traits (days-to-heading, days-to-maturity, early growth habit, and plant height) were made using an intervarietal mapping population for GPC. CIM was done, using QTL Cartographer, for all the above four growth traits with phenotypic data scored in six different environments. Our earlier studies on QTL analysis for these traits were confined to a single environment and involved an ITMI population (Kulwal et al. 2003). The number of QTL detected ranged from seven for plant height to 21 for days-to-heading. A total of 64 QTL for all of the four traits were detected (for details, see Table 1). QTL that were consistent across the environments included one each for days-to-heading and days-to-maturity, both located on chromosome 5B. No consistent QTL were detected for early growth habit or plant height.

<u>QTL interval mapping for yield and yield-contributing traits.</u> For eight different yield and yield-contributing traits, QTL interval mapping (CIM) was by QTL Cartographer using data collected on RILs (GPC population) grown in six different environments. For different traits, the number of QTL ranged from seven, for grain weight, to 17, for grain yield, with a total of 92 QTL for all the eight traits (for details, see Table 1). One consistent QTL each were detected for spike length on chromosome 2B and for grain weight on chromosome 3A. No consistent QTL were detected for the remainder of the traits.

High-resolution mapping of the genomic regions containing an important QTL for GPC.
For the purpose of high-density mapping of an important QTL for grain-protein content, an F_2 population of about 2,000 plants was derived from a cross between two RILs, one of them containing high GPC alleles and the other containing low GPC alleles for the selected QTL. DNA was isolated from individual F_2 plants, which are being genotyped with the markers flanking the selected QTL to identify recombinants for the targeted region. So far, 19 F_2 homozygous recombinants for the markers flanking the selected QTL have been identified.

Developing and using EST–SNPs and anchored SSRs in bread wheat.
Developing, validating, and using EST–SNPs.
As is widely known, more than 580,000 ESTs are now available for bread wheat. This resource was used for the development of SNPs under the umbrella of the Wheat SNP Consortium (WSC). Forty-eight EST-contigs, each having 20 to 89 ESTs, were searched for the presence of HSVs (homoeologue specific variations) and SNPs. In this study, 462 HSVs were detected in 47 EST-contigs, allowing subclustering of the 47 EST-contigs into 174 subcontigs and facilitating detection of 230 putative SNPs in 42 EST-contigs. An average density of one SNP every 273.9 bp was calculated. Out of 230 SNPs, 123 (53.5 %) represented transitions, and the remaining 107 (46.5 %) represented transversions, suggesting that transitions are relatively more frequent than transversions. In this study, 42 locus specific STS primers were designed and used for PCR with genomic DNA from 30 diverse bread wheat genotypes. Only 39 (92.8%) primers amplified fragments in 15 to 30 genotypes. The remaining three primers failed to give any product. Ten of the 39 primers each amplified a solitary band (representing a single homoeolocus) in each of 237 (79 %) of the 300 possible

primer-genotype combinations (10 primers x 30 genotypes). Only the above 10 primers were considered suitable for validation of 30 putative SNPs that were detected *in silico* in the amplifiable region (amplicon) of the corresponding EST-contigs. Out of 30 putative SNPs, only seven SNPs were validated; however, eight new SNPs also were detected through direct sequencing of PCR products from 30 genotypes.

The above 15 SNPs (seven validated + eight new) detected in this study allowed construction of 11 haplotypes. The above data also was used for the construction of a dendrogram to study genetic similarity/diversity.

Developing and using anchored SSRs.
A large number of SSR markers (*wmc* markers) were earlier developed under the aegis of an international effort 'Wheat Microsatellite Consortium (WMC)'. In this exercise, although the sequences of as many as ~1,200 clones were found to contain SSRs, primers could be designed for only ~600 SSRs, leaving another ~600 sequences that either had poor quality or were considered unsuitable for designing of primers mainly due to the occurrence of SSRs too close to an end of the sequence. We utilized a part of these sequences for designing 52-anchored SSR primers. In this study, a set of 105 52-anchored SSRs were developed. These 105 52-anchored SSR primers were used for developing STMS markers. A subset of 45 of these anchored SSR primers also was used for microsatellite-anchored fragment length polymorphism (MFLP) analyses. In the STMS analysis, the proportion of functional anchored-SSR primers was close to that reported earlier for simple SSR primers and in MFLP analysis. The average number of polymorphic bands per primer combination was 11.9, although anchored-CT/GA SSR primers gave a relatively higher average number of polymorphic bands (17.88). The above MFLP data also was used for genetic diversity analysis among eight bread wheat genotypes (representing parents of four intervarietal mapping populations available from our laboratory). The average polymorphic information content (PIC) was found to be 0.057, and the average genetic similarity (GS) was 0.451.

Use of C_0t fractionation (CF) and methyl filtration (MF) for genomics research in bread wheat.
To demonstrate the utility of C_0t fractionation (CF) and methyl filtration (MF) in assaying wheat genome complexity, a rather small fraction (671.67 kb) was sequenced and analyzed for the presence of protein-coding genes, noncoding (nc) RNA genes, SSRs, and transposable elements (TEs). Results demonstrated the utility of gene-enrichment techniques (high C_0t and MF) in assaying comparatively large number (12-fold) of genes. The above gene-enrichment techniques still retain as much as more than 23 % repeat elements. Of most interest are the fractions assayed by CF and MF, which vary substantially for repeat and low-copy content, indicating the need of using both of the above techniques in parallel to study entire genome complexity of wheat.

The SSRs were three times more abundant in low-copy (high C_0t and MF) fractions of wheat genome than in the repeat (reassociated DNA; RD) fraction. We also observed that low-copy sequences have more trinucleotide SSRs, particularly those with the 'CCG/CGG' motif. These results conform with our earlier results on wheat EST–SSRs (Gupta et al. 2003).

A large proportion of MF, high C_0t and RD sequences also were similar with already known miRNA (micro RNA) sequences available in the public domain. Target mRNAs for a large proportion of the candidate miRNAs also could be detected on the basis of their similarity with wheat ESTs, further confirming their validity and presence in low-copy, transcriptionally active, hypomethylated regions of the genome.

Physical mapping of SSRs on all the 21 chromosomes of bread wheat.
Approximately 2,150 SSRs loci already have been mapped genetically in bread wheat, but only ~1,050 SSR loci have been mapped physically leaving more than ~1,100 SSR loci that have not been placed on the physical maps so far. In the present study, 42 nullisomic-tetrasomic, 24 ditelocentric, and 164 homozygous overlapping deletion lines from a total of 436 available deletion lines were used for bin localization of SSRs. A set of 527 SSRs was tried, leading to successful mapping of 270 SSRs on 313 loci covering all the 21 chromosomes. A maximum of 119 loci (38 %) were located in the B genome, and a minimum of 90 loci (29 %) mapped in the D genome. Similarly, homoeologous group 7 had a maximum of 61 loci (19 %), and group 4 a minimum of 22 loci (7 %). Of the 270 SSRs, 39 SSRs had multiple loci, but only eight of these detected homoeologous loci. The linear order of loci in physical maps largely corresponded to those on the genetic maps. Apparently, distances between each of only 26 pairs of loci significantly differed from the corresponding distances on genetic maps. Some loci, which were genetically mapped close to the centromere, were physically located distally, whereas other loci that were mapped distally in the genetic maps were located in the proximal bins in the physical maps. This result suggested that although the linear order of the loci was largely conserved, variation does exist between genetic and physical distances.

Radiation hybrid (RH) mapping in bread wheat.
In order to determine the linear order of markers placed in a particular bin, more deletions were induced by irradiating seeds of monosomic lines for chromosomes 1A, 2A, and 3A of bread wheat cultivar Chinese Spring. Seeds of the above monosomic lines were exposed to three different dosages of gamma rays (30, 40, and 50 krad) to find out optimum dosage required for induction of maximum number of chromosome breakages at minimum mortality rate. Irradiated seeds were sown in the field, and DNA was isolated from first four tillers of each plant. PCR analysis of the irradiated monosomic plants is being conducted using 10, 16, and 19 SSR markers already physically mapped on bread wheat chromosome 1A, 2A, and 3A, respectively (Goyal et al. 2005). This study will help in further subdividing the available deletion bins, to help further fine physical mapping.

Future work.
Marker-assisted selection for high GPC and PHST.
We are in the process of introgression of one QTL each for high GPC and PHST into elite, Indian bread wheat genotypes with low GPC and susceptibility to PHS through backcrossing programs. In the backcrossing program, we are using Yecora Rojo as donor parent for high GPC (procured from J. Dubcovsky of University of California, Davis, USA) and SPR8198 as donor parent for PHST (procured from Punjab Agric Univ, Ludhiana, India). The F_1 plants derived from the crosses between several recipient patents (K9107, HD2687, Raj3765, PBW373, HI977, HD2329+*Lr24*+*Lr28,* PBW343+*Lr9,* PBW343+*Lr19,* and PBW343+*Lr24*) with the above two donor parents are already raised in field and backcrosses will be done in this season.

High-density mapping.
High-density mapping of 3.4 cM on 2D carrying a major QTL for high GPC. The F_2 plants that were homozygous recombinants for the markers flanking the selected QTL will be further used for high-density mapping of the selected region. SAMPL, AFLP, STS, and SSR markers will be used for genotyping of the selected homozygous recombinant F_2 plants to saturate the selected region. Wheat EST markers already mapped in the targeted region and those mapped in the syntenous regions in other grasses also will be used for saturation mapping of the selected region. More SSRs will be developed from an arm-specific library and will be used for saturation mapping of the targeted region.

High-density mapping of 17 cM on 3A carrying a major QTL for PHST. Two strategies will be followed for high-density mapping of a 3A region carrying a major QTL for PHST. In the first approach, we will develop different EST-derived markers from the ESTs already physically mapped in the bin (3AL-3) to which our QTL belongs. We also are trying to ascertain the putative order of the above EST-derived markers using sequence of rice chromosome 1 as a reference. In the second approach, we are developing molecular markers from the chromosome arm (3AL) specific library developed in a collaborative project with J. Dolezel, Olomouc, Czech Republic. The above exercises will lead to enrichment of the interval containing QTL of interest with molecular markers, which may ultimately lead to the isolation of the QTL of interest.

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Effect of sowing date on the interaction of loose smut and flag smut of Indian wheat cultivars.

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Introduction. Simultaneous occurrence of loose smut and flag smut of wheat has been reported (Aujla and Sharma 1997; Bedi et al. 1959). These authors reported that flag smut-infected plants showed twisting and bending of coleoptile in the seedling stage with the formation of bleached spots on the coleoptile. Some plants produce smutted heads that emerged later than healthy spikes. All the spikes on the affected plants were smutted and produced very few tillers. Some plants were infected with both smuts. No information is available in the literature on the interaction of smuts on different wheat cultivars grown over India. The present investigation was made under field conditions.

Materials and Methods. A field experiment was conducted at Plant Pathology research area of Plant Pathology research of area of CCSHAU-Hisar during 1997–2000 crop season. Loose smut spores were artificial inoculated in previous crop season in all 25 cultivars so as to serve as loose smut infected seed for next crop season. Each subplot for a cultivar had six rows of 2-m length. Sowing dates of 25 November and 15 December were used for all treatments. Loose smut inoculated seeds were smeared with flag smut teliospores at 2 gm/100 gm of seed having 78 % viability. All normal agronomic practices were followed. Disease incidence was observed as the percent infected tillers in each subplot. Tillers having both diseases were counted for both diseases separately.

Table 1. The effect of sowing date on the interaction of loose smut and flag smut of wheat at three different sowing dates, CCS Haryana Agricultural University, Hisar.

	Percent disease incidence					
	25 November		5 December		30 December	
Cultivar	Loose smut	Flag smut	Loose smut	Flag smut	Loose smut	Flag smut
C306	33.57	12.50	26.33	11.88	21.44	9.83
Sonalika	46.66	1.71	34.22	0.90	27.57	0.50
WH 147	36.55	16.35	28.44	14.83	22.75	11.83
WH 157	28.44	12.50	25.83	11.66	18.66	9.16
WH 283	25.33	0.00	16.66	0.00	10.33	0.00
WH 29	28.77	0.00	21.33	0.00	18.33	0.00
WH 416	33.33	18.11	28.33	14.33	19.83	12.11
WH 533	26.11	13.33	21.66	10.75	19.66	8.33
WH 542	29.66	16.33	26.66	12.33	23.33	9.33
WH 896	0.00	0.00	0.00	0.00	0.00	0.00
Sonak	26.66	11.66	21.33	10.66	16.66	9.66
HD 2009	24.33	14.33	18.66	11.88	12.33	10.16
HD2285	24.66	14.66	16.66	12.33	12.83	10.83
HD 2329	27.93	2.83	18.66	0.00	13.33	0.00
HD 2687	34.28	14.57	29.83	14.71	26.16	11.57
PBW 175	23.66	16.33	20.77	12.83	19.14	10.11
PBW 343	35.44	12.50	29.16	10.66	18.11	8.11
PBW 373	37.77	16.25	31.57	13.66	26.33	10.33
PBW 435	38.33	16.66	31.44	12.83	24.33	10.66
Raj 1555	0.00	0.00	0.00	0.00	0.00	0.00
Raj 3077	37.33	11.33	28.33	9.83	22.67	7.66
Raj 3765	38.66	10.33	29.66	9.11	21.77	8.96
Raj 3777	33.66	10.57	26.33	8.83	21.44	7.83
UP2338	29.66	19.83	17.83	16.33	14.57	13.44
UP 2425	26.77	12.57	21.66	10.11	16.57	8.57
C.D. (0.5 %)	2.98	3.45	3.78	2.87	3.11	2.67

Results and Discussion. Results of this study are found in Table 1. *Ustilago segetum* var. *tritici* is internally seedborne, but *Urocystis agropyri* is an external soil contaminant. Both pathogens move side by side systemically in the same plant. The highest loose smut incidence (46.66 %) was found on Sonalika, followed by Raj 3765, but Sonalika showed resistance to flag smut. The highest flag smut incidence was observed on UP2338, followed by PBW 435 (16.66 %) under normal sowing conditions. A delay in sowing drastically reduced the incidence of both diseases. Sonalika had the highest incidence of loose smut (27.57 %) followed by HD 2687 (26.16 %). The maximum incidence of flag smut was in UP 2338, followed by WH 416. Two cultivars, WH 896 and Raj 1555, had resistance against loose smut and flag smut, whereas Sonalika, WH 283, WH291, and HD2329 also exhibited resistance to flag smut. Interestingly, the same tiller expressed both diseases separately. Loose smut incidence was predominant over flag smut in same cultivar, even though flag smut symptom appeared before those of loose smut. Delayed sowing caused less disease incidence, because of fungus inactivation or less spore germination accompanied with falling temperatures. The same observations were made by Beniwal et al. (1992) and Bedi et al. (1959), confirming our results.

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Effect of sowing date on the interaction of flag smut and earcockle of wheat cultivars.

Rajender Singh, M.S. Beniwal, and S.S. Karwasra.

The simultaneous occurrence of earcockle (*Anguina tritici*) with the fungus *Urocystis agropyri* was reported by Bedi et al. (1959), Aujla and Sharma (1977), and Pruthi and Bhatti (1982). Whether or not concomitant occurrence of the fungus with nematode has any synergistic or antagonistic effect on the development of disease incidence is unknown. Therefore, we attempted to study effect of sowing on concomitant of flag smut and earcockle on wheats cultivated in India.

A field experiment was conducted at Plant Pathology research farm of CCSHAU-Hisar during the 1997–2000 crop season. Before sowing, seed of each cultivar were smeared with dry teliospores powder having 78 % viability at 2-gm inoculum/100 gm of seed. Each subplot for a cultivar had six 2-m rows. Sowing dates of 25 November, 15 December, and 30 December were used for all treatments. Each row received 10 nematode galls. All normal agronomic package practices were followed. Disease incidence was observed as a percent infected tiller basis in each subplot. The same tiller having both diseases were counted separately.

The highest flag smut incidence (15.37 %) was observed on Raj3765, followed Raj 3777 (14.96 %) at normal sowing, but in delay sowing, disease incidence declined to 10.87 and 9.91%, respectively (Table 2). WH283, WH291, WH896, HD2329, and Raj1555 were found to be resistant in normal and late sowing, possibly because of falling temperatures that prolonged the time of teliospore germination. Conversely, with delayed sowing (30 December), earcockle incidence increased to 38.83 % (HD 2285) but decreased at the normal sowing date (25 November). *Anguina tritici* have more time for infection with a prolonged time for seed germination. If both flag smut and earcockle were observed on same tiller, they were counted separately. In normal and late sowings, earcockle incidence predominated over flag smut. The same observations were made by Pruthi and Gupta (1986) and Beniwal et al. (1992) and confirm our results. Pruthi and Gupta (1986) reported that the presence of fungi with nematodes has an adverse effect on the number, motility, and development of larvae at normal sowing time.

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Effect of sowing date on the interaction of loose smut, flag smut, and earcockle of wheat cultivars grown in India.

Rajender Singh, M.S. Beniwal, S.S. Karwasra, and Sher Singh.

Introduction. The simultaneous occurrence of loose smut, flag smut, and earcockle of wheat has been reported (Bedi et al. (1959) and Aujla and Sharma (1977), who reported that flag smut infected plants/tillers showed twisting and bending of the coleoptile in the seedling stage with formation of bleached spots on the coleoptile. The same plant produced smutted spikes that emerged later than the healthy ones. Plants were infected with both smuts. They also noticed that two-thirds of the lower spikes were nearly totally filled with black loose smut sori. The upper portion of this spike was infected by earcockle, the black galls of which were clearly visible. No information is available in the literature on the interaction of smuts and earcockle of the different wheats cultivated in India and the effect of different sowing dates. The present investigation was made under field condition.

Materials and Methods. We conducted a field experiment at the Plant Pathology Research Area of CCSHAU-HISAR during 1997-2000 Loose smut spores were artificially inoculated in the previous crop season in all cultivars to serve as inoculum for next crop season. Each cultivar subplot was 6 2-m rows. Sowing dates, 25 November, 15 December, and 30 December, were used for all treatments. Loose smut-inoculated seed was inoculated with teliospores at 2 gm/100 gm seed and sown. Each cultivar had 78 % viability in each subplot. Each row also received 20 nematode galls. All normal growing practices were followed. Disease incidence was observed on a percent infected tiller basis in each subplot. If the same tiller had symptoms for all diseases, each was counted separately.

Table 2. The effect of sowing date on the interaction of flag smut and earcockle of wheat cultivars, CCS Haryana Agric Univ, Hisar.

	Percent disease incidence					
	25 November		15 December		30 December	
Cultivar	Flag smut	Earcockle	Flag smut	Earcockle	Flag smut	Earcockle
C 306	12.81	2.33	11.11	26.14	7.58	31.22
Sonalika	2.57	16.46	1.83	21.16	1.16	28.27
WH 147	14.96	20.94	10.86	28.76	8.45	35.53
WH 157	12.93	17.88	11.93	20.44	9.57	25.44
WH 283	0.00	20.81	0.00	28.33	0.00	35.11
WH 291	0.00	21.11	0.00	29.14	0.00	37.44
WH 416	13.47	17.07	11.61	21.33	8.36	26.17
WH 533	12.11	18.77	10.81	21.57	8.84	28.25
WH 542	14.66	17.11	11.27	21.27	9.61	25.33
WH 896	0.00	10.16	0.00	14.44	0.00	16.66
Sonak	11.33	16.44	10.43	21.57	8.36	27.11
HD 2009	13.24	18.94	11.91	21.71	8.75	28.14
HD 2285	16.66	21.44	13.83	29.81	10.93	38.83
HD 2329	2.83	20.66	1.93	3.66	1.33	30.16
HD 2687	11.16	19.57	10.66	22.83	8.93	29.57
PBW 175	10.25	17.11	6.83	20.83	5.55	26.44
PBW 343	14.77	18.33	11.44	21.77	9.11	27.53
PBW 373	10.81	15.77	9.91	18.16	8.16	21.11
PBW 435	11.37	18.93	8.73	22.33	6.93	24.77
Raj 1555	0.00	13.57	0.00	16.73	0.00	18.87
Raj 3077	14.86	20.33	11.28	24.97	9.88	27.83
Raj 3765	15.37	20.34	11.71	25.66	10.87	28.77
Raj 3777	14.96	19.93	12.93	24.33	9.91	29.33
UP 2338	12.88	18.33	10.11	21.88	8.73	27.28
UP2425	14.16	17.44	11.25	20.93	8.77	26.84
C.D.at(.05%)	2.56	3.11	3.67	2.98	3.89	3.96

Results and Discussion. Loose smut is internally seed borne, but *Urocystis agropyri* and *Anguina tritici* are externally seed borne. All inoculula move systemically in parallel in same plant. Loose smut-infected spikes emerged earlier than healthy spikes. Flag smut symptoms appeared first 45

Table 3. The effect of sowing date on the incidence and interaction of loose smut (LS), flag smut (FS), and earcockle (N) of wheat in artifically inoculated field trials at Hisar, India between 1997–2000.

	Percent disease incidence								
Sowing time	25 November			15 December			30 December		
Cultivar	LS	FS	N	LS	FS	N	LS	FS	N
C306	39.77	10.71	18.22	37.5	9.11	24.71	28.51	5.88	28.57
Sonalika	43.18	1.33	14.36	38.18	1.11	18.66	32.5	0.83	26.66
WH 147	39.64	12.86	18.84	32.22	8.66	26.66	27.33	6.75	31.83
WH 157	38.29	10.83	15.68	30.96	9.83	18.33	26.66	7.83	23.33
WH 283	33.33	0.00	18.83	29.33	0.00	26.33	22.22	O.00	33.33
WH 291	37.24	0.00	19.16	32.22	0.00	27.44	27.66	0.00	34.93
WH 416	32.57	11.37	15.97	26.16	9.71	19.57	21.44	6.66	24.57
WH 533	38.91	10.00	16.66	31.17	8.18	20.83	26.57	7.14	26.55
WH 542	39.71	12.50	16.00	32.93	9.37	20.16	28.16	7.91	26.33
WH 896	0.00	0.00	8.16	0.00	0.00	12.33	0.00	0.00	14.16
Sonak	30.00	10.24	15.37	26.66	8.33	18.66	23.33	6.66	25.33
HD 2009	30.54	11.14	17.84	27.33	9.82	20.11	24.57	6.81	26.44
HD 2285	28.18	14.57	20.14	24.71	11.88	28.91	21.77	9.14	36.66
HD 2329	31.15	2.77	19.88	27.11	1.83	22.76	24.37	1.17	28.57
HD 2687	31.44	10.96	18.47	28.14	8.66	21.93	25.71	7.66	27.63
PBW 175	30.33	8.66	15.00	25.33	6.66	18.71	20.16	4.57	24.14
PBW 343	34.16	14.51	16.14	28.83	10.14	19.96	24.71	8.73	26.71
PBW 373	31.57	10.42	13.57	27.33	7.81	16.71	23.66	6.44	20.83
PBW 435	29.62	10.87	16.75	21.33	8.11	20.44	18.62	6.18	25.81
Raj 1555	0.00	0.00	10.11	0.00	0.00	13.42	0.00	0.00	15.73
Raj 3077	28.77	12.16	15.83	24.22	10.71	18.93	20.16	8.16	24.44
Raj 3765	28.57	14.28	20.11	24.77	11.53	24.39	20.71	8.44	28.77
Raj 3777	30.83	12.66	18.33	25.91	9.87	23.71	21.16	7.14	27.66
UP 2338	37.67	11.77	16.66	31.14	8.91	20.55	27.14	6.93	25.16
UP 2425	32.53	12.96	14.71	26.81	9.96	18.83	22.27	7.17	23.44
C.D. (0.05 %)	2.89	3.42	3.86	2.11	3.98	4.12	2.87	3.34	4.42

days-after-sowing, and were followed by earcockle and loose smut symptoms (Tables 2, p. 58, and Table 3). At the normal sowing time, the highest incidence of loose smut was observed in Sonalika (43.18 %) followed by C-306 (39.17 %) but was reduced to 32.5 % and 28.5 %, respectively, at later sowings. No loose smut or flag smut was found on WH 896 and Raj 1555. Sonalika, HD 2329, WH 283, WH 291, WH 896, and Raj 1555 also expressed resistance against flag smut. The highest flag smut (28.18 %) and earcockle incidence (14.57 %) was observed in HD 2285 in a normal sowing but with a delay in sowing, flag smut incidence declined to 9.14 % and earcockle incidence increased to 36.66%. Disease incidence in Raj 3765 (9.14 %) also declined (8.44) at later sowing dates. Sonalika, HD 2329, WH 283, WH 291, WH 896, and Raj1555 expressed resistance against flag smut in all sowing times. None of the cultivars was resistant to earcockle. HD 2285 had the maximum earcockle incidence (20.14 %) followed by Raj 1555 (20.11 %), when sown late. However, loose smut incidence was predominant over earcockle and flag smut. We noticed that with later sowings, loose smut and flag smut incidence was adversely affected, whereas earcockle incidence was enhanced. A reduction in teliospore germination along with falling temperatures in November and December and the presence of the nematode *A. tritici* may provide more time for infection due to a prolonged germination time. Similar observations were made by Beniwal et al. (1992) and Pruthi and Gupta (1986) on single spikes, which confirm our results. Pruthi and Gupta (1986) reported that the presence of fungus and nematodes has an adverse affect on the number, motility, and development of larvae. In some plants, the same tiller showed symptoms of all three diseases.

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Influence of plant extracts on teliospore germination of Neovossia indica in wheat.

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Of eight plant extracts tested, the maximum inhibition of teliospore germination was found in neem *(Azadirachta indica*), up to 91.75 %, followed by onion (83.35 %). The minimum level of inhibition was observed in *Cannabis sativa* (38.35 %). Plant extracts are known to have antimicrobial properties and are easily available, ecofriendly, and cheap. The use of extracts from higher plants for controlling diseases dates to 470 BS (Sharvelle 1963). The Karnal bunt pathogen perpetuates in the seed and soil in the form of teliospores. No chemical is able to completely inhibit teliospore germination. Water extracts from plants were evaluated for their effect on teliospore germination.

Materials and Methods. Plant extracts were prepared by macerating leaves or bulbs in distilled water at 1:1 (w/v) from ak (*Calotropis procera,* leaves), datura (*Datura metel*, leaves), safeda (*Eucalyptus globules*, leaves), onion (*Allium cepa*, leaves), bhang (*Cannabis sativus*. leaves), neem (*Azadirachta indica*, leaves), garlic (*Allium longicuspus*, bulb), and zinger (*Zingiber officinale*, leaves). After dilution of the standard extract to 1 %, 0.5 %, and 0.25 %, teliospore germination was recorded. In one treatment, the teliospores from bunted seed were directly sprinkled over the different concentration of the plant extract solutions to evaluate their germination percentage. In another experiment, teliospores from treated seeds were sprinkled over distilled water in the petriplates and incubated at 20°C for 20 days. Teliospore germination was recorded weekly by recording the total and the number of germinated teliospores scored under a microscopic field (10 x 10). The percent teliospore germination was calculated. For all dilutions, bunted seeds were dipped for 48 hrs to evaluate their efficacy against seed-borne inoculum lying protected beneath the pericarp. Simultaneously, seed germination also was tested.

Table 4. Influence of plant extracts on teliospore germination. Figures in parenthesis are angular transformed values.

Plant	Extract (%)	Teliospore germination (%)		% disease control
Datura	1.00	4.73	(12.52)	76.35
Datura	0.50	7.66	(18.15)	61.70
Datura	0.25	9.75	(20.70)	51.25
Onion	1.00	3.33	(10.47)	83.35
Onion	0.50	5.66	(13.69)	71.70
Onion	0.25	8.33	(16.74)	58.35
Eucalyptus	1.00	4.51	(12.25)	77.45
Eucalyptus	0.50	7.93	(16.32)	60.35
Eucalyptus	0.25	10.83	(19.19)	45.85
Bhang	1.00	8.33	(16.74)	58.35
Bhang	0.50	10.91	(19.28)	45.45
Bhang	0.25	12.33	(20.53)	38.35
Neem	1.00	1.65	(7.27)	91.75
Neem	0.50	2.33	(8.73)	88.35
Neem	0.25	3.55	(10.78)	82.25
Garlic	1.00	4.00	(11.54)	80.00
Garlic	0.50	6.66	(14.89)	66.70
Garlic	0.25	9.25	(17.66)	53.75
Zinger	1.00	3.66	(6.83)	81.70
Zinger	0.50	6.83	(15.12)	65.85
Zinger	0.25	9.80	(18.24)	51.00
Ak	1.00	4.80	(12.66)	76.00
Ak	0.50	8.30	(16.74)	58.50
Ak	0.25	10.90	(19.28)	45.50
Check		20.00	(26.57)	

Results and Discussion. Although there was no adverse effect of the plant extracts on seed germination, the treatments were ineffective at eliminating seed-borne inoculum (Table 4) from broken seed dipped in neem, onion, and garlic extracts. Teliospores from within the intact pericarp of the treated seeds germinated. The lowest teliospore germination was observed in extracts from neem leaves, but none of plant extracts completely inhibited teliospore germination. Extracts from garlic, onion, and neem were effective in making the teliospores unviable, but it could not penetrate the pericarp of the seed. Bulb extracts of garlic have been found inhibitory to *T. indica* and *R. solani* (Sundaraj et al. 1998; Sharma and Nanda 2000). Our investigation may vary due to different isolates found at Hisar.

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Facilitating the approach of participatory plant breeding to increase wheat yields in east and far-east regions of India.

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Introduction. Wheat occupies a prime position in terms of production among the food crops in the world. In India, wheat is the second most important cereal crop and plays an important role in the food and nutritional security system of our country. Wheat alone contributes approximately a 25 % share of the total food grain production of the country. Wheat is consumed primarily in the form of an unleavened, pan-backed bread called chapati. Four wheat species, *T. aestivum* subsp. *aestivum, T. turgidum* subsp. *durum, T. turgidum* subsp. *dicoccum, and T. aestivum* subsp. *sphaerococcum,* are cultivated and consumed in one or the other form. In India, common bread wheat is the main crop, which occupies approximately 88 % of the area followed by *T. turgidum* subsp. *durum* (10 %) and *T. turgidum* subsp. *dicoccum* (2 %). Statistics from 2003–04 indicate the area under wheat cultivation to be approximately 27 million ha with a total production over 70 million tons. In terms of production and acreage, India is second to China among the wheat-growing countries in the world.

Wheat research and the yield gap in Indo-Gangetic Plains. Wheat improvement work in India began in 1905 when systematic research efforts were initiated with a series of selections from local types followed by pure-line selection that resulted in to the development of several better yielding, disease resistant, and quality wheats such as NP 4 and NP 6. With the inception of the All India Coordinated Wheat Improvement Project (AICWIP) in 1965, more than 200 wheat cultivars have been released in India for cultivation under various agroclimatic and production conditions. The results obtained from frontline demonstrations have shown an apparent yield gap in different agroclimatic conditions to the tune of 1.5 t/ha. The North Eastern Plains Zone, comprised of eastern UP, Bihar, Jharkhand, West Bengal, and Assam provinces, has about 9 million ha area under wheat with approximately 2.9 t/ha productivity compared to 4.1 t/ha in the North Western Plains Zone. Many improved, high-yielding genotypes have been released for different production conditions of North Eastern Plains Zone but very few could percolate to the farmers' fields. A myriad of reasons have been highlighted time and again.

The need for Participatory Varietal Selection (PVS) and Participatory Plant Breeding (PPB). In order to ensure the percolation of cultivars to the real beneficiary, a number of approaches have been suggested. Recently, the PVS and PPB approaches have been utilized to make wide adoption of improved cultivars and bridge the gap between potential and realized yields. PPB involves the plant breeder and farmers/clients in plant-breeding research and has been suggested as an effective alternative to formal plant breeding as a strategy for achieving productivity gains under low-input conditions. PPB is informal, with the involvement of farmer in helping plant breeders to develop plant ideotypes and also to provide feedback of farmers' preferences, helping decision making about the development and release of cultivars and seed production. In PPB, farmers take part in the dialogue regarding desirable plant characteristics, their presence or absence in specific genotypes, and also the traits farmers would like to see introduced. The farmers in this process are involved from the very beginning of plant-breeding programs that involves eliciting farmer's criteria for ranking alternative materials or contrasting plant characteristics in order of preference and then searching for parents, which offer some of the desired traits. PPB needs to be used only when the possibility of utilizing conventional and PVS approaches have been exhausted and when the search process fails to identify any suitable cultivars for commercial production in various microclimatic conditions. PPB also can exploit the results of PVS by using identified cultivars as parents of crosses. Compared to PVS/PPB, the increase in biodiversity will be at the intra- and intervarietal level and the effects of PPB will be more uneven than those of PVS, because the potential increase in the genetic diversity within a village is extremely large, whereas the increase in diversity with PVS is limited due to the limited cultivar diversity, i.e., only in the range of few cultivar choices.

Objectives, traits, and target area of PPB in India. The primary objective of PPB is tailoring genotypes to the specific micro agroclimatic and production conditions in such a manner that we develop a genotype for target environment rather than changing the environment. Defining target-area conditions, farmers' needs, and the environment are important. The collective efforts of researchers and farmers must address the farmer preferred traits and the target-area requirements through the alternate breeding approach of PPB. These two aspects in fact are prerequisites for initiating any PPB concept so as to define both traits and environment for their area of jurisdiction or stations that are further refined after a feedback through farmer appraisal and baseline surveys. In general, the target population of traits in the this particular area for which the program is designed represents a rainfed, limited irrigation condition, where drought and heat stress, short duration, and susceptibility to diseases (leaf blight and brown rust) were the major constraints. However, problem of high temperature coupled with high humidity causing a high incidence of leaf blight and spike sterility also are prevalent in high rainfall areas such as Assam and parts of West Bengal. The generalized traits that are well defined include early maturity, drought and heat tolerance, disease resistance, and bold amber grains with good chapati-making quality. A slight problem with preharvest sprouting, shattering, and late spike sterility is found in some parts of the target areas.

Keeping all above factors in view, we initiated a multipronged strategy to deal with the problems affecting the wheat yields directly or indirectly and thus to give an impetus to the wheat improvement program in the target areas of Ranchi and Assam where a sound breeding program is lacking due to various reasons. The Directorate of Wheat Research, Karnal, in close collaboration with the CIMMYT South Asia Regional Office, Kathmandu, Nepal, formulated and initiated a Department for International Development (DFID) funded project on entitled 'Participatory Research to Increase the Productivity and Sustainability of Wheat Cropping System in the State of Haryana, India'. The work on material development for facilitating the participatory plant breeding approach to be carried out at Shillongani and Ranchi Centre, was assigned to DWR Karnal. Accordingly, a base line survey was conducted in the target area to know the farmers' preference for the traits in a new cultivar. As anticipated and visualized through our experience of work in target area, total grain yield was ranked as the number one preference by the farmers, followed by a combination of yield, bold grain, and good chapati-making quality. A summary of the farmers preferred traits and their combinations are in Table 1.

Table 1. Ranking of preferred wheat traits based on farmers preferences compiled to surveys conducted by the Directorate of Wheat Research, Karnal, in the North Eastern and North Western Plains and Central Zones of India.

Rank	Trait	Farmers surveyed (%)
1	Yield and duration	160 (53)
2	Yield, bold grain, and good chapati quality	72 (24)
3	Bold grain	27 (9)
4	Yield and chapati-making quality	23 (8)
5	Chapati-making quality	9 (3)
6	Yield and bold grain	6 (2)
7	Good price and total profit	3 (1)
	Total	**300**

Targeted crosses under PPB program. A set of seven diverse and promising cultivars with desired traits were selected for attempting the targeted crosses as per the need of both stations. The parental lines included at least one of the promising cultivars from North Eastern Plains Zone (DBW 14, HUW 468, PBW 443, and HUW 533), North Western Plains Zone (PBW 502), and Central Zone (DL 788-2 and GW 273). The maturity duration of the selected lines ranged from 106–142 days; yield potential was above 50 q/ha for irrigated conditions. During cultivar selection, disease flora and fauna were assessed and all cultivars were resistant to the brown rust and tolerant to leaf blight (Table 2, p. 63). Hybridizations were primarily focused at improving the agronomic base to enhance yield levels and the acceptance of cultivars in the areas.

Table 2. Passport data of the seven parental lines utilized in the crossing program of cultivars from the North Eastern Plains (NEPZ), North Western Plains (NWPZ), and Central (CZ) Zones of India. Brown rust resistance expressed as percent or T (trace) or MR (moderately resistant); leaf blight resistance expressed as percent.

Parent	Production conditions	Duration (days)	Height (cm)	1,000-kernel weight (g)	Best yield (q/ha)	Brown rust incidence	Leaf blight incidence
DBW 14	NEPZ (IR-LS)	106	79	40	51.0	0	35
HUW 468	NEPZ (IR-TS)	123	98	42	54.5	0	46
DL 788-2	CZ (IR-LS)	116	88	43	52.8	5–MR	56
PBW 443	NEPZ (IR-TS)	120	98	40	54.6	0	36
HUW 533	NEPZ(TS-RF)	124	103	40	34.6	0	25
PBW 502	NWPZ (IR-TS	142	92	42	55.3	0	34
GW 273	CZ (IR-TS)	122	86	47	58.7	T–MR	56

Planning, executing, and sharing of the crosses was implemented by DWR, Karnal. The F_1 seed, along with the parents were planted in an off-season nursery in Dalang Maidan (10,000 feet above mean sea level) in the Lahaul and Spiti districts of Himachal Pradesh for generation advancement and evaluation. With the need for F_2 material seed in mind for some important crosses, up to 800 F_1 seeds were sent for multiplication in the off-season nursery. Details on the material and information generated during last two crop seasons are presented in Table 3.

Table 3. Crosses attempted, advanced, and shared by Directorate of Wheat Research, Karnal, from cultivars listed in Table 2 targeted for different cropping areas of India.

Cross	F_1 seed obtained	Quantity of F_2 seed shared (g)	Target area
DBW 14/HUW 468	400	915	Assam
PBW 443/HUW 533	800	820	Assam
DBW 14/HUW 533	800	1000	Jharkhand
DL 788-2/PBW 502	800	540	Jharkhand
GW 273/HUW 468	800	1200	Jharkhand

The F_2 material was supplied to both the centers namely Ranchi and Shillongani for their use as PPB base material. In addition, a set of 95 advanced bulks from selected crosses in the F_6 and F_7 generations also was evaluated at DWR during 2002–03 crop season. Out of this evaluation, 25 promising bulks were selected based on yield, maturity duration, plant height, and disease reactions were multiplied and shared with the Ranchi and Shillongani centers during the 2003–04 crop season to support the activities of PPB. Results on the performance of material under the target area suited to local needs are being utilized for fine-tuning the program for further enhancing the yield levels in east and far-east regions of India.

Acknowledgment. The authors are grateful to Dr. G.O. Ferrara, CIMMYT, SARO, Kathmandu, Nepal, and the DIFD Agency for technical and financial support provided for the present study. We also thankfully acknowledge the support from the coöperators in India.

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Induction of variability through chemical mutagenesis in wheat.

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Wheat productivity in India has reached the saturation level because of the intensive use of available gene pool material in breeding programs. Mutation techniques are a novel approach for enhancing the level of genetic variability of a species within a short time. Selection can isolate superior genotypes (mutants) for various traits. Investigations on the effects of chemical mutagens for inducing variability have received much attention because of their importance in plant breeding. Among chemical mutagens, ethyl methane sulphonate (EMS) and sodium azide (SA) were used for inducing mutations in cereals (Awan et al. 1980; Georgiev 1982). Our experiment aimed to isolate and characterize mutants for yield traits using EMS and SA.

Approximately 1,000 healthy seeds of four high-yielding wheat genotypes, HP1633, HP1731, K9006, and K9107, were presoaked in distilled water for 1 h and treated in separate sets containing 0.01, 0.02, 0.03, and 0.04 M EMS (pH 7.0) and 0.5, 1.0, 1.5, and 2.0 mM SA (pH 3.0) prepared in fresh phosphate buffer. The seeds were completely submerged in the solutions (500 ml) for 4 h and then washed thoroughly in running water for 2 h before sowing to remove the residual chemicals. One thousand untreated dry seeds of all the four genotypes, soaked in distilled water for 4 h, served as the control.

A total of 36 treatment combinations including four controls were sown immediately after treatment with EMS and SA in Rabi 1995–96 at the Agriculture Research Farm, Banaras Hindu University, Varanasi. The plot size was 20 rows of 5 m with inter and intrarow spacing of 25 cm and 10 cm, respectively. All plants of each treatment representing M_1 generation were harvested singly for producing an M_2 generation. Seeds from individual M_1 plants were space planted in a single 5-m row. Untreated seeds (control) also were sown after each 10^{th} row for comparison. Individual plants were observed for various yield traits, and nine plants showing wide differences were selected and harvested separately to give the M_3 generation. Mutants were confirmed as true breeding, because all mutant seeds yielded morphologically similar plants in the M_3 that were quite distinct from the control. These mutants were harvested and planted in randomized block design with three replications in a double-row plot of 5 m in length in the crop season 1998–99. Ten plants from each mutant progeny row were used for characterization of the mutants for plant height (cm), number of tillers/plant, openness of flower glumes (degree), ear length (cm), number of grains/spike, 100-seed weight (g.), yield/plant (g), grain shining, ear position, and lodging.

The data were subjected to AONVA (Panse and Sukhatme 1967). For yield traits, ANOVA using the mutant and control populations indicated all the treatments differed significantly for plant height, number of tillers/plant, openness of floret, spike length, number of grains/spike, 100-seed weight, and yield/plant.

Characterization of mutants. Nine mutants, superior for yield traits, were subjected to various doses of EMS and SA (Table 5. p. 65). Both EMS and SA were effective in inducing variability in wheat genotypes at low and high concentrations of the chemicals, depending on the sensitivity of the genotype to the chemical and the concentration. The mutants were isolated and characterized for ten traits. WM1 (wheat mutant 1) was derived from the parent HP1633. WM2 and WM3 were mutants of HP1731. Chemical mutagenesis of K9006 produced mutants WM4, WM5, and WH6. WM7, WM8, and WM9 were isolated from the progenies of K9107.

Wheat mutant 1 (WM1). This mutant is high-yielding and bold seeded, with relatively higher number of grains/spike. WM1 had a significantly longer spike and wider angle of openness of flower than the control.

Wheat mutant 2 (WM2). A high-yielding mutant of HP1731 that had shiny, bold grains, a longer spike, and more grains/spike. WM2 also had a significantly wider angle of openness of flower than the control.

Wheat mutant 3 (WM3). This mutant was dwarf and a wider openness of glumes of the florets, but WM3 is poor for other traits.

Wheat mutant 4 (WM4). WM4 was a dwarf, high-yielding mutant having bold and shiny grains. This mutant also had significantly longer spikes and more profuse tillering than the parent K9006.

Wheat mutant 5 (WM5). This dwarf mutant was high-yielding and long-spiked with shiny grains and profuse tillering. WM5 had more seeds/spike and wider openness of glumes of the florets. This mutant also had a high stem strength, indicating its superiority for lodging resistance.

Wheat mutant 6 (WM6). This dwarf and high-yielding mutant possessed long, erect spikes with wider openness of glumes of the florets.

Wheat mutant 7 (WM7). WM7 was a high-yielding mutant having shiny, bold grains. WM7 also was for number of seeds/spike and openness of florets over the parent K9107.

Wheat mutant 8 (WM8). This dwarf mutant had significantly more seeds/spike and openness of florets compared to the K9107 parent.

Wheat mutant 9(WM9). WM9, also a dwarf mutant, had profuse tillering and more grains/spike, and a wider openness of the florets.

In general, most of the mutants were high yielding compared to parent cultivars and can be effectively utilized in

Table 4. Performance of mutants derived from ethyl methane sulphonate (EMS) and sodium azide (SA) and their controls for various traits in wheat. Plants were grown during the 1998–99 crop season.

Material	Parent	Mutagen	Mutagen oncen-tration	Plant height (cm)	Number of tillers/plant	Opemess of flower	Spike length (cm)	Number of grains/spike	100-seed weight (g)	Yield/plant (g)	Grain shining	Spike position	Lodging
CONTROL													
HP1633				96.89	9.56	3.17	11.38	45.68	3.56	15.43	Normal	Semidrooping	Susceptible
HP1731				90.01	10.22	2.83	12.10	53.19	3.57	18.46	Normal	Semierect	Susceptible
K9006				108.26	9.28	3.37	13.78	55.32	4.03	19.24	Normal	Semierect	Susceptible
K9107				108.74	9.37	3.10	12.86	52.42	4.69	21.71	Normal	Erect	Resistant
MUTANT													
WM1	HP1633	SA	0.5 mm	97.23	9.39	**5.47**	**11.56**	**51.68**	**4.63**	**18.45**	Normal	Semi drooping	Susceptible
WM2	HP1731	EMS	0.01 m	91.56	9.87	**3.13**	**12.32**	**54.35**	**3.74**	**20.42**	**Shiny**	Semierect	Susceptible
WM3	HP1731	SA	2.0 mm	**75.27**	10.25	**3.03**	12.10	53.47	3.01	16.62	Normal	Semierect	Susceptible
WM4	K9006	EMS	0.01 m	**104.26**	**9.81**	3.17	**15.27**	55.40	**4.63**	**22.18**	**Shiny**	Semierect	Susceptible
WM5	K9006	EMS	0.02 m	**105.07**	**15.40**	**3.53**	**15.11**	**55.65**	3.95	**20.99**	**Shiny**	Semierect	**Resistant**
WM6	K9006	SA	1.5 mm	**105.45**	9.54	**3.63**	**16.37**	55.47	3.75	**19.77**	Normal	**Erect**	Susceptible
WM7	K9107	EMS	0.03 m	107.64	9.54	**3.27**	12.43	**53.62**	**4.93**	**23.81**	**Shiny**	Erect	Resistant
WM8	K9107	SA	1.0 mm	**76.60**	9.63	**3.47**	11.13	**52.91**	3.62	18.33	Normal	Erect	Resistant
WM9	K9107	SA	1.5 mm	**79.78**	**14.33**	**3.37**	10.46	**55.98**	2.83	22.01	Normal	Erect	Resistant
S.E. ±				0.65	0.14	0.05	0.06	0.14	0.03	0.20			
C.D. 5%				1.34	0.28	0.10	0.12	0.29	0.06	0.41			

hybrid-development program because of their wider openness of glumes of the florets, which is expected to promote out crossing.

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Conservation of wheat germ plasm under natural conditions in the Lahul-Spiti Valley in the Himalayan Hills of India.

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The germination of 30 randomly selected wheat accessions from the wheat germ plasm maintained in different types of packing under natural conditions in Lahul Spiti, Himanchal Pradesh, was tested for 4 consecutive years. We observed that the seeds stored in aluminum envelopes had more than an 88 % germination rate and, thus, seeds can be maintained up to years in this type of packaging in a cost-effective manner.

Genetic resources are the prerequisite for a successful breeding program. India has achieved a tremendous jump in wheat production and ranks second worldwide, a result of using indigenous and exotic gene pools extensively in breeding programs. At present, conserving all the available germ plasm is a necessity. Conservation of these accessions requires a highly specific setup for maintaining the seed viability for long periods. Sixty-eight released cultivars were sent for conservation under natural condition (cold, dry environment) at the Wheat Summer Nursery (WSN) Facility at Dalang Maidan in the Lahul-Spiti Valley of the Himanchal Pradesh state for the first time in 1998. This station is located in the Himalayan Hills Range at more than 10,000 ft above mean sea level. The germination percent of the cultivars ranged from 98 % to 100 %. An experiment tested the effect of the prevailing environment on germination of wheat seeds conserved in different packaging over the years.

Of these 68 accessions, 30 (24 *T. aestivum* subsp. *aestivum,* four *T. turgidum* subsp. *durum*, one *T. turgidum* subsp. *dicoccum*, and one triticale) were selected randomly for the study. The seeds were stored in three types of packaging, cloth bags, waterproof envelopes, and aluminum envelopes. Beginning in 1999, seeds of these 30 accessions were removed from all packaging and germination tested over four consecutive years (1999–2002). ANOVA (Panse and Sukhatme 1967) was done and critical differences were used to compare germination in different packaging and duration of conservation.

Table 5. Mean germination percent of seed stored for different years.

Year	Symbol	Germination %
1999	A1	95.70
2000	A2	92.68
2001	A3	89.12
2002	A4	82.63
C.D. at 5 %		1.13

Table 6. Mean germination percent of wheat seed stored in different packaging.

Type of packaging	Symbol	Germination %
Cloth bag	B1	87.26
Waterproof envelope	B2	90.93
Aluminum envelope	B3	91.91
C.D. at 5 %		1.53

Table 7. Mean germination percent of wheat seed stored in different packing in different years.

Packaging material	Cloth bag	Waterproof envelope	Aluminum envelope
Year			
1999	95.00	95.40	96.70
2000	91.07	92.80	94.17
2001	85.77	90.07	91.53
2002	77.20	85.09	88.23
C.D. (5 %)	3.07		

ANOVA indicated the highly significant differences for the various packaging methods, year, and the 'packaging x year' interaction. Results on germination percent of the genotypes each year indicated a significant reduction over the years compared to first year but remained good during the first 3 years of their storage under natural conditions in the Lahul Valley. A drastic reduction in germination was observed in the fourth year (Table 5, p. 66). Although seed stored in aluminum envelopes had the maximum germination, they were comparable to those stored in waterproof envelopes (Table 6, p. 66). Considering the 'year x packaging material' interaction (Table 7, p. 66), we found that the germination percent was highest in the aluminum envelopes but nonsignificant differences during the first three years in aluminum and in waterproof envelopes were observed. During the fourth year, marginally significant differences in the germination rates of the seed from aluminum envelopes was observed but the germination percent was still sufficient for a good crop stand.

A significant reduction in germination of seed stored in waterproof envelopes was observed compared to those stored in aluminum envelopes. In seeds stored in cloth bags, a significant reduction in germination percent across all years was observed. From these results, we found the genotypes HD2009 (95.17 %), PBW34 (93.42 %), C306 (93.17 %), CPAN3004 (93.17 %), HD2285 (93.08 %), GW190 (92.42 %), Dl788-2 (91.8 3%), Dl802-3 (91.67 %), HD2189 (91.67 %), HUW234 (91.08 %), HW2004 (91.0 %), Raj1555 (90.83 %), GW173 (90.50 %), HD2329 (90.42 %), and HP1633 (90.17%) were the most promising with a mean germination greater than 90 %.

We concluded that no loss in viability occurred in the seeds packed in aluminum envelopes or in waterproof envelopes during the first 3 years, but during the fourth year, germination percent was better for the seeds stored in aluminum envelopes. Thus, the seeds can be conserved under natural conditions of Lahul-Spiti in cost effective manner for up to 4 years in aluminum envelopes.

Acknowledgment. Authors are thankful to Mr. Rajinder Pal Sharma for technical help in conducting the experiment.

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URJA (HD 2864)–a wheat cultivar for the late-sown conditions of central India.

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The wheat-growing areas in India is divided into six zones based on agroclimatic conditions. The Central Zone is comprised of the Madhya Pradesh, Gujarat, parts of Rajasthan, and Utter Pradesh provinces with an area of around 5 x 10^6 ha and has a hot, dry climate. The wheat cultivars grown in this area contributes to about 10–15 percent of the total wheat production in India. The Central Zone has a yield gap of nearly 1.5 t/ha in the average productivity of wheat compared to the North Western Plains Zone, which has highest productivity in the country (4.4 t/ha). This gap is mainly because of complexities arising from the exposure of the wheat crop to the unfavorable temperatures, especially during grain-filling stage, and limited availability of water. Thus, heat tolerance and efficient water and nutrient utilization is required. The wheat scenario in central India is more aggravated by the high intensity of stem and leaf rusts and foot rot, which cause severe yield losses. Cultivars released for commercial cultivation in central India, in addition to having high yield potential, should also have good early vigor, early maturity, heat tolerance in late-sown conditions, and resistance to leaf and stem rusts.

The bread wheat **Urja** (HD 2864), released in 2004 for central India under late-sown conditions, was developed using a modified pedigree method with the parentage DL509-2/DL377-8. Four wheat cultivars, LOK-1, GW173, Vidisha, and MP4010, are grown in this zone under late-sown, irrigated conditions, however, LOK-1 is the most popular. LOK-1 has become susceptible to leaf and stem rusts and needs replaced by another cultivar with high-yield potential and genes for rust resistance. During 3 years of testing in multilocation yield trials in central India, Urja had yields of 41.7 q/ha, compared to LOK-1 (37.8 q/ha, check), GW173 (40.7 q/ha), Vidisha (39.5 q/ha), and MP4010 (40.8 q/ha) (Table 1, p. 68). Urja has shown significant superiority over the check Lok-1 and numerical superiority over GW 173, Vidisha, and MP 4010 by the margins of 10.31, 2.45, 5.82, and 2.45 percent, respectively. Urja was in the first nonsignificant group in 19 out of 28 locations, exhibiting stability in performance. The performance stability of Urja is attributed to superior adaptability of the genotype to various agroclimatic conditions prevalent in the zone. At one location, the cultivar had the highest yield potential at 68.2 q/ha. Urja (HD 2864) exhibited better response to yield under different agronomic trials and recorded the highest grain yield (39.4 and 25.5 q/ha) and ranked 1st under late and very late sown conditions, respectively, compared to Lok-1 (34.3 and 21.5 q/ha), GW 173 (39.0 and 25.5 q/ha), and MP 4010 (37.5 and 25.3 q/ha) (Table 2).

Table 1. Yield data of Urja (HD 2864) tested under multilocation trials in irrigated, late-sown conditions of the Central Zone of India. An asterisk (*) indicates significantly superior to HD 2864; values in parentheses indicate the rank of the entry.

			Checks				
Year	No. of trials	Urja (HD 2864)	Lok-1	GW 173	Vidisha	MP 4010	C.D.
Mean yield (q/ha).							
2001–02	4	42.2 (2)	—	39.3 (12)	—	—	4.6
2002–03	12	42.2 (3)	38.1* (14)	41.7 (4)	38.7* (12)	41.6 (5)	1.4
2003–04	12	41.0 (2)	37.6* (13)	40.1 (4)	40.4 (3)	40.1 (4)	1.4
Weighted mean	—	41.7	37.8	40.7	39.5	40.8	—
% increase or decrease over checks and qualifying cultivars.							
2001–02	—	—	—	+6.87	—	—	—
2002–03	—	—	+9.71*	+1.18	+8.29*	+1.42	—
2003–04	—	—	+9.09*	+2.29	+1.53	+2.29	—
Weighted mean	—	—	+10.31	+2.45	+5.82	+2.45	—
Frequency in top NS group.							
2001–02	—	3/4	—	1/4	—	—	—
2002–03	—	9/12	5/12	6/12	2/12	6/12	—
2003–04	—	7/12	5/12	6/12	5/12	7/12	—
Mean	—	19/28	10/24	13/28	7/24	13/24	—

Table 2. Yield (q/ha) of Urja (HD 2864) to changes in agronomic conditions. Data based on agronomic trails conducted at four centers in the Central Zone of India.

	Urja (HD 2864)		Checks					
			LOK-1		GW 173		MP 4010	
Date of sowing	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank
Late	39.4	1	34.3	6	39.0	2	37.5	5
Very Late	25.5	1	21.5	6	25.5	1	25.3	3
Mean	32.4	1	27.9	6	32.2	2	31.4	4

On the basis of 3 years of data, Urja has shown a high level of resistance to leaf rust and stem rust compared to the check LOK-1 and GW 173. Urja has adult-plant resistance to various pathotypes of leaf rust and stem rust, whereas LOK-1 is susceptible. The very high level of resistance of Urja to foot rot disease (6.0 %) compared to LOK-1 (65.0 %), GW 173 (20.0 %), Vidisha (40.0 %), and MP 4010 (15.0 %) adequately addresses the problem in early crop establishment in the zone. The unique feature of Urja is the high grain hardness score (15.8), which indicates more flour recovery (because of more compaction of the starch molecules) compared to those for LOK-1 (11.9), GW 173 (11.5), Vidisha (14.4), and MP 4010 (13.4). The better grain hardness of Urja also is indicative of better storage ability. The millers prefer hard wheats because of greater profits from more flour recovery. Urja also has a high protein content (12.67 %), good grain appearance (6.05/10), hectoliter weight (83.35 kg), and good chapati-making quality (7.54/10).

Urja does not contain the T1B·1R translocation, therefore, has a total balance of traits that makes it more profitable for farmers; high yield potential, better disease resistance, amenable to late sowing thereby indicating heat tolerance, high grain weight, and appropriate industrial acceptance.

Genetic analysis of stem rust resistance in synthetic-hexaploid wheats.

S. Salim Javed, S.S. Singh, and J.B. Sharma.

Stem rust of wheat is the most destructive of the three rusts. An apparently healthy crop 3 weeks before harvest can be reduced to a black tangle of broken stems and shriveled grain by harvest. Breeding for resistance represents the most cost-effective and environmentally safe method for controlling stem rust. Well coördinated research worldwide has contained the stem rust pathogen. No major epidemics of stem rust have occurred since the 1960s. However, no resistance can be permanent. Recently, instances of break down of resistance have been seen. During last 3 years in Uganda and South Africa, the genes *Sr31, Sr8b*, and *Sr38* have become susceptible (Pretorius 2000; Boshoff 2002). Thus, identifying additional resistance genes from various sources is a necessity. *Aegilops tauschii*, representing the D-genome donor of hexaploid wheat, has been identified as an important source of resistance to a wide array of diseases of common wheat (Cox et al. 1994). One effective way to make use of this rich source of resistance genes is by producing synthetic-hexaploid wheats from the crosses, between *T. turgidum* and *Ae. tauschii* (Mujeeb-Kazi et al. 1987). A high degree of genetic variability for stem rust resistance has been observed at both the seedling and adult-plant stages in synthetic-hexaploid wheats. This source of resistance could be incorporated into hexaploid wheats to diversify the existing gene pool for stem rust resistance.

Forty-two synthetic bread wheats were tested against pathotype 40A of the stem rust pathogen at the seedling stage under glasshouse conditions and at the adult-plant stage under field conditions. Rust severity was recorded according to the modified Cobb's scale described by Peterson et al. (1948) and was estimated on the basis of percentage area covered with pustules. On the basis of adult-plant response upon inoculation with pathotype 40A, six synthetic-hexaploid wheats with responses up to 5R were selected. Synthetic 4 had a trace, whereas Synthetic 42, Synthetic 55, Synthetic 59, Synthetic 60, and Synthetic 86 were 5R. These six synthetic-hexaploid wheats were selected for further study.

The six synthetic-hexaploid wheats were subjected to multipathotype testing with different races 21-1, 21-A-2, 34, 40A, 40-1, 117-3, 117-6, and 295. Based on infection types produced at seedling stage and free-threshability, three synthetics (synthetic 4 (Altar 84/*Ae. tauschii* 188), synthetic 55 (Gan/*Ae. tauschii* 180), and synthetic 86 (Doy 1/*Ae. tauschii* 372)) were selected. Of these six synthetics, synthetic 4 had a reaction of 0; to all races tested, whereas synthetics 55 and 86 had a score of 1^-. These three synthetic hexaploids were selected for genetic analysis.

To understand the genetic behavior of resistance in the synthetic wheats, crosses were made between the three selected synthetics and Agra Local, a hexaploid wheat that is highly susceptible at the seedling and adult-plant stage to all known stem rust pathotypes in India. The F_1, F_2, and F_3 populations of these crosses were tested for resistance to three different pathotypes (40A, 117-6, and 21-1). The pathotypes were chosen because of their higher virulence on durum wheat, thus, resistance from *Ae. tauschii* could be detected, and they belonged to different groups. The same populations were tested as adult plants with pathotype 40A under field conditions.

In Synthetic 4, the F_1 was resistant to all the three pathotypes tested, indicating dominant nature of resistance. The F_2 seedling segregation data suggested a monogenic, dominant nature of resistance against all the three pathotypes. The monogenic, dominant nature was confirmed in the F_3 families. The adult-plant response in the F_2 seedlings inoculated with pathotype 40A also indicated the monogenic, dominant nature of resistance/ The F_3 adult-plant data confirmed these results. Thus, a single, dominant gene governed the resistance in synthetic 4. This particular resistance is effective at all plant growth stages. The correlated behavior of F_3 families to all three races indicated that the same resistance gene governs resistance to all the three races.

In Synthetic 55, the resistance also was monogenic, dominant in nature. The monogenic, dominant nature of resistance was confirmed by F2 and F_3 data. This gene conferred resistance to the three pathotypes (40A, 117-6, and 21-1). Adult-plant resistance indicated that the gene was effective at all stages of plant growth. The correlated behavior of F_3 families with the above three pathotypes indicated that the same gene conferred resistance to the three pathotypes. Allelism tests determined whether or not the gene conferring resistance is same or different in Synthetics 4 and 55. Because no susceptible segregants were found in the F_2 seedlings of the cross between these two synthetics, we concluded that same gene conferred resistance in these two synthetics.

The F_1 was resistant in Synthetic 86 indicating a dominant gene for resistance. The F_2 seedling segregation ratio fit a 13:3 ratio, indicating that two genes for resistance, one dominant and one recessive, controlled resistance at the seedling stage. The distribution of the F_3 families in a 7:8:1 ratio of resistant:segregating:susceptible confirmed that one dominant and one recessive gene controlled the resistance. The adult-plant studies indicated that the resistance was controlled by three genes (one dominant and two recessive genes). Because Synthetic 86 had seedling mottling and pseudo-black chaff, characteristic markers for *Sr2*, the second recessive gene operative only at adult-plant stage could be *Sr2*. Allelism tests indicated that the dominant gene found in Synthetic 86 is different from that found in Synthetics 4 and 55.

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HW 3083, a genetic stock with multiple disease resistance.

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IARI, Wellington, has developed several genetic stocks by employing pedigree and backcross-breeding methods resulting in the introgression of several disease-resistance genes into derived lines. One such line, HW 3083, has been identified by the All India Co-Ordinated Wheat Improvement Project as resistant to leaf rust, stem rust, yellow rust, and powdery mildew under both artificial and natural conditions. The resistance to all the three rusts and powdery mildew is attributed to the presence of the *Ae. speltoides*-derived, leaf rust-resistance gene *Lr28* and *S. cereale*-derived, linked genes *Sr31*, *Lr26*, *Yr9*, and *Pm8*. We also identified a new genetic source for the resistance to new *Yr9* virulence (78 S 84).

HW 2049, postulated to have rust resistance genes Lr19 and Sr25.

K.A. Nayeem, M. Sivasamy, A.J. Prabakaran, and M. Prashar.

Alien rust-resistance genes *Lr19*/*Sr25* derived from *Ag. elongatum* were transferred into several well-adopted Indian bread wheat cultivars by backcrossing (Tomar and Menon 1999). Gene identification was done at the Directorate of Wheat Research, Flowerdale, Shimla. The cultivar HW 209 was screened against all the virulent pathotypes of black, brown, and yellow rusts and was postulated to have rust-resistance genes *Lr19* and *Sr25* (Table 1, p. 71). This stock has been registered with NBPGR after approval at the Plant Germplasm Registration Committee of Indian Council of Agricultural Research held 31 May, 2004, and registered HW 2049 as follows: Genotype, HW 2049; INGR No., 04016; and National Identity, IC 408338. HW 2049 has the best combination of resistance to brown and black rusts (*Lr19* and *Sr25*) (Table 2, p. 71). The passport data for 35 characters indicated variation only in protein content 12.02 %, medium maturity, and a 5.9-cm spike. The rest of the traits are similar to the recurrent parent HD 2285 (Table 3, p. 72). The genetic stock is available for use in wheat-breeding programs.

Table 1. Seedling reaction to different isolates of wheat rust in the cultivars HD 2049 and HW 2002 and recurrent parents HD 2285 and Sonalika evaluated at the Directorate of Wheat Research, Shimla, India.

	Brown rust				Black rust				Yellow rust		
Rust isolate	12.2	77.5	104-1	104-2	62G29	62G29-1	3G79	7G11	46S103	46S119	46S102
HD 2285	3^+	3^+	3^+	3^+	2^+	2^-	2^-	2	—	3	2^+
HD 2049	1	;	;	;1	2	—	2^-	2^-	3	3C	;
Lr19/Sr25	0;	;1	;12	;1	2^-	2^-	;1	;1	3^+	3^+	—
Kalyansona	3	3^+	3^+	3	3^+	3^+	2	3^+	3^+	3^+	0;
HW 2002	;1	;-	$;1^-$	0;	;	3^+	2^-	2^-	3^+	3C	—
Sr24/*Lr24*	0;	;	$;1^-$	0;	2^-	2^-	0;	2^-	3^+	—	0;

Reference.

Tomar SMS and Menon MK. 1999. Fast rusting to stem rust in India on bread wheat cultivars carrying *Lr28* and *Lr32* Wheat Inf Serv 88:32-36.

Table 2. Adult-plant reaction to different wheat rusts in the wheat cultivars HD 2049, HW 2002, and HW 2031 and recurrent parents HD 2285, Kalyansona, and Sonalika evaluated at the Directorate of Wheat Research, Shimla, India, in 2003. F indicates free from all pathotypes of brown rust at the Wellington Research Station.

	Gene(s) present	Rust reaction		
		black	brown	yellow
HD 2285	—	30MS	100S	30S
HD 2049 (HD 2285/Sunstar*6/C 80-1)	*Lr19*, *Sr25*	15R–MR	F	30S
Kalyansona	—	80	80S	90S
HW 2002 (Kalyansona*6//TR380-14*7/3Ag#14)	*Lr24, Sr24*	TMS S	5MR F	40S
Sonalika	—	—	60S	80S
HW 2031 (Sonalika*8//CS2A/2M#4/2)	*Lr28*	80S	F	70S

Confirmation of Lr24 and Sr24 genes in line HW 2002.

K.A. Nayeem, M. Sivasamy, A.J. Prabakaran, and M. Prashar.

At IARI, Wellington, scientists have successfully transferred *Ag. elongatum*-derived, linked rust resistant genes *Sr24*/*Lr24* into 19 elite Indian bread wheat cultivars including Kalyansona. The backcross derivative line HW 2002, was screened against virulent races of all the three rusts at Flowerdale, Shimla, during 2003 (Table 1), for gene identification and subsequently registered with the Plant Germplasm Division of NBPGR. HW 2002 has exhibited adult-plant resistance (TMS) for black, brown rust (5 MR), and yellow (40S) rusts (Table 2). The seedling reaction of HW 2002 is resistant to both brown and black rusts (*Lr24*/*Sr24*). Passport data indicates that HW 2002 is similar with the recurrent parent Kalyansona for all traits (Table 3). The genetic stock is available for use in wheat-breeding programs.

Lr28 in a Sonalika background.

K.A. Nayeem, M. Sivasamy, A.J. Prabakaran, and M. Prashar.

The IARI Regional Station, Wellington, functions as the nodal center for providing a National Off-season Facility for Rabi crops and develops numerous backcross lines with known rust-resistance genes in Indian wheat backgrounds. The station is a hot-spot for foliar diseases and provides natural screening for rusts and powdery mildew under field conditions. The gene *Lr28* was first introduced by McIntosh in the Australian wheat cultivar Sunland. Now *Lr28* has been incorporated in the Sonolika background by Tomar and Menon (1999). The gene confers a high degree of resistance and is derived from *Ae. speltoides*.

Table 3. Passport data of HW 2049 (HD 2285*6//Sunstar*6/C80-1) and HW 2002 ((Kalyansona*6//TR380-14*7/3Ag#14) and the recurrent parents HD 2285 and Kalayansona.

	HW 2049	HD 2285	HW2002	Kalayansona	HW 2031	Sonalika
Days-to-heading	63	63	62	62	60	60
Days-to-maturity	113	112	114	114	110	110
Plant height (cm)	70.0	72.6	76.6	76.6	81.2	81.2
Spike length (cm)	5.9	6.2	8.7	8.7	9.1	9.1
Spikelets/spike	13.0	12.8	13.4	13.4	13.2	13.2
Seeds/spike	22.0	20.8	26.8	26.8	28.6	28.6
Flag leaf length (cm)	24.78	25.0	28.94	28.94	24.9	24.9
Flag leaf width (cm)	1.50	1.64	1.56	1.56	1.10	1.10
1,000-kernel weight (g)	29.4	29.71	32.0	32.0	—	—
Protein content (%)	12.02	12.98	11.94	11.94	12.9	12.9
Growth habit	erect	erect	erect	erect	erect	erect
Coleoptile color	green	green	green	green	green	green
Auricle color	green (colorless)	green (colorless)	green	green	green	green
Auricle pubescence	none	none	none	none	none	none
Flag leaf angle	semierect	semierect	semierect	semierect	erect	erect
Waxiness	peduncle	peduncle	peduncle	peduncle	peduncle	peduncle
Foliage color	dark green	dark green	green	green	green	green
Spike color	white	white	white	white	white	white
Spike shape	clavate	parallel	parallel	parallel	tapering	tapering
Spike density	dense	dense	dense	dense	lax	lax
Spike length	short (< 9.0 cm)	short (< 9.0 cm)	short	short	medium	medium
Awn length	short (< 6.5 cm)	short	short	short	long	long
Awn color	white	white	white	white	white	white
Outer glume shoulder shape	round	square	round	round	square	square
Outer glume pubescence	none	none	none	none	none	none
Glume beak length	short (< 2mm)	short	medium	medium	short	short
Glume beak curvature	weak	weak	medium	medium	medium	medium
Grain color	amber	amber	white	brown	amber	amber
Grain shape	oblong	oblong	elliptical	elliptical	elliptical	elliptical
Grain texture	hard	semihard	semihard	semihard	semihard	semihard
Grain size	medium	medium	bold	bold	bold	bold
Brush hair length	short	short	short	short	short	short
Brush hair profile	blunt	blunt	painted	painted	blunt	blunt
Germ width	medium	medium	wide	wide	wide	wide
Grain crease	shallow	shallow	shallow	shallow	deep	deep

The Indian line 'CS 2A/2M 4/2' has the *Ae. speltoides*-derived gene *Lr28*, which has a high degree of adult plant resistance to leaf rust at Wellington. The gene *Lr28* was transferred into the bread wheat cultivar Sonalika, which is susceptible to leaf rust. Gene selection at the seedling stage was made during 2003 at the Directorate for Wheat Research, Flowerdake, Shimla, against the most virulent pathotypes of stem, leaf, and stripe rusts. The line HW 2031 has given the maximum response of fleck (0;) for all pathotypes, which indicated an immune reaction to brown rust (Table 2). The line has early maturity, 12.9 % protein content, and bold, amber grains (Table 3). This line has been officially registered with NBPGR as HW 2031 (INGR 04015, National Identity IC 408334, registered for brown rust with *Lr28* gene). The adult-plant reactions to brown rust exhibited an F, free from all the pathotypes of brown rust prevailing at Wellington. Thus, the gene *Lr28* has been successfully transferred and is an effective gene from tolerance to brown rust. The genetic stock is available for use in wheat-breeding programs.

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Tomar SMS and Menon MK. 1999. Fast rusting to stem rust in India on bread wheat cultivars carrying *Lr28* and *Lr32* Wheat Inf Serv 88:32-36.

Introgression of single, double, and multiple genes for resistance to rusts and powdery mildew by backcross breeding.

K.A. Nayeem, M. Sivasamy, and M.K. Menon.

For the last 5 years, total wheat worldwide production declined and during 2001 only 570 x 10^6 tons of wheat was produced. India provided 13 % of world's food production. By 2020, the population of India is estimated to be 1.3 x 10^9 and to feed this population, India will need 109 x 10^6 tons of wheat grains alone, which is a 37 x 10^6 ton increase in production from the present level of 72 x 10^6 tons. Each year, production must increase by 2.5 x 10^6 tons to keep up with supply and demand. A 2 % genetic gain in yield per year is needed. Apart from increasing area under cultivation of wheat in nontraditional areas, development of high-yielding, disease-resistant cultivars in a mosaic pattern by deploying genes should be the strategy for the future.

Scientists worldwide have exploited alien rust-resistance genes from *Ae. ventricosa, T. turgidum* subsp. *dicoccoides*, and rye. Forty-nine leaf rust, 38 stem rust, and 32 stripe rust resistance genes comprise race-specific and race nonspecific genes that already have been symbolized. At the IARI Regional Station, Wellington, several genes have been incorporated into popular Indian wheat cultivars by backcrossing. Some of the cultivars have been released, i.e., HW 2004 (Amar) for the Central Zone for commercial cultivation (*Lr24*); HW 2045 for the North Western Plain Zone, (*Lr19* + *Sr25*), HW 2044 (*Lr19* + *Sr25*) for the SH Zone, and HW 2034 (MACS 6145) with *Lr28* for North Western Plains Zone.

Effective genes at Wellington include *Lr19*, *Lr24*, *Lr26*, *Lr28*, *Lr32*, *Lr37*, *Lr39*, *Lr41*, *Lr42*, and *Lr45* for the existing leaf rust pathotypes; *Sr24*, *Sr31*, *Sr34*, *Sr36*, and *Sr38* for stem rust; and *Yr9*, *Yr10*, *Yr15,* and *Yr17* for stripe rust. All of these genes have already been introgressed into the lines C 306, HD 2402, HD 2285, HS 240, HD 2329, Kalyan Sona, Sonalika, UP 262, WL 711, LOK-1, WH 147, HD 2687 Raj 3077, Parbhani 51, PBW 343, PBW 226, and UP 2338 with single dominant gene/genes. Linked genes *Sr24+Lr24*, *Lr19, Sr25*, *Sr31+Lr26+Yr9+Pms8*, *Lr37*, *Sr38,* and *Yr17*, *Sr36+Pm6* were introgressed. The linked and multiple genes of *Sr31+Lr19* in HD 2285, H1 1077, Lok-1 (HW 4064); *Sr31+Lr32* in HD 2285 (HW 4049), Kalyan Sona (HW 4125), Lok-1 (HW 4053); *Sr36+Pm6* and *Lr19+Sr25* in WH 147; and *Lr32+Yr15* in HD 2329 are already successfully transferred.

ITEMS FROM ITALY

ISTITUTO SPERIMENTALE PER LA CEREALICOLTURA—EXPERIMENTAL INSTITUTE FOR CEREAL RESEARCH
via R. Forlani, 3 – 26866 S. Angelo Lodigiano (LO), Italy.

Effect of cereal bug attacks on bread wheat quality.

M. Corbellini, P. Vaccino, A. Curioni, and L. Tavella.

Cereal bugs are one of the main wheat pests in southeastern Europe, western Asia, and northern Africa. Recently outbreaks of *Eurygaster maura* have been observed in northwestern Italy even if its populations are usually well controlled by egg parasitoids. The bugs feed on spikes, piercing the developing grains and injecting their saliva rich in proteolytic enzymes into the endosperm and affecting baking quality because of the detrimental effect of proteases on gluten structure.

In order to pinpoint the relationships between the timing of the bug attack and gluten degradation, a study was set up by caging plants of two bread wheat cultivars characterized by different seed texture and bread-making quality and introducing adults of *E. maura* in four different grain-filling stages. The timing of the bug attack was related to the amount of bug damage and to the qualitative decline shown by the decreasing of protein content and SDS-sedimentation volume. Results from SDS gel electrophoresis of storage proteins showed that bug damage was associated with the degradation of some gliadin or glutenin components; however, despite any evident technological damage, the degradation of protein components was not always observed. The latency of the proteases injected by the insects may be one explanation. In order to activate the proteases, a micromethod was set up by mixing small quantities of flour with water at 30°C. Extraction of glutenin components from these microdoughs followed by one-dimensional SDS–PAGE revealed progressive degradation of two components of the HMW glutenins in damaged samples, associated with the appearance of minor fragments with lower Mr that should represent the product of the proteolytic activity. The results were confirmed by HPLC analyses. The soluble fraction profiles of both damaged and undamaged samples do not show any variation. On the contrary, a breakdown of the first peak of the insoluble fraction, representing the high Mr typical of the gluten network, is evident in the damaged samples.

Under the experimental conditions, maximum degradation of gluten aggregates was observed with bug attacks at the late milk-ripe stage of grain filling, suggesting that chemical crop protection avoid general treatment throughout the plant life-cycle.

Breeding for the waxy character in bread wheat.

G. Boggini, M. Cattaneo, C. Basone, and P. Vaccino.

Waxy mutations in bread wheat are derived by the loss of functionality of the granule-bound starch synthase I (GBSSI), the enzyme involved in amylose synthesis, encoded by three different *Wx* genes at the single-copy homoeologous locus *Waxy*. The loss of one or more GBSS isoforms results in the reduction (partial-*waxy*) or absence (*waxy*) of amylose in the starch. *Waxy* wheats may find application in the production of modified food starch and their flour may be used to extend the shelf life of baked products; moreover, they strongly influence Asian noodle quality.

The breeding program at our institute to develop *waxy* wheat lines adapted to the Italian environment is in progress. F_4 generations derived from nine crosses were selected for agronomic traits. Grains were analyzed by SDS–PAGE, and the flour of the double-null mutants were analyzed for starch-pasting properties using a Rapid Visco Analyzer.

Strampelli cultivars: biochemical, technological, and agronomical characterization.

G. Boggini, A. Brandolini, M. Perenzin, S. Empilli, P. Vaccino, R. Stefanini, and M. Cattaneo.

Nazareno Strampelli was one of the most important breeders in the world. His work preceded that of Norman Borlaug and the 'Green Revolution' by nearly 30 years. During his long career, he released more than 75 bread wheat cultivars, largely grown in Italy and all over the world, that also appear in the pedigree of significant recent cultivars. The agronomic and quality description of these cultivars, their comparison with modern cultivars, and their rescue from loss were the aim of this work.

The cultivars were clustered in different groups according to the coefficient of parentage, on the basis of the pedigrees described by Strampelli. The narrow genetic background of Strampelli germ plasm was confirmed by the limited variability observed in gliadin and glutenin composition. Molecular genetic diversity also was assessed by means of AFLP analysis.

The detailed results of this study were summarized on a CD, edited by the Institute for Cereal Research. The CD may be requested from cattaneo@iscsal.it.

Puroindoline and kernel hardness in Triticum aestivum.

N.E. Pogna, L. Gazza, G. Boggini, M. Corbellini, and P. Vaccino.

Kernel hardness, an important technological characteristic influencing milling and uses of bread wheat, is under the genetic control of *Pina-D1* and *Pinb-D1* loci coding for puroindoline a (pin A) and puroindoline b (pinB), respectively. We investigated both extra-soft and hard bread wheat cultivars lacking pin A. Extra-soft cultivars tend to have high amounts of pin on the surface of starch granules as compared to soft cultivars sharing the same pin composition. With the exception of five European extra-soft cultivars, which likely have a modified DNA conformation in a specific promoter region, the extra-soft cultivars analyzed showed no differences in their pin sequence with respect to soft cultivars. This result suggests the presence of factors other than pins that could modulate kernel texture as well, and investigations, in particular on starch conformation of extra soft cultivars, are in progress. In addition, we found that extra-soft cultivars have higher amounts of pin gene transcripts and a different temporal distribution of the above mentioned transcript. We now are investigating the promoter region of these extra-soft bread wheat cultivars.

Fortuna and Glenman are two null pin A, hard common wheats that show a cytosine deletion in position 265 in the coding region of pin A gene, which resulted in a TGA stop codon at position 361. The novel gene is the first null a allele due to a point mutation revealed in the *pina-D1* locus. We now are characterizing the other hard bread wheat cultivars lacking Pin A.

Publications.

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CD-ROM.

"Le varietà di frumento tenero costituite da Nazareno Strampelli" by R. Stefanini, M. Cattaneo, and G. Boggini.

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Reaction of 31 cultivars of durum wheat to wheat soilborne mosaic virus during 2003–04.

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Wheat soilborne mosaic virus is widespread in northern and central Italy where it causes severe losses on both common and durum wheat crops. Yield losses of up to 50 % and 70 % have been recorded on susceptible cultivars of common wheat and durum wheat, respectively. WSBMV also is present in a number of farms in southern Italy and in Sicily. During the 2003–04 season, 31 durum wheat cultivars were assayed in a severely WSBMV-infested field situated near Minerbio (Bologna) to study their reaction to this virus. The cultivars were grown in 10-m^2 plots distributed in the field according to a randomized block design with three replicates. As in previous years, resistance to WSBMV was evaluated on the basis of DAS-ELISA readings (on two dates), symptom severity (on four dates, using a 0–4 scale), and agronomic performance. Although symptom severity (mean score = 1.6; range = 0.3–3.4) was moderately high, disease pressure was insufficient to adequately discern all susceptible entries. Cultivars Duilio, Quadrato, and Torrebianca, for instance, had low ELISA values despite their reknown susceptibility to WSBMV. Cultivars Prometeo and Concadoro, assayed for the first time, proved susceptible in terms of symptom severity, ELISA values, and agronomic performance. Simple correlation coefficients between agronomic data, ELISA values, and symptom scores (Table 1) were relatively high and mostly statistically significant. Regression analysis indicated that the cultivars with the highest disease scores suffered grain losses attributable to WSBMV of about 50 %. Among the durum wheat cultivars marketed in Italy, only seven (Colorado, Dupri, Dylan, Ionio, Neodur, Provenzal, and Tiziana) of the 91 we have tested so far have shown high levels of resistance to WSBMV.

Table 1. Simple correlation coefficients between disease ratings, ELISA values, and various plant characters for 31 cultivars of durum wheat grown in the 2003–04 season in a field infested by wheat soilborne mosaic virus. Values with * are significant at P = 0.05; ** are significant at P = 0.01.

	Disease severity	ELISA values
Grain yield	–0.859**	–0.874**
Test weight	–0.340	–0.325
Plant height	–0.766**	–0.797**
1,000-kernel weight	–0.537**	–0.497**
Heading date	0.330	0.266
ELISA values	0.928**	—

Reactions of 36 cultivars of common wheat to wheat soilborne mosaic virus during 2003–04.

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Thirty-six cultivars of common wheat were grown in a severely WSBMV-infested field near Minerbio (Bologna) during the 2003–04 season. Entries were grown in 10-^{m2} plots distributed in the field according to a randomized block design with three replicates. Resistance to WSBMV was evaluated on the basis of DAS-ELISA readings (on two dates), symptom severity (on four dates, using a 0–4 scale), and agronomic performance. Symptoms (mean score = 0.4; range = 0.1–0.8) were extremely mild and, as in all our previous trials, milder than those observed on the durum wheat cultivars assayed in an adjacent field. Common wheat cultivars Nomade and Paderno, assayed for the first time, were classed as susceptible based on their relatively high ELISA values. ELISA values, symptom scores, and agronomic data were not significantly correlated with each other (Table 2).

Table 2. Simple correlation coefficients between disease ratings, ELISA values, and various plant characters for 31 cultivars of common wheat grown in the 2003–04 season in a field infested by wheat soilborne mosaic virus. Values with * are significant at P = 0.05; ** are significant at P = 0.01.

	Disease severity	ELISA values
Grain yield	–0.318	0.179
Test weight	0.008	0.143
Plant height	0.267	0.059
1,000-kernel weight	–0.232	–0.024
Heading date	–0.109	–0.383*
ELISA values	0.044	—

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Reduced height gene in Triticum polonicum IC12196.

Triticum turgidum subsp. *polonicum* IC12196 is a GA_3-insensitive semidwarf accession. To assess allelic relationships, IC12196 was hybridized with the GA_3-insensitive cultivar Cando (*Rht-B1b*), the tall cultivar LD222 (*Rht-B1a*), and the GA_3-sensitive semidwarf durum wheat cultivar Icaro (*Rht 18*). The GA_3-response of F_2 seedlings from the cross 'Icaro/IC12196' segregated into the ratio 3 (insensitive): 1 (sensitive). All F_2 seedlings from the cross, 'Cando/IC12196' were GA_3-insensitive. A single, dominant gene allelic to *Rht-B1b* on chromosome 4B determines the GA_3-insensitivity of IC12196. The allele may be either *Rht-B1b* itself or one of the alternative alleles at *Rht-B1* locus, although further experiments will be required to distinguish between these possibilities. The allele at the *Rht-B1* locus of IC12196 was tentatively designated as $Rht\text{-}B1^{IC12196}$. IC12196 may be alternative source of semidwarfing genes at the locus *Rht-B1*, and it may have potential for the development of durum wheat cultivars.

Chlorophyll b-deficient mutants of Triticum monococcum subsp. monococcum.

The primitive cultivated wheat *T. monococcum* subsp. *monococcum* often is viewed as a source of genes to be used in durum and bread wheat breeding programs. In the present study, two chlorophyll-deficient mutants of *T. monococcum* subsp. *monococcum* were used to analyze the consequences faced by chlorophyll-deficient mutation. We assessed the inheritance of chlorophyll-deficient mutants *purple mutant* and *Moegi mutant*. Both mutations are determined by different single recessive genes. The *Moegi mutant* is one of the *chlorina* mutations based on light environmental effect on chlorophyll accumulation. A striking difference was found between the *purple mutant* and the wild type, which had much higher PSII and Fv/Fm at the given level of absorbed photon irradiance that can be attributed due to the severe reduction of in PSII antenna size in the absence of LHCII.

Chromosomal location of the homoeologous genes effecting phenol color reaction of kernels in durum wheat.

Polyphenol oxidase activity was estimated by the color reaction of kernels to phenol solution. We found that the genes located on homoeologous group-2 chromosomes have an important effect on the level of phenol colour reaction of kernels. The genes *Tc1* and *Tc2* are responsible for high phenol color reaction of kernels and were mapped to the long arms of chromosome 2A and chromosome 2B, respectively. The map distances were estimated to be 46.8 cM for *Tc1* and 40.7 cM for *Tc2* from the centromere using double-ditelosomics of durum wheat.

Telosomic mapping of chlorina mutant genes on the long arm of homoeologous group-7 chromosomes.

Chlorina mutations of hexaploid wheat have somewhat less chlorophyll a and significantly less chlorophyll b than wild-type plants. Ditelosomic lines for long arms of homoeologous group-7 chromosomes of Chinese Spring (CS) and NILs of Novosibirskaya 67 with the chlorina mutant gene were used to map homoeologous chlorina mutant loci (*Cn-A1, Cn-B1*, and *Cn-D1*). The distance from the centromere to each of three loci for chlorina mutant genes was mapped at 47.2

cM for *Cn-A1* on chromosome 7AL, 42.2 cM for *Cn-B1* on chromosome 7BL, and 42.0 cM for *Cn-D1* on chromosome 7DL. The newly developed CS ditelosomic 7DL line was useful to analyze the genes on chromosome 7D.

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Effect of sensory viscoelasticity texture on Japanese udon noodle-making quality.

Hiro Nakamura.

Japanese soft noodle (udon) wheat cultivars and lines have different texture characteristics, flour protein contents, and flour amylose contents for cooked udon. Udon-making quality fingerprints were used to determine flour protein content, flour amylose content, flour breakdown scores on the Buhler viscograph test, and sensory viscoelasticity texture scores on cooked udon in this study aimed at improving Japanese udon-making quality. We have speculated on the relationship between flour protein content (%), flour amylose content (%), peak viscosity or breakdown on viscograph tests, sensory tests on cooked noodles (eating-quality of the noodles), and good udon-making quality.

Japanese consumers consider cooked udon texture to be an important quality attribute, and many Japanese consumers prefer cooked udon that has the good viscoelasticity, surface firmness, surface smoothness, and taste of the cultivar Tihokukomugi. Evaluation methods for Japanese udon wheat quality assessment were developed by the Ministry of Agriculture and Forestry in 1985 in coöperation with other National Institutes related to wheat. Few studies have been reported on Japanese wheat quality, however, the most important characteristic of wheat quality acceptability are udon sensory tests related to udon-making quality. Little information is available about the most important quality factors of udon-making quality in Japan. By the late 1980s, amylose content in wheat flour was being used for useful analyses in Australia. Low amylose content of flour is correlated with good udon-making quality. In Japan, a major objective of wheat breeders is to develop new, high flour yielding cultivars with improved udon noodle-making quality.

At the Wheat Breeding Institute, a greater effort is being placed on the improvement of udon quality in the Japanese breeding program, and Japanese hexaploid wheats are unique in terms of new types of N-terminal amino-acid sequences.

Many types of noodles are produced throughout the world. Udon is a type of noodle prepared from a dough containing wheat flour, water, and salt. The standard of identity for noodles in Japanese specifies that they usually are made from hexaploid, not durum, wheat. Udon is the most popular noodle in Japan. The major components of starch are amylose and amylopectin, and the amylose content is a main factor affecting wheat udon noodle quality. Amylose content of wheat contributes to starch pasting and gelatinization properties. The eating quality of Japanese udon noodles was negatively correlated with starch amylose content and positively correlated to starch amylopectin content. Our objective was to develop an instrumental method of determining good udon-making quality after cooking.

To determine the effect not only of flour amylose content but also flour protein content on udon quality, the low amylose (flour amylose content ranging from 22.2 to 23.1 %) line Tohoku 206 (named Nebarigoshi for new cultivar registration) with good udon-making quality; the commercial cultivars Koyukikomugi, Kitakamikomugi, Nanbukomugi, Akitatuko, Shiranekomugi, Shunyo, and controls; the ASW (good udon quality) wheat Norin 61 (a standard-quality for sensory evaluation tests on cooked noodles); and Tihokukomugi (good udon quality) were chosen for udon-making quality evaluation. Japanese udon was developed over many years using domestic wheat, and such products have long been accepted by the Japanese. However, ASW is a wheat class mainly and desirably used for the production of udon in Japan at present. ASW is reported to be superior to Western White (WW) wheat in udon quality. Japan has continuously imported udon wheat as ASW wheat from Australia for many years to produce flours for udon-noodle products. Procedures are needed to test the improved udon-quality wheats to meet the demands of targeted noodle markets.

Correlation analysis provides a useful assessment of udon-quality lines and commercial cultivars for quality evaluations (Table 1). Result also showed that flour protein content was significantly correlated with the sensory viscoelasticity scores on cooked noodles ($r = -0.3913$, $P < 0.05$), udon surface firmness on cooked noodles ($r = -0.5128$, $P < 0.01$), total sensory eating-quality score on cooked noodles ($r = -0.4211$, $P < 0.05$), and peak viscosity on viscograph ($r = -0.5600$, $P < 0.01$). Flour amylose content was significantly correlated with the sensory viscoelasticity score on cooked noodles ($r = -0.7123$, $P < 0.01$) and breakdown on viscograph ($r = -0.8732$, $P < 0.01$). The relationship between sensory viscoelasticity scores on cooked noodles and total sensory eating-quality score on cooked noodles was important to this study. The highest correlation coefficient was $r = 0.9927$, $P < 0.01$ and revealed that good udon-making quality index can be determined by the sensory viscoelasticity scores on cooked noodle in general. The correlation between the sensory viscoelasticity scores on cooked noodle and total eating-quality scores ($r = 0.9927$, $P < 0.01$), sensory taste scores on cooked noodles ($r = 0.7325$, $P < 0.01$), breakdown ($r = 0.7877$, $P < 0.01$), and amylose content ($r = 0.7123$, $P < 0.01$) also were relatively high and significant.

Table 1. Correlation Coefficients (r) of flour protein content (PC), sensory viscoelasticity score on cooked noodles (VISCO), sensory surface firmness score on cooked noodles (FIRM), sensory surface firmness score on cooked noodles (SMO), flour amylose content (AMY), sensory taste score on cooked noodles (TASTE), total eating-quality score on cooked noodles (TOTAL), peak viscosity (PV) or breakdown (BD) on viscograph in Japanese soft udon-noodle quality. An * implies significance at P < 0.05, ** significance at P < 0.01.

	PC	VISCO	FIRM	SMO	AMY	TASTE	TOTAL	PV	BD
PC	—	—	—	—	—	—	—	—	—
VISCO	–0.3913*	—	—	—	—	—	—	—	—
FIRM	–0.5128**	0.8050**	—	—	—	—	—	—	—
SMO	–0.3437	0.9145**	0.6776**	—	—	—	—	—	—
AMY	0.1203	–0.7123**	0.4339*	0.6948**	—	—	—	—	—
TASTE	–0.2866	0.7325**	0.6002**	0.8302**	0.4425*	—	—	—	—
TOTAL	–0.4211*	0.9927**	0.8501**	0.9327**	0.6912**	0.7638**	—	—	—
PV	–0.5600**	0.5787**	0.4061*	0.5336**	0.5077**	0.3992*	0.5646**	—	—
BD	–0.2597	0.7877**	0.5199**	0.7591**	0.8732**	0.5636**	0.7697**	0.7136**	—

Because the correlation between the sensory viscoelasticity score on cooked noodle and total eating-quality score strongly related to good udon-making quality ($r = 0.9927$, $P < 0.01$), good udon-making quality can be determined by measuring the sensory viscoelasticity scores on cooked noodles. Protein content is not correlated with surface firmness on cooked noodle. Glutenin:gliadin ratios also vary considerably within and among soft wheat cultivars, supporting a relationship between protein composition and end-use potential. On the other hand, Japanese udon-quality wheats also induced qualitative differences between the composition of 53-kDa endosperm protein band and the HMW-glutenin subunit 2*. The 53-kDa protein band played an important role in good sensory viscoelasticity scores on cooked noodles related to most important udon eating quality in Japanese wheats. Protein content was correlated with surface firmness, viscoelasticity, total eating-quality scores on cooked noodles, and peak viscosity in this study. The protein content of udon has been shown to significantly influence the cooking quality of udon. Not only flour starch-amylose content but also flour protein content strongly effects udon product characteristics made from soft-grained wheat. In fact, protein content also may be an important contributor to udon-wheat functionality and product quality. Protein content of pasta influences pasta-making quality, similar to that of udon-making quality in this study. Udon wheats have noodle-quality factors and end-uses very different from those of hard wheats, and udon wheats have been bred with lower protein content than that of hard bread wheat.

Correlation analysis also has provided a useful assessment of Japanese udon-noodle lines and commercial cultivars for good udon-making quality. Results also revealed that the sensory taste score on cooked noodles was significantly correlated with the sensory viscoelasticity score on cooked noodles ($r = 0.7325$, $P < 0.01$), surface-firmness ($r = 0.6002$, $P < 0.01$), and surface-smoothness on cooked noodles ($r = 0.8302$, $P < 0.01$). The total eating-quality score on cooked noodles was significantly correlated with sensory viscoelasticity score on cooked noodle ($r = 0.9927$, $P < 0.01$), sensory surface-firmness on cooked noodles ($r = 0.8501$, $P < 0.01$), and the sensory-smoothness on cooked noodles ($r = 0.9327$, $P < 0.01$) also were relatively high and significant. Quality characteristics that contribute to the production of improved udon noodles include the sensory viscoelasticity score on cooked noodles, high starch peak viscosity, high breakdown score on viscograph, low flour amylose content (high amylopectin content), and reasonable flour protein content. The Australian commercial cultivar Rosella is a soft-grained wheat with high pasting properties that is used in the production of Japanese udon noodles. The landrace AUS 4635 has a high starch pasting peak viscosity, high breakdown, low amylose content, low protein content, soft grain texture, and high protein quality flour. This wheat is an ideal parent to use in a breeding program that aims to increase the genetic variation available for developing new wheats with good udon-quality characteristics. The genetic diversity of wheat breeding program is relatively narrow when compared with the genetic resources available.

The quality of the cooked udon noodle is judged by sensory viscoelasticity scores on cooked noodles. These sensory viscoelasticity scores on cooked noodles (eating quality) contribute mainly to the total eating-quality scores related to good udon-making quality in Japan. The sensory viscoelasticity scores could be most important Japanese soft udon-quality evaluation index. The present study developed and/or evaluated wheat cultivars with high-quality Udon characteristics for Japanese breeding programs. Further work using a greater number of pure cultivars or lines with different genetic backgrounds, however, is needed to confirm these results in this study.

Acknowledgment. The author gratefully acknowledges the staffs of field section and wheat breeding laboratory at Tohoku National Agricultural Experiment Station for helping with the analyses and crops production.

ITEMS FROM KAZAKHSTAN

KAZAKH RESEARCH-PRODUCTION CENTER OF GRAIN PRODUCTION AND CIMMYT.
Almaty, Kazakhstan.

Evaluation of CIMMYT spring wheats in northern Kazakhstan.

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Spring wheat is the main food crop in northern Kazakhstan. The wheats cultivated in this region have some great disadvantages: low yield potential in dry years, susceptibility to lodging, and low disease and pest resistance.

Germ plasm with various biological and agronomic characteristics is a basis of plant-breeding programs (Vavilov 1935; Kronstad 1996). To develop new cultivars meeting the requirements of modern agricultural production, we utilize new, primary breeding material developed by the leading agricultural research centers.

Despite considerable difficulties in transferring germ plasm across CIS country borders, a significant number of new accessions where obtained during the last year from different institutions in the Russian Federation (Omsk, Krasnoyarsk, Novosibirsk, Kurgan, and Barnaul) and Byelorussia within the germ plasm exchange network. Considerable contributions to germ plasm collections were made by CIMMYT (International Maize and Wheat Improvement Center). During 1996–2003, we evaluated more than 10,000 entries of spring wheat.

After several years of study, the CIMMYT material has shown that germ plasm from international nurseries, such as the SAWYT (Semi-Arid Areas Wheat Yield Trial), SAWSN (Semi-Arid Areas Wheat Screening Nursery), ESWYT (Elite Selection Wheat Yield Trial), and IDYN (International Durum Yield Nursery), are not always well adapted to the extreme conditions of our region because of poor drought tolerance, little growth, or long vegetative periods. Therefore, our search for new, better-adapted material during the last 2–3 years has included nurseries such as the GAWYT (Global Adaptation Wheat Trial), FAWWON (Facultative and Winter Wheat Observation Nursery), and HLWSN (High Latitude Wheat Screening Nursery), and among cultivars of North American origin (USA, Canada).

When breeding for resistance to leaf rust, the most widespread and harmful disease of wheat in northern Kazakhstan, the IDTN Candidates nursery, including isogenic lines of cultivars with known *Lr* genes deserves, the greatest interest. Shuttle breeding has been employed with the participation of CIMMYT–Mexico, and new improved germ plasm has been developed from CIMMYT material and cultivars from the U.S. and Canada.

Shuttle breeding is implemented through the following plan: crosses and multiplication of segregating populations are made in Mexico, selections from segregating populations are made at various sites in Kazakhstan and western Siberia depending on the aim of the breeding. Developed material combines resistance to fungal diseases, which is conferred by Mexican germ plasm, and high adaptability to local conditions, which is contributed by the local cultivars. Presently, selections are carried out in F_3–F_5 segregation populations of improved germ plasm, which were developed from the crosses with the Kazakhstan cultivars Akmola 2, Akmola 3, Ishimskaya 92, Kazakhstanskaya early maturing, Tselinnaya 24, Tselinnaya 3C, Skent 1, and Tselinnaya yubileinaya were used as parents. Progeny of the elite spikes is studied at the initial stages of the breeding process (F_3 and F_5 observation nursery).

Along with the study of the yield components in the collection nurseries, CIMMYT material, we evaluated for resistance to diseases and pests, which are widespread in the region in the special disease nurseries using artificial inoculation. Lines are selected based on yield and other valuable agronomic characters and further evaluated in breeding nurseries and advanced trials. The best entries are distributed annually to the breeders in Kazakhstan and Siberia for the further evaluation and practical use in their programs.

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REPUBLICAN STATE ENTERPRISE, BARAYEV RESEARCH-AND-PRODUCTION CENTRE OF GRAIN FARMING, AND THE MINISTRY OF AGRICULTURE OF THE REPUBLIC OF KAZAKHSTAN.
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Use of the fungus Trichoderma lignorum against pathogenic micromycelium affecting wheat plants in the droughty steppe of northern Kazakhstan.

Irina Victorovna Rukavitsina and Zorya Petrovna Karamshuk.

In the intensive agricultural production conditions in northern Kazakhstan, one factor limiting the growth of grain crop productivity on chernozem soils is a fungal disease caused by pathogenic species *Alternaria*, *Fusarium*, and *Bipolaris*. Among existing measures of control, the most widespread and effective are chemical. However, the use of chemicals quite often promotes environmental pollution and has a negative effect on public health. Attention now is given to searching for biological means of plant protection using fungal antagonists. Antagonism is widely distributed among fungi and can be a result of competition for nutrients, the activity of antibiotics developed by fungi, and the direct effect on pathogenic fungi (hyperparasitism). Our interests include studying the antagonism between fungi causing black germ disease and root rots in grain crops.

As an antagonist against plant pathogenic species *Alternaria*, *Fusarium*, and *Bipolaris*, we investigated the fungus *Trichoderma lignorum* (strain 156-T). The study of antagonistic mutual relationship between the these fungi was done using counter cultures on Chapek-Dox medium. Fungi were isolated from soil in the germination zone, the surface of wheat seeds, and infected tissue in the root-zone of wheat stems. Isolated, pure-culture, plant pathogenic fungi were identified according to specific composition.

The results showed that *Tr. lignorum* has the greatest antagonistic activity, shown in the form of hyperparasitism related to *Alternaria tenuis*. On the Chapek-Dox nutrient medium, *Tr. lignorum* mycelium overgrew that of *A. tenuis* that had colonized the surface. When growing on *A. tenuis, Tr. lignorum* uses the nutritional substances produced for growth. In this case, *Tr. lignorum* is hyperparasitic on *A. tenuis*.

In the interaction between *Fusarium oxysporum* and species of *Trichoderma,* territorial antagonism has been discovered. In the presence of *F. oxysporum, Tr. lignorum* actively increases in biomass. Upon encountering *F. oxysporum* mycelium the *Trichoderma* actively occupies the medium around *F. oxysporum* and then oppresses and stops the development of the fungus.

Mutual aggressive antagonism was noted between *Tr. lignorum* and *Bipolaris sorokiniana*. Active growth stops in both fungi at a distance between the colonies. The basic biomass of both species is at the border of the colony. The antagonism is expressed by defusing antibiotics into agar. In this case, the mutual influence of antibiotics is the short growth of aerial mycelium both fungi.

This research has shown mutual aggressive antagonism between *B. sorokiniana* and *Tr. lignorum*, territorial antagonism between *Tr. lignorum* and *F. oxysporum*, and hyperparasitism between *Tr. lignorum* and *A. tenuis*. Developing a biological substance on a basis of *Tr. lignorum* strain 156-T will promote the increase plant protection against pathogenic species of *Alternaria*, *Fusarium*, and *Helmintosporium*.

ITEMS FROM MEXICO

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER — CIMMYT
INIFAP–CIRNO, Campo Experimental Valle del Yaqui, Apdo. Postal 515, Cd. Obregón, Sonora, México CP 85000 and CIMMYT Int., km 45 Carret, México-Veracruz, El Batán, Texcoco, Edo. de México CP 56130.

Evaluation of elite triticale (X Triticosecale) genotypes for resistance to Karnal bunt (Tilletia indica Mitra) under artificial field inoculation in the Yaqui Valley, Sonora, Mexico, during the 2003–04 crop cycle.

Guillermo Fuentes-Dávila and Karim Ammar.

Introduction. Karnal bunt occurs naturally on bread wheat (Mitra 1931), durum wheat, and triticale (X *Triticosecale*; Agarwal et al. 1977). Affected kernels are usually partially infected and completely infected ones are rare (Mitra 1935; Bedi et al. 1949; Chona et al. 1961). Since the early 1980s, it has been reported about the resistance and immunity shown by triticale cultivars and experimental advanced lines under artificial inoculations (Meeta et al. 1980; Fuentes-Davila et al. 1992); therefore, advanced lines were selected primarily for their resistance to a new race of yellow rust that appeared in Central Mexico and to which most CIMMYT triticales are susceptible (Hede et al. 2002). Sources of resistance to this race also include progenies from crosses with either bread or durum wheat. Continued evaluation for new developed advanced lines and cultivars is important as a measure to avoid possible economic problems to farmers, that could result from the release of a susceptible cultivar.

Materials and Methods. Twenty elite triticale advanced genotypes were evaluated for Karnal bunt resistance during the crop cycle 2003–04. Planting dates were 20 November and 5 December, 2003, using approximately 10 g of seed for a bed with two rows 1-m long. A mist-irrigation system was used 3–5 times/day for 15 min each time to provide a humid environment in the experimental area. Inoculation was by injection during the boot stage applying 1 ml of an allantoid sporidial suspension (10,000/ml) to ten heads/genotype. Harvest was manual, and evaluating and counting of healthy and infected kernels was by visual inspection. Tested genotypes included the long-term yield check Pollmer TCL 2003, recently released as feed-grain cultivar in the state of Sonora, and two new candidates for commercial release in the same state. These three genotypes are susceptible to yellow rust in central Mexico. The remaining 17 genotypes are new advanced lines selected for their

Table 1. Triticale genotypes that did not show any infected kernels after artificial field inoculation with Karnal bunt (*Tilletia indica*) on two planting dates during the 2003–04 crop cycle in the Yaqui Valley, Sonora, Mexico.

Entry No.	Pedigree
1	Pollmer_2.1.1
	CTY88.547-22RES-1M-0Y-2M-1Y-0M-1B-0Y
2	Liron_2/5/DIS B5/3/SPHD/PVN//Yogui_6/4/KER_3/6/Bull_10/Manati_1
	CTSS94Y00486T-E-1M-0Y-0B-1Y-0B-4B-0Y
5	Presto//2*Tesmo_1/MUSX 603/4/ARDI_1/Topo 1419//Erizo_9/3/Susi_2
	CTSS94Y00465T-C-2M-0Y-0B-1Y-0B-2B-0Y
6	Erizo_10/Bull_1-1//Manati_1/4/Sika 26/Tesmo_3//Lynx/3/Fahad_2
	CTSS97Y00340S-6Y-0M-0Y-0B-1Y-0B-0Y-4B-0Y
7	BAT*2/BCN//CAAL/3/Erizo_7/Bagal_2//Faras_1
	CTSS99Y00246S-1Y-0M-0Y-5B-1Y-0B
13	Ardi_1/Topo 1419//Erizo_9/3/Liron_1-1/4/Fahad_4/Faras_1/5/CT775.81/Ardi_1//Anoas_1
	CTSS99B00483S-0M-10Y-11M-2Y-0M
18	Pollmer_2.2.1*2//Faras/CMH84.4414
	CTSS99B00990F-0TOPY-0M-2Y-14M-1Y-0M
19	Rondo/2*Erizo_11//Kissa_4/3/Presto/4/Passi_3-2//GNU*2/SPB
	CTSS99FM00153T-0TOPY-0M-5Y-4M-1Y-0M
20	Bull_10/Manati_1*2//Faras/CMH84.4414
	CTSS99B00975F-0TOPY-0M-35Y-4M-2Y-0M

resistance to yellow rust in the Central Mexican Highlands and, internationally, represent the genotypic variability available in the current feed and forage triticale germ plasm of the CIMMYT program.

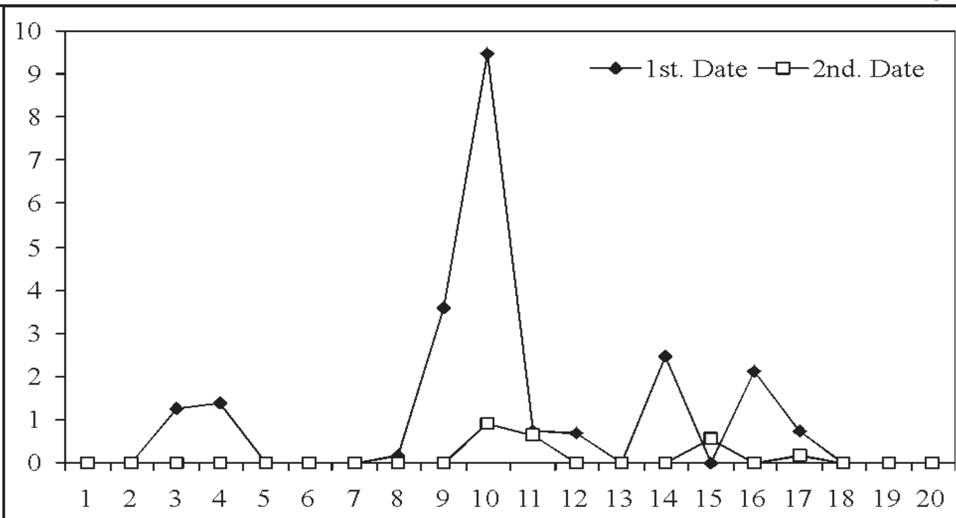

Fig. 1. Percentage of infection with Karnal bunt (*Tilletia indica*) of 20 triticale (*XTriticosecale*) genotypes artificially inoculated in the field during the 2003–04 crop cycle on two dates in the Yaqui Valley, Sonora, Mexico.

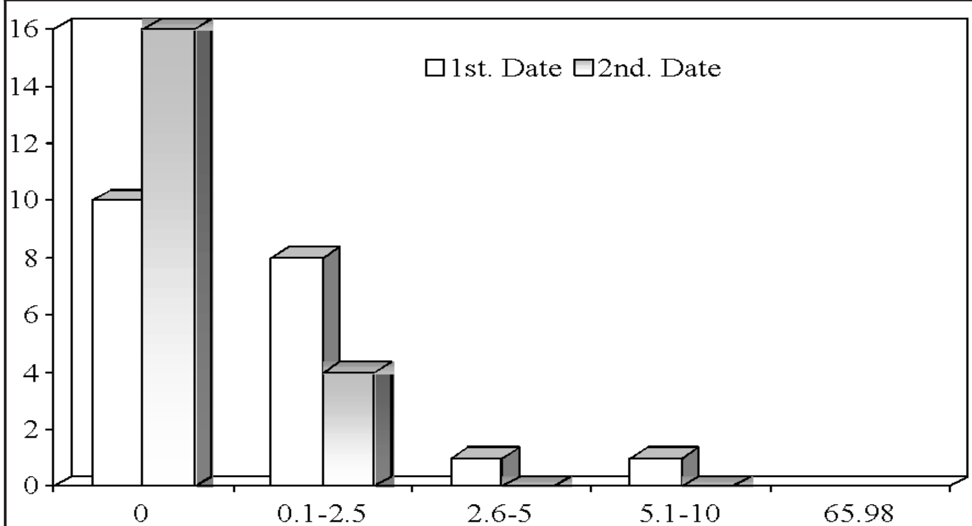

Fig. 2. Results of artificial field inoculatin on two dates with Karnal bunt (*Tilletia indica*) of 20 triticale (*XTriticosecale*) genotypes artificially inoculated in the field during the 2003–04 crop cycle on two dates in the Yaqui Valley, Sonora, Mexico. The level of infection of WL711 is the mean of the three highest infection scores.

Results and Discussion. The range of infection for the first planting date was 0–9.47, with a mean of 1.13. Ten lines did not have any infected kernels (Fig. 1). The range of infection for the second planting date was 0–0.92, with a mean of 0.11. Sixteen lines did not have any infected kernels. The difference between the mean percent infection of the first and second planting dates and the mean of the three highest levels of infection of the susceptible check WL711 (65.98 %) was 64.9 and 65.87 %, respectively (Fig. 2). Only the line Dahbi_6/3/Ardi_1/Topo 1419//Erizo_9/4/Copi_1-1, CTSS99B00002S-0M-1Y-1M-1Y-0M, fell within the 5.1–10 % infection category with 9.47 % on the first date. Lines with less than 5 % infection are considered resistant (Fuentes-Dávila and Rajaram 1994). Nine lines did not have any infected kernels in either evaluation (Table 1, p. 83). These results indicate that the high level of resistance to Karnal bunt in triticale has been maintained in the new elite germ plasm coming out of the CIMMYT program. Collaborative efforts between INIFAP and CIMMYT to ensure adequate levels of Karnal bunt resistance in new promising material is being continued in order to provide a sound, safe, and commercially viable feed grain option for the growers in the state of Sonora.

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ITEMS FROM PAKISTAN

AGRONOMIC RESEARCH STATION
Bahawalpur, Pakistan.

Role of seeding rates on wheat yield.

Muhammad Aslam, Manzoor Hussian, Arshad Hussain, Muhammad Safdar, Muhammad Masood Akhtar, M. Akhtar, and Asghar Ali Malik.

Introduction. Wheat is the most important Rabi cereal crop of Pakistan. Wheat is grown on area of 80.109 x 10^6 ha with an annual production of 16.6 x 10^6 tons with an average yield of 2,053 kg/ha. The present study was designed to determine the appropriate seeding rate for obtaining maximum wheat yield under irrigated conditions of the Bahawalpur region. Singh and Uttam (1999) obtained higher yield using 125 seed/ha, whereas Ram et al. (1998) suggested 160 kg/ha to get maximum yields.

Materials and Methods. The study was conducted at six different farmer's field in the Sadiqabad, Uch Sharif, Duniapur, Burewala, Lodhran, and Jampur provinces. The four seeding rates (125, 150, 175, and 200 kg/ha) were studied with a plot size of one kanal/seeding level. Phosphorus, in the form of DAP, and potash, in the form SOP, was applied as a basal dose at sowing. The wheat cultivar Inqlab-91 was sown during study period on a well-prepared seed bed with a tractor drill. All agronomic practices were kept normal and uniform for all treatments in order to demonstrate the effect of seeding rate on different sites in the Bahawalpur region in farmer's fields.

Results and Discussion. Table 1 shows that grain yield was affected significantly by various seeding densities. Plots seeded at 150 and 175 kg/ha gave significantly higher grain yield (3,248 and 3,238 kg/ha, respectively). We concluded that a seeding rate of 150 kg/ha was the highest yielding, most economical on average, and large quantities of seed can be saved and must avoid to the unnecessary excessive seeding. Similar results were found by Ram et al. (1998), Singh (1999), and Zubair (1989).

Table 1. Grain yield (kg/ha) as effected by different seeding densities. Data is from six different farmers' fields from different provinces in Pakistan.

	Seeding rate (kg/ha)			
Site	125	150	175	200
Sadiqabad Chak No.191/P	4,066	3,933	3,900	3,730
Uch Sharif	3,800	4,000	3,800	3,800
Duniapur Chak No.8/M	2,200	3,100	3,100	2,500
Burewala Chak No.331/Toppianwala	1,900	2,900	2,800	2,300
Lodhran	2,090	2,700	2,830	2,533
Jampur	2,270	2,860	3,000	2,700
Mean	2,721	3,248	3,238	2,927

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The effect of different levels of N and P fertilizer on grain yield in wheat.

Muhammad Aslam, Manzoor Hussian, Abdul Rashid, Muhammad Arshad Gill, Abdur Rashid, Ghulam Hussian, Asghar Ali Malik, M. Arshad, and L.H. Akhtar.

Introduction. Wheat is a major food grain of Pakistan and is the biggest volume crop grown in the country. The use of N–P fertilizers play an important role to obtian the highest grain yields. We began this project to determine the best N–P levels for obtaining reasonable yields. The studies are in the line with those of Pandey (1999), who concluded that increases in grain yield with N–P levels up to 150–75, and Rafique et al. (2000), who obtained the greatest yields with application of 150–100 N–P kg/ha.

Materials and Methods. This study was conducted at six different sites of the region of southern Punjab, Sadiqabad, Uch Sharif, Duniapur, Burewala, Lodhran, and Jampur, on farmers' fields under an 'Integration of Agricultural Research and Extension Activities' project for the year 2002–03. The wheat cultivar Inaqlab-91 was sown during the study period on a well-prepared seed bed with tractor drill. The four fertilizer levels were 80–58–60, 120–89–-60, 160–115–60, and 200–146–60 (NPK) with a plot size of one kanal for each level. All agronomic practices were normal and uniform for all fertilizer levels.

Results and Discussion. A fertilizer level of 160–115–60 N–P–K kg/ha gave the highest average grain yield of 2,983 kg/ha (Table 2). The maximum wheat yield of 3,900 kg/ha was obtained at the 160–115–60 and at 200–146–160 levels, thus a 160-115-60 rate is the most economical for obtaining reasonable yields of wheat sown after cotton. Similar results also have been reported by Paddy (1999) and Rafique (2000).

Table 2. N–P–K fertilizer levels used in six different farmers' fields to determine optimum level for highest average grain yield.

	Fertilizer level (N–P–K, kg/ha)			
Site	80–58–60	120–89–60	160–115–60	200–146–60
Sadiqabad	3,330	3,867	3,900	3,900
Uch Sharif	2,350	3,100	3,500	3,000
Dunia Pur	1,700	2,300	2,500	2,400
Burewala	1,300	1,500	2,000	1,900
Lodhran	2,270	2,830	3,130	2,930
Jampur	2,100	2,470	2,870	2,770
Mean	2,176	2,678	2,983	2,817

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The role of planting time in wheat yield.

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Introduction. Wheat is a staple food of Pakistan that provides approximately 72 % of the calories and proteins in the average diet. Pakistan is the 7th largest wheat producer, accounting for 2.73 % of the world's wheat production and the Punjab province is the main wheat producer in Pakistan (Anon 1997–98). Southern Punjab, although a cotton zone, contributes approximately 44 % to the wheat production of the province. Cotton has a long cultivation period in the field, so approximately 80 % of the wheat crop is being planted under late-sown conditions and planting time is the practice most affecting grain yield. Early sowing always produces a higher yield then later sowings. Ibrahim and Abdullah (2000) observed that delaying sowing by 1 month reduced grain yield by 27 %. Shah and Akmal (2002) found that early planted cultivars yielded the maximum of 282 spike-bearing tillers/m^2, had a relatively higher seed weight/spike at 1,999, and 49 seeds/spike. Rachon (1997) concluded that late sowing reduced the number of reproductive tillers formed, the weight grain/spike, number of grain/plant, weight of grains/plant, and 1,000-kernel weight. Ahmed et al. (1997) found that late sowing resulted in reduced plant height, spike length, grain/spike, and low yield in all cultivars.

Materials and Methods. This study was done at six different sites in the southern Punjab region, Sadiqabad, Uch Sharif, Dunia Pur, Burewala, Lodhran, and Jampur, in farmers' fields under 'Integration of Agriculture Research and Extension Activities' for the year 2002–03. The wheat cultivar Inqlab-91 was sown on a well prepared seed bed with a tractor drill. Two plantings, 14 and 24 December with a plot size of 4 kanal for each planting time were studied. All agronomic practices were normal and uniform for all sowing times.

Results and Discussion. The data for wheat grain yield showed that the maximum average yield of 3,257 kg/ha was obtained when the crop was sown on 14 December (Table 3). When sowing delayed until 24 December, yield decreased at all six sites, ranging from 21–36 %. These results are in line with those of other researchers (Rachon 1997; Ahmed 1997; Ibrahim and Abdullah 2000; Shah and Ahmad 2002).

Table 3. Wheat grain yield (kg/ha) at two sowing dates in six farmers' fields at various locations in Punjab province, Pakistan.

	Sowing date		
Site	14 December	24 December	% decrease
Sadiqabad	3,640	2,800	27
Uch Sharif	3,400	2,700	21
Donia Pur	3,500	2,630	25
Burewala	2,300	1,600	36
Lodhran	3,300	2,550	23
Jampur	3,200	2,440	24
Mean	3,257	2,453	25

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Performance of some wheat genotypes at six different sites in the Bahawalpur region.

Ghulam Hussian, Muhammad Aslam, Muhammad Arshad Gill, M. Hussian, Abdul Rashid, M. Arshad, and Lal Hussian Akhtar.

Introduction. Wheat is a major food grain of Pakistan and is the largest volume crop grown in the county. The aim of this project was to observe the performance of wheat cultivars at different six sites (Tehsil level) in the Bahawalpur region.

Materials and Methods. This study was conducted at six different sites in the Bahawalpur region, Sadiqabad, Uch Sharif, Donia Pur, Burewala, Lodhran, and Jam Pur, on farmers' fields as a demonstration of production technology under a 'Integration of Agriculture Research and Extension Activities Project' in 2002–03. Wheat cultivars were sown during the study period on a well prepared seed bed with a tractor drill. Five wheat cultivars, Drawar-97, BWP-2000, Iqbal-2000, and Inqlab-91, were sown with plot size a one kenal for each cultivar. All agronomic practices were normal and uniform for all cultivars.

Results and Discussion. The grain yield of two cultivars, Inqlab-91 and Manthar-3, were similar but significantly higher than other three cultivars at the six different locations (Table 4).

Table 4. Wheat yield (kg/ha) of five cultivars grown at six different sites in Pakistan in 2002–03.

Site	Drawar-97	BWP-2000	Manthar-3	Iqbal-2000	Inqlab-91
Sadiqabad	3,300	3,460	3,667	3,233	3,933
Uch Sharif	3,600	3,200	3,300	3,050	3,700
Donia Pur	3,400	2,800	3,200	2,800	2,900
Burewala	2,300	2,310	2,900	2,310	2,760
Lodhran	2,370	2,700	2,270	2,406	2,200
Jampur	2,320	2,600	2,100	2,516	2,000
Mean	2,872	2,845	2,906	2,719	2,910

Heat tolerance—a new project on wheat.

Manzoor Hussain, M. Rafiq,
G. Hussain, M. Zahid Aslam, A. Rashid, A.H. Tariq, and M. Arshad.

Introduction. In the cotton zone of Pakistan, the wheat crop is sown after cotton, i.e., in late November and month of December, which is considered to be late planting. Grain formation and filling generally is completed under high temperature during the months of March and April. Because of high temperatures, most genotypes have a lower grain weight, which is one of the main causes of low yield in the region. Heat stress is one of the most important factors affecting crop yield. Wheat is particularly susceptible to yield losses as a result of heat stress (Wrigley et al. 1994). Optimum temperature for growth and yield of wheat is in the range of 18–24°C. Even a period as short as 5–6 days of exposure to temperatures between 28–32°C result in 20 % or greater decreases in yield (Stone and Nicolas 1994).

In southern Punjab in Pakistan, temperatures often fluctuate to 30°C and above during the grain-filling stage of the wheat crop. The optimum temperature for photosynthetic activity of wheat from anthesis to maturity is 20°C or lower (Al-khatib and Paulsen 1989). Harding et al. (1990) determined that elevated temperatures accelerate senescence, reduce the duration of viable leaf area, and diminish photosynthetic activity. Hurkman and Tanaka (1987) studied the effects of high temperature on thylakoid membranes, which lead to a loss in the number of chloroplasts per cell. Heat stress effects the quality of the harvested products, reducing bread-making quality by affecting gliadin synthesis (Blumenthal et al. 1993) and starch quality by affecting the ratio of A (large) to B (small) starch granules (Stone and Nicolas 1995). Therefore, we initiated a new project on heat tolerance at the Regional Agricultural Research Institute, Bahawalpur.

Materials and Methods. A total of 330 lines from 26 crosses in the F_3 generation was planted on 18 December at Regional Agricultural Research Institute, Bahawalpur. Late planting insured grain formation and filling under high temperature conditions in the field. Selections were made on the basis of 1,000-kernel weight. Inqulab 91 was sown as the check for comparison. Temperature at grain filling also was recorded.

Table 5. Effect of temperature on grain filling in 330 F_3 lines from 26 crosses planted on 18 December, 2003, at the Regional Agricultural Research Institute, Bahawalpur, Pakistan. Temperature during the grain-filling period was 34–40°C.

Strain number	1,000-kernel weight (g)	No. of crosses	No. of lines
1	40 +	Two	7
2	35-40	One	10
3	30-35	Seven	25
4	<30	Sixteen	288
Inqilab 91 (check)	36	—	—

Results and Discussion. The temperature during the grain-filling period (first 2 weeks of April) was 34-40°C, which is high (Table 5). For all 330 F_3 lines, 1,000 grain weight were recorded and categorized as under. Only two crosses gave yields greater than 40 g. These crosses are (1) 94049//Inqlab-91/NR.8624/3/Inqlab-91 (BR 5050-1B-) and (2) Bulbul/Oasis//Skauz/3/BCN (BR5022-8B-).

Seventeen entries were better than resistant to heat at grain filling among the 330 lines (Table 5). Most of the entries were affected by heat with a reduction in grain weight. A difference in grain weight from 40–30 grams indicates sensitivity of the genotypes to high temperature.

Conclusions. The selected lines will be retested under increased temperature during the next few years. High temperatures decrease grain weight, which is an important factor of grain yield. Clear differences in the 1,000-kernel weight of different genotypes shows that heat-tolerant cultivars can increase grain yield.

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Wheat seed production system in Pakistan.

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Seed has played a critical role in agricultural development since prehistoric humans domesticated the first crops. In modern agriculture, seed is the vehicle to deliver almost all agriculture-based technological innovations to farmers so that they can exploit the genetic potential of new cultivars. The availability, access, and use of seed of adapted modern cultivars is, therefore, a determinant to the efficiency and productivity of other inputs (irrigation, fertilizers, and pesticides) for increasing crop production to enhance food security and alleviate rural poverty in developing countries. For seed to play this catalytic role, it should reach farmers in a high quality state, i.e., genetically pure and high physical, physiological, and health quality. In contrast to fertilizers and pesticides, farmers select and save seed to plant the following year. Any off-farm seed from other sources should be of high quality. Wheat is a high-volume, low-profit seed crop and has been produced primarily by heavily subsidized, government seed programs. The private sector, however, may not focus on wheat seed because of its characteristics (self pollinating, high-volume, and low-profit). Private seed enterprises consider wheat seed to be of secondary importance. Because wheat is an entirely self-pollinating crop with a very low percentage of cross-pollination (1–4 %; Doerfler 1976), the risk of genetic contamination is very small. Appropriate isolation is , however, required to minimize physical contamination. Minimum isolation distances (in meters) used in some Middle Eastern and North African countries are listed in Table 6.

Table 6. Appropriate isolation distance (m) according to seed type needed to minimize physical contamination in wheat used in some countries of the Middle East and North Africa.

	Seed class		
Country	Prebasic	Basic	Certified
Cyprus	-	2	2
Egypt	5	5	5
Iran	5	5	5
Sudan	4	4	4
Syria	2	2	2
Tunisia	1	1	1

Because wheat is self pollinated crop and the grain can be stored for later use, farmers tend to replant their own seed. About 80 % seed used by the farmers in Pakistan is from their own production. In Pakistan, the private sector is more active in the highly profitable cotton seed production. Wheat seed in Pakistan is produced by farmers with concern of the public and private sector under control of the Federal Seed Certification and Registration Department (FSC and R). Purity is maintained with constant inspections under strict rules. The entire seed-production system in Pakistan is discussed below.

Cultivar evolution. Wheat cultivars are developed by breeders working in the public sector. A strong cultivar approval system is present in the country. Cultivars are approved by a technical committee then the cultivar is taken to the provincial seed council where they are registered by the Federal Seed Certification Department in Islamabad.

DUS test. The DUS test in Pakistan is made by the Federal Seed Certification and Registration Department. This trial consists of advance strains from the National Uniform Wheat Yield trial. A DUS test is a descriptive assessment that establishes the identity of the new cultivar using morphological characters, uniformity, and stability. The test is a useful tool for seed production, certification, and plant cultivar protection. The DUS tests usually run for 2 years. The new cultivar is compared with existing cultivars to establish its distinctness, a cultivar description is prepared, and differences with other cultivars are noted. In some countries, the cultivar is tested in on-farm verification trials under farmers' management conditions during the last year. After the DUS test and other trials, a cultivar is released for use. Many developing countries give priority to agronomic (VCU) trials rather than descriptive (DUS) tests. Although both tests are important, the benefits of the two tests must be considered based on the immediate needs in the country to use available resources efficiently and economically.

Seed production.

1. **Prebasic seed.** The initial source of seed produced by the concerned breeder. This seed is supplied to the Punjab Seed Corporation.
2. **Basic seed.** Basic seed is provided by breeders and multiplied by the Punjab Seed Corporation in their own fields and then is supplied to the private sector and seed corporations.
3. **Certified seed.** Basic seed is multiplied by public and private sectors in farmers' fields and government farms. The seed is inspected by the FSC and R. Inspection is done on standing crops. After harvest, seed is tested in the laboratories of the FSC and R. Germination, 1,000-kernel weight, adulteration percentage, and purity are checked by the FSC and R.
4. **Approved seed.** The final class of purity is the 'approved seed' category. Seed lots not qualifying as certified seed are categorized as approved seed. Standards are similar to those for certified seed. Certified and approved seed categories are put into the markets for sale. Farmers can buy the seed from local markets.

Price of seed. Price of seed of different categories are fixed by the Provincial Governments.

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Wheat cultivation in Sindh Pakistan.

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Introduction. The province of Sindh, between 23°40'N and 28°30'N and 66°40'E and 71°10'E, can be compared with Egypt. For the past 1,000 years, the two countries have received the gift of alluvium deposited by the Indus and Nile Rivers. Flood plains of both countries attracted early Neolithic people to experiment and develop food and feed crops.

Local names for wheat are Kanak and Gandum. Other names are popatiyea, Khapli, ravva, godhumalus, and Samba. Wheat cultivation started during the Neolithic period, probably as early as 6,000 to 7,000 years ago. The wheat crop requires a well-pulverized but compact seedbed for good and uniform germination. Three ploughings in the summer, repeated harrowing in the rainy season, followed by three or four cultivations immediately before sowing produce a good firm seedbed for the dry crop on alluvial soil. *Triticum aestivum* occupies 85 % of total area under wheat. *Triticum turgidum* subsp. *durum* is the second most important occupying 14 % of wheat-growing area. Durum wheat is the most important species under rainfed conditions. *Triticum turgidum* subsp. *dicoccum* is grown on very restricted scale. In Pakistan, wheat covers an area of 8,306,600 ha. In Sindh, wheat covers an area of 1,120,300 ha. Wheat production in Pakistan was 18,237,600 tons (2,196 kg/ha) last year; production in the Sindh was 2,624,900 tons (2,343 kg/ha).

The yield of high-yielding varieties (HYV) of wheat was 2,553 yield kg/ha in 1999–2000. Other cultivars averaged 981 kg/ha. The total wheat yield 2,491 kg/ha. In 1999–2000, HYV covered an area of 8,129,300 ha, other wheat cultivars covered an area of 333,700 ha. The total area planted with HYV was 8,463,000 ha. For the year, wheat production of HYV was 20,751,300 tons; the production of other cultivars totaled 21,078,600 tons.

As of 1 December, 2004, overall wheat sown in Punjab and Sindh remained slightly below the monthly target of 60 %, 67.2 % of the area was sown in Sindh in November 2004. Overall, wheat sowing remained at 54.3 %. The provincial governments of Punjab and Sindh were given the target of 6.2 x 10^6 ha and 0.8 x 10^6 ha, respectively, and the concerned food departments were asked to ensure wheat sowing of 60 % of the area in November. The decision was taken to achieve a total production of 20.2 x 10^6 tons of wheat so that the government would not have to import wheat in the next fiscal year.

Wheat covers 8.5 x 10^6 hectare in Pakistan. Unlike previous years when 40 % of the targeted area was sown in November, the Punjab, with an area of 6.2 x 10^6 ha and in other to increase the per hectare yield from 1,000 kg to 1,300 kg, had 4.16 x 10^6 ha sown to wheat before 27 November. This number compares to a little over 4 x 10^6 ha sown during the same period of the previous year. Similarly, in Sindh, the sown area remained at 0.332 x 10^6 hectares before 23 November, compared to 0.25 x 10^6 ha in the previous year. The targeted area sown to wheat in NWFP is 0.77 x 10^6 ha, 0.34 x 10^6 ha in Balochistan, and 0.1 x 10^6 hectares in the Azad, Jammu, and Kashmir provinces. However, the Federal Ministry of Food and Agriculture has not yet received final figures from these areas.

Wheat is grown in subtropical areas at higher altitudes in the tropics to produce locally adapted cultivars. The optimum temperature for germination is 29°C. Under favorable conditions germination take place in 4–5 days. Seeding rate varies from 50–200 kg/ha. Time of maturity is 95–150 days depending upon cultivar. Seeds should be used 50–60 kg/ha. Seed beds are 1.5-2-in rows with a distance 6–8 in giving 80–10 plants/acre. In November sowing, 50 kg/acre are used; the December sowing rate is 60 kg/acre. Recommended sowing dates for some popular cultivars are given in Table 1.

Table 1. Sowing season of various cultivars of wheat in northern and southern parts of Sindh province, Pakistan.

Cultivar	North	South
Sarsubz	1–25 November	10 Nov–15 Dec
Soghat 90	1–25 November	1–25 November
Mehran 89	1–20 November	7–30 November
Abadgar 93	1–20 November	7–30 November
Anmol 91	21 Nov–15 Dec	1–20 December
Tando Jam 83	21 Nov–15 Dec	1–20 December
Marvi 2000	1–25 November	1–15 December
Momel 2002	1–20 November	1 Nov–20 Nov

Cultivars of wheat in Sindh.

Cultivars for upper Sindh. Abadgar 93, Mehran 89, Sarsubz, Kirn 95, Sogat 90, T.J. 83, and Anmol 91. Time of sowing from 1–25 November and 1–30 December.

Cultivars for lower Sindh. Abdagar 93, Mehran 89, Sarsubz, Kiran 95, Sogat 90, T.J. 83, and Anmol 91. Time of sowing from 1–30 November and 130 December. Recommended sowing at a seed depth of 2 in and a between row distance of 9 in.

Cultivars for western Sindh. Pavon-7, ZA-77, Sindh 81, Sarsubz, Bluesilver, and Tando Jam 83.

Cultivars for eastern Sindh. Pavon, Sarsab, ZA-77, Sindh 81, Blue silver, Tando Jam-83, H-68, C-591, c-273, Drik, and Pak-70 (Anon 2000),

Cultivars for Sindh, Pakistan. Cultivars for Pakistan are PB-85, V-86369, WDK-85, FSD-85, V-8624, CHKL-86, V-85060-1, PAK-81, FSDD-83, K-Noor-83, V-88022, V-86371, C-217, C-250, and C-591 (Rizvi 1998); C.pH47, A.T. 38, Hsw III, C-591, C-518, H-68, I.P. 120, Mexi-Pak-65, Pak-70, Inia-66, Noori, Blue Silver, Yacora, T.J. 75, and Munshi-76 (Khoso 1977).

Soil. Wheat requires a deep loam or alluvial soil that is well drained and has a uniform and mellow texture that helps to produce a profuse root system. Dwarf cultivars give better results when grown at a depth of 1.5–2.0 in on level land (Khoso 1977). Well-drained loam and clay loam are considered good for wheat, but it also can grow in sandy soil.

Timing of sowing. Proper sowing depends upon the cultivar and climatic conditions. In the Kotri Barrage area and Hyderabad district, local cultivars H-68 and c-591 can be sown 15 days earlier. Sowing of dwarf cultivars should be completed in November, whereas late cultivars can be sown up to 10 December (Khoso 1977). Sowing depth varies between 1.5–2.5 in. The row-to-row distance should be 9 in.

Preparation of seed for sowing. Wheat has certain seedborne diseases such as Karnal or partical bunt, loose smut, and flag smut. The crop will benefit from Belaton (1 gm), Vitavax-200 (2 kg), Topsin-M (2 gm), Benlate (2 kg) mixed with the seed before sowing. Before planting, Aldrin 55 or BHO 10 % dust at the rate of 25 kg/ha is recommended..

Proper time and seeding rate. Wheat seed should be healthy, free from disease, unbroken, not mixed with weed seeds, and have a germination rate near 95 %. For storage, Datayafa Stakin (25–30 tablets/ft^3) or Malathion (1:3 water spray) is recommended. Pollination is completed in 3–5 days. Seeding rates for some popular cultivars are given in Table 2.

Table 2. Proper time and seeding rate for some popular cultivars in Sindh, Pakistan.

Cultivar	Sowing dates	Seeds/acre
Sindh 81	1–30 November	50 kg
Sindh 81	10–30 November	50 kg
ZA 77	1–20 November	50 kg
ZA 77	7–30 November	50 kg
Pavion	1–20 November	50 kg
Pavion	7–20 November	50 kg
Sursub Z	1–15 December	50 kg
Sursub Z	10 Nov–15 Dec	50 kg
Blue Silver	21 Nov–15 Dec	60 kg
Blue Silver	1–24 December	60 kg
Tandojam 83	21 Nov–15 Dec	60 kg
Tandojam 83	1–21 December	60 kg

Climate. It is grown in tropical and subtropical areas. It need rainfall 12 to 35 inches and a latitude of 30^0 to 60^0. Its growing season is 100 days . It can be grown up-to-the height of 10,000 feet.

Herbicides for wheat. Recommended herbicides include Dicuran, Areton, Dozanex, Tolken, Buctril-1, 2-4-D, Bakral M, Logran Exter, Green Star, Boroe site, Dicron M, Talkon, Earlian, Panther, Graminan, Stamp, Pomaspur, Proturex, Promaspur, Turbuneler D.P 70, Stamp, Bactral M, Bramenal, Talkan, Logran, Topick, and Pochung.

Fertilizer. Some recommended fertilizer regimes based on soil type are given in Table 3. Wheat benefits from nitrogen and phosphorus applied in the ratio of 2:1. All phosphorus is applied at sowing; high doses of nitrogen may split into two applications, at sowing time and with the second irrigation. (Khoso 1977). Nitrogen (55 kg), phosphorus (27 kg), two bags of DAP, and one bag urea at planting time or 2.5 bags phosphorus during planting and 1.5 bags of urea at the first and second irriga-

Table 3. Some fertilizer recommendations for the wheat-growing area of Sindh, Pakistan.

Soil type	At sowing	1st irrigation	2nd irrigation
Weak soil	3 bags N:P:K (10:23:15); 2 bags DAP; or 1 bag Engrozorour + 1 bag MoP	1 bag urea	1 bag urea
Medium soil	2 bags N:P:K (10:23:15); 1.5 bags DAP; or 1 bag Zorour + 1 bag MoP	1 bag urea	0.5 bag urea
Fertile land	2 bags NPK (10:23:15); 1 bag DAP; or 1 bag Zorour + 1 bag MoP	1 bag urea	0.5 bag urea
	At sowing	After sowing	
Weak	2 bags DAP	1 bag urea with water, 0.75–1 bag afterward	
Medium	1.5 bags DAP	1 bag urea with 1st watering application 0.5–0.75 bag urea afterward	
Fertile land	1 bag DAP + 0.33 bag urea	1 bag of urea with 1st watering	

tions. Three bags of urea/acre, twice, first at sowing and at the first irrigation time. Phosphorus (2 bags/acre), potassium (2 bags/acre) or nitrogen (80–120 kg/ha), phosphorus (40–60 kg/ha), potassium (40 kg/ha), and zinc (50 kg/ha). The N:P:K ratio should be 10:23:15 with three bags/acre. During March and April, wheat usually withers with heat. An application of 50 lb phosphorus + 40 lb nitrogen, 30 lb nitrogen (Bux 1964), or 2–3 tons of FYM/ha + organic matter. give good results.

Rotation. Normally rabi wheat is followed by kharif. Green manure crops such as sanai, moong, guar, lobia, or hubam clover are sown immediately after kharif to enrich the soil. Gram, linseed, barley, and mustard are included in rotations. Unirrigated wheat is rotated with jowar, bajara, or cotton in kharif in preceding year. Wheat grown mixed with barley, mustard, gram, lentil, and safflower are common.

Irrigation. Three irrigations are needed as follows:

1st 20–25 days after sowing, during root development,
2nd Emergence of spikes, and
3rd Initial stage of seed formation.

Other irrigation recommendations are for three inches (Khoso 1977); 4–6 irrigations needed with the first at crown-root initiation stage about 20–25 days after sowing, the second at late tillering, followed by irrigations at late jointing, flowering, milk, and dough stages (Wadhwani 1987) as follows:

1st 15–20 days or waterlog soil and give first irrigation 22–30 days after sowing
2nd 20–22 days after first irrigation
3rd 22 days second irrigation
4th in March or April to avoid seed desiccation
5th 15–20 days after last irrigation

The crop requires a growing season of 100 days and an annual rainfall of 700 mm.

Tillage. Wheat is a freely tillering annual 0.3–0.8-m tall with a seminal root number of 3–6. Table 4 lists the effect of primary and secondary tillage on the grain yield of barani wheat in the 1982–83 Rabi season at National Agriculture Research Centre. Islamabad.

Table 4. Effect of primary and secondary tillage on grain yield (kg/ha) of barani wheat in the 1982–83 Rabi season at the National Agricultural Research Centre, Islamabad.

Primary tillage method	Depth (cm)	Secondary tilling method: Mould	Cultivator	Subsoil	Disc	Mean
Mould board	30	4.50	3.98	4.30	4.46	4.30
Subsoil	45	3.90	3.78	3.70	3.82	3.80
Chisel	25	3.92	3.18	3.60	3.48	3.54
Cultivator	10	3.70	3.78	3.90	3.50	3.27
Mean	25	4.00	3.68	3.78	3.82	3.84

Diseases of wheat crop. Leaf spot diseases include *S. nodorum* blotch, *S. tritici* blotch, and yellow spot (Loughman 1994). These diseased are caused by three different fungal pathogens but disease symptoms and biology are the same. Infected leaves show irregular or oval-shaped spots, which initially are small, then turn yellow. Moisture enables the pathogens to sporulate, disperse, and infect, reducing photosynthetic area and causing early leaf senescence. Sever disease in a young crop can reduce tillering and delay flowering. Late infection can hasten maturity and reduce the time available for grain filling resulting in shrivelled seed.

Septoria nodrum bloch is caused by two stages of fungus. The sexual stage, *Leptosphaeria nodorum*, occurs on infested stubble and produces conidiospores from perithecia. The disease is initiated by aerial spore dispersal. The asexual stage occurs on infested stubble produces pycinidispores from minute brown pycnidia that spread the disease to new crop foliage. This disease is most damaging in warm moist conditions. Most damage occurs on the leaves.

Septoria tritici blotch also is caused by two stages of same fungus. The sexual stage, *Mycosphaeraerella graminicola*, occurs on infested stubble and produces ascospores from perithecia that initiate the disease by aerial dispersal. Ascospores can be dispersed moderate distances in the air. Ascospores in large quantities result in the development of an earlier and more severe infection. The asexual stage occurs on stubble and diseased plants producing pycnidiospore from small black pycnidia that spread the disease on to new crop foliage. Pychnidiospores are spread by splash dispersal. Pycnidia are produced in the rows between the veins of infected leaves, which are visible to naked eye.

Yellow spot is caused by two stages of same fungus. The sexual stage, *Pyrenophora tritici-repentis*, occurs on infested stubble by the appearance of pseudoperithecia, which can be seen in the autumn and early winter as black, raised, oval bodies about the size of a pin head. The aerial release of spores initiates the disease. Ascospores of the yellow spot fungus are dispersed only a short distance. The asexual stage, *Drechslera tritici-repentis*, produces conidia on leaf tissue killed by the fungus and spreads the disease in to new crop foliage.

All three diseases occur together and severity of each varies with season and location. Other pathogens of the wheat crop in Pakistan are listed below.

Diseases of wheat according to Wadhani (1987)

Disease	Pathogen
Black mold	*Cladosporium herbarum*
Glume blotch	*Septoria nodorum*
Leaf blotch	*Septoria tritici*
Pythium root rot	*Phythium gromini colum*
Selerotial disease	*Pellicularia rotifii*
Dilophosphorus leaf spot	*Dilophosphjora rotfaii*
Leaf blight	*Atternaria triticina*
Foot rot	*Helminthosporium sativum*
Hill bunt	*Tilletia foetida* and *T. caries*
Karnal bunt	*Neovossia indica*
Flag smut	*Urocystis tritici*
Loose smut	*Ustilago tritici*
Stem rust	*Puccinia graminis*
Stripe rust (yellow rust)	*Puccinia graminis*
Leaf rust (brown rust)	*Puccinia recondita*
Powdery mildew	*Erysiphe graminis*
Mosaic streak virus	
Ear cockle	*Anguium tritici*
Tandu (yellow rot)	*Corynebacterium tritici* and nematode *Anguina tritici* complex
Molya or cercal root rot worm	*Heterodera avonae*

Diseases of wheat and their pathogen according to Joshi et al. (1978)

Disease	Pathogen
Black rust	*Puccinia graminis*
Brown rust	*Puccinia recondita*
Yellow rust	*Puccinia striiformis*
Loose smut	*Ustilago nuda*
Flag smut	*Urocystis agropyri*
Hill bunt	*Tilletia caries*
Karnal bunt	*Neovossia indica*
Leaf blight	*Alternaria triticina*
Leaf blotch	*Septoria tritici*
Nematode disease molya	*Heterodera avenae* (treatment DBCP 60 % EC at the rate of 30 l/ha)

Diseases of wheat and their pathogen according to Khoso (1977)

Disease	Pathogen
Leaf spot	*Alternaria tenuissima, A. alternata, A. tricola, Drechslera sorokiniama D. catenaria, D. nodulosa*, *D. tetramera*, *Helminthosporium atypicum*, *Dilophospora alopecuri*, *Leptosphaerulina trifoli*, *Chaetomium dolichotrichum*, and *Pyricularia oryzae*.
Glume blotch	*Septoria nodorum*, *Poma sorghina*

Powdery mildew	*Erysiphe graminis, Sclerophthora macrospora*
Root rot , foot rot and seedling blight	*Curvularia verruciformis*, *Drechslera sorokiniane*, *D. tetramera*, *D. halodes*, *D. bicolor*, *D. bicolor*, *D. nodulosa*, *Fusarium moniliforme*, *F. dimuerum*, *F. semitectum*, *F. avenaccum*, *F. graminerarum*, *F. culmorum*, *Gaeumannoyces graminis*, *Pythium graminocolum*, *Sclerorolfsil*, and *Rhizoctonia solani*.
Sooty mold	*Cladosporium herbarum*
Seed borne	*Alternaria alternata*, *A. triticina*, *Drechlera sorokiniana*, *D. tetramera*, *Cochliobolus tritici*, *Nigrospora spharica*, *Curvalria pallescens*, *C. geniculata*, *C. verruculosa*, *C. tritici*, *Sclerotium*, *Stemphyliunia* and, *Phiobolus*.
Ear cockle	*Anguina tritici*
Tundu	*Anguina tritici* and *Corynebacterium tritei*.
Molya	*Heterodera avenae*
Virus	Chirke disease of cardaman (Mosaic streak of wheat).
Physiological diseases	Nitrogen deficiency, zinc deficency, and potash deficency.

Seed infection. Seeds can become infected with *S. nodorum* or *P. tritici-repentis* if moisture occurs late in the season. Seed infected with *P. tritici-repentis* causes pink grain that effects crop marketability but does not carry disease to next crop if used as seed. Seed infected with *S. nodorum* will infect the next crop.

Insect pests. The major insects affecting wheat in storage are the Kapra beetle (*Troqoderma granarium*), grain borer (*Rhyzoperths dominica*), grain weevil (*Sitophilus oryzae*), and the red-color beetle (*Tribolium castaneum*). These insects cause approximately 2–4 % damage to stored grain (Rizvi 1998).

Chemical composition of wheat. The whole grain contains the following chemical percentages:

Water	13.0 %
Protein	11.5 %
Fat	2.0 %
Carbohydrate	70.0 %
Fibre	2.0 %
Ash	1.5 %

White flour contains

Water	12.4 %
Protein	10.0 %
Fat	1.0 %
Carbohydrate	76.0 %
Fibre	0.3 %
Ash	0.3 %

Storage. Storage life depends upon moisture content. Grain with less than 10 % moisture stores well.

Uses. Wheat also is used for the production of alcoholic beverages and industrial alcohol. Grain may be fed to livestock and the straw provides valuable fodder. The straw is used for wickerwork, baskets, hats, thatching, and packing.

Fumigant gases. Fumigants include carbon disulfide, carbon tetrachloride, chlorpierine, Dichlorovos, ethylene dichloride, hydrogen cyanide, methyl formate, sulfuryl fluoride, phosphine or methyl bromide phosphine. Methyl bromide is the preferred fumigant for ship fumigation because is has a shorter exposure time. The doses required for fumigation with phosphine is 1–2 g phosphine/m^3 administered for a minimum of 5–7 days. Phosphine should not be used below 12°C. The most convenient method for application of hydrogen cyanide is by means of impregnated discs, which is affective for medical quarantine fumigation. The substantial harvest and postharvest losses greatly contribute the low yield of wheat (Rizvi 1998).

Types of fumigants. Fumigants divided in to three classes. solid-based fumigants, liquid fumigants, and low-boiling fumigants.

Solid-based fumigants. Aluminium phosphide or magnesium phosphide. Phosphine gas is released by a reaction with atmospheric moisture**.** Aluminum phosphide is available in pellet and tablet form.

$AlP + 3H_2O$ —————> $Al(OH)_3 + PH_3$
$Mg_3P_2 + 6H_2O$ ————> $3Mg(OH)_2 + 2PH_3$

Liquid fumigants. Liquid fumigants include carbon tetrachloride, ethylene dibromide, and ethylene dichloride. Liquid fumigants are conveniently applied.

Low boiling-point fumigants. Methyl bromide gas penetrates quickly and is dispersed readily at the end of treatment. Methyl bromide is a powerful organic solvent. Methyl bromide supplied with 2% chlorpicrin added. Harvested wheat is sprayed with Malathion (25:1).

Properties of methyl bromide (monobromomethane) include chemical formula, CH_3Br; boiling point, 3.6°C; molecular weight, 99.94; specific gravity, 1.732 at 0°C; T.L.V, 15 ppm, and G/m^3 to ppm (30°C), 260.

Harvesting. The wheat crop should be harvested immediately after maturity, when the grains harden and the straw becomes dry and brittle.

Improvement. The objectives of wheat breeding include the following:

1. Grain yield, which depends upon the amount of tillering, number of spikes/unit area, length and density of spikes, number of grains/spikelet, and grain size.
2. Maturity, of which early maturity is usually desired because it may enable the cultivar to escape hot weather, drought, and some diseases.
3. Standing ability with short, stiff straw resistant to lodging.
4. Free from shattering.
5. Resistance to diseases and pests, particularly to the rusts.
6. Suitability to the local environment and methods of cultivation, including extension into hotter regions of the tropics.
7. Quality, including market quality, for which pure, clean, and sound grain is required and milling and baking qualities.

New technique to generate genetically modified GM wheat. In a reverse genetic, nontransgenic approach to wheat crop improvement by TILLING, or targeting induced local lesions in genomes, Ann Slade and colleagues of Anawah Inc., Seattle, WA, introduced a technique that can identify new mutations in a polyploid plant, such as wheat, and uncover inherent variation within a genome and eliminate the need to introduce foreign DNA to get a new strain. With TILLING, DNA from multiple individuals is pooled, and PCR is used to amplify a targeted region of the genome. The PCR product from the pool is heated and reannealed, allowing DNA strands from mutants and wild types to base pair with each other. Individuals comprising the positive pools are sequenced to determine which individual carries the mutation and further tests may be undertaken to reveal the nature of the mutation. Unlike conventional mutation breeding, TILLING provides a direct measure of the mutations induced. Slade identified 246 alleles of the *waxy* gene of wheat and was able to produce a new strain yielding large amounts of amylopectin in its grains. This full waxy wheat can be useful to making breads and pastas, and enhance the strength and printing properties of paper produce (http://www.nature.com/cgi-taf/DynaPage.taf?file=nbt/journal/vaop/ncurrent/full/nbt1043.html).

Conclusion. Methods that help increase yield/acre include selection of land and its preparation, better cultivars and time of sowing, proper fertilizer, killing of weeds, healthy seed, proper cultivation, proper irrigation, and proper harvesting and storage. If we take care of above factors, better quality and higher yields will follow.

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