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ITEMS FROM MEXICO

CIMMYT—INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER
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Wheat chemistry and quality improvement.

Roberto J. Peña.

Quality characterization/screening for wheat quality improvement. At CIMMYT, wheat experimental lines are tested for quality attributes and classified according to its potential end-use. Breeders and agronomists receive quality data, a classification of the lines according to their potential end use, and recommendations of the best sources of quality. This action helps breeders to identify lines to be used as quality sources in new crosses and allows screening and selection of quality-desirable lines throughout the breeding process. The wheat quality classification we use was developed based on observed and documented relationships between specific quality traits and end-use quality (bread, cookies, noodles, pasta, etc); actual observation of wheat-based food processing in different countries; and consultations with NARS.

Crop improvement, quality testing/screening. Approximately 18,700 entries were tested for wheat quality characterization using a few rapid small-scale tests to full-quality analysis. The tested materials included late-segregating lines (tested in Obregon), advanced lines (from both the spring and winter wheat programs), elite lines for candidates to international nurseries, and lines from national programs and special projects in breeding and agronomy (tested in El Batan).

Breeders received recommendations on the best quality sources (for diverse uses) to include in new crosses. We also suggested which lines to advance or include in international nurseries or to consider for cultivar registration (in the case of National programs).

In addition, SDS–PAGE to determine *Glu-1*/*Glu-3* glutenin composition and T1B·1R translocation status was applied to 8,000 bread and 4,175 durum wheat samples. The samples analyzed for glutenin composition were part of the wheat-improvement programs and special projects, including theses work of graduate students.

Sources of grain quality. Identifying the best sources of quality for new crosses has been an effective strategy to combine grain yield and quality. The proportion of lines having acceptable to excellent quality in the CBRF (2007–08) and CBBWIR (2007–08) populations were 40.2% and 27.1% , respectively. The top 10 best sources of gluten extensibility

Table 1. Best sources of quality of the crossing block populations sown in Obregon, Mexico in 2007–08 (Glutenin strength rated as strong (S) or medium strong (MS)).

Cross	Pedigee	Gluten strength	HMW-glutenins			LMW-glutenins		
			Glu-A1	*Glu-B1*	*Glu-D1*	*Glu-A3*	*Glu-B3*	*Glu-D3*
CBBWIR 2007–08								
Juchi F2000	TC920338-S-9C-04R-1C-0R-1C-0R	S	2*	7+9	5+10	e	c	a
CHEN/*Ae. tauschii* //2*Weaver/3/ Oasis/5*BORL95	CMSS99M00619S-040M-030Y-030M-15Y-1M-0Y	S	1	7*+8	5+10	b	d	b
Waxwing*2/Varis	CGSS04Y00020T-099M-099Y-099ZTM-099Y-099M-3WGY-0B	MS	2*	7+9	5+10	c	h	b
Kingbird	CMSS99M00216S-040M-030Y-030M-16Y-2M-0Y	S	2*	17+18	5+10	b	h	b
Kiritati//Attila*2/Pastor	CGSS02Y00142S-099M-099Y-099M-35Y-0B	S	1	17+18	5+10	c	i	b
Kiritati// PBW65/2*SERI.1B	CGSS02Y00139S-099M-099Y-099M-14Y-0B	S	1	17+18	5+10	c	i	b
3570		MS	1	7+8	5+10	c	g	a
Waxwing*2/Brambling	CGSS01B00053T-099Y-099M-099M-099Y-099M-22Y-0B	MS	2*	7*	5+10	c	b	b
Waxwing*2/Tukuru	CGSS01B00058T-099Y-099M-099M-099Y-099M-12Y-0B	MS	2*	7*	5+10	c	b	b
Whear/Sokoll	CMSS04Y00201S-099Y-099ZTM-099Y-099M-11WGY-0B	MS	1	13+16	2+12	c	b	c
CBRF 2007–08								
INIA Churrinche		S	2*	7+8	5+10	a	b	a
Attila*2/PBW65//Berkut	CMSA01M00074S-040P0M-030ZTM-040SY-040M-35Y-0M-0SY	S to MS	2*	17+18	2+12	c	g	b
Whear/Vivitsi/3/80.1/3* Batavia//2*WBLL1	CGSS03B00079T-099Y-099M-099Y-099M-13WGY-0B	MS	2*	7+9	5+10	d	h	b
ND643//2*Attila*2/ Pastor	CGSS02B00113T-099B-099Y-099M-099Y-099M-7WGY-0B	MS	2*	17+18	5+10	e	h	c
ND643/2*WBLL1	CGSS02B00105T-099B-099Y-099M-099Y-099M-1WGY-0B	MS	2*	7+9	5+10	c	h	b

(a mayor challenge in wheat quality improvement) from each crossing block population are shown in Table 1 (p. 111). Several of these lines showed HMW-glutenin subunits 1 or 2*, 18+18 or 7+8, and 5+10, and a predominance of *Glu-B3* LMW-glutenin subunits h, b, and g, which have shown to be the most beneficial for gluten extensibility.

To continue with the emphasis on quality improvement, two quality CB trials (CBBWIRIQ and CBRFIQ) including the best sources of gluten strength and extensibility were prepared (58 lines for Ravi Singh and 92 lines for Yann Manes) to facilitate breeders the use of the best sources of quality in new crosses during the Y. 08-09 crop cycle.

Quality methodologies. In order to satisfy the quality testing/screening needs of both the spring and winter wheat programs comprised within the GWP of CIMMYT and those of collaborating partners, it is necessary to use reliable analytical methods that offer high throughputs. During 2008, accelerated protocols were developed to increase the number of lines analyzed for dough rheological properties by at least 100%.

Alveograph. Thanks to the acquisition of the modern Alveo-Consitograph in 2006, we standardized and modified the methodology used with the small-scale (60-g flour) old alveographs in such away that the number of samples tested per day increased from 20–25 to 45–50 in 2008.

Bread-making test. Modifications in the bread-making protocol and the more efficient use of equipment and staff allowed us to increase from 30 to 50 the number of lines tested for bread-making properties in 2008. This action allowed us to offer bread-making quality data again, after 3 years of not being able to perform this test due to the loss of one staff member.

Mixolab. An accelerated method for the use of the Chopin–Mixolab as tool to evaluate/screen for gluten and for starch properties was developed. The new accelerated Chopin-Mixolab protocol allows determining dough (gluten) mixing properties as well as starch pasting properties using one, single, small flour sample. The accelerated protocol also was found to have a highly significant correlation with Falling Number, a test determining grain sprouting. Therefore, the Mixolab protocol has a plus when screening wheat lines sown under high-rainfall conditions. The accelerated Mixolab protocol has been submitted as a section of the Mixolab Handbook, which will be distributed internationally (Peña and Posadas-Romano, Submitted in 2008).

DON analysis. The low-cost (50–60% lower) analytical test, based on a commercial fluorimetric kit protocol (Fluoroquant) for determining DON concentration developed in 2007, was validated using wheat lines cultivated in Uruguay, Paraguay, and Batan. An HPLC analysis of DON extracts obtained with the commercial test kit and low-cost extraction protocols were very similar ($R^2 > 0.96$ was obtained in all comparisons). Gabriel Posadas from the Wheat Chemistry and Quality Laboratory will travel to Uruguay in 2009 to implement the low-cost protocol in the laboratory of INIA-La Estanzuela by in early 2009. With this we complete our responsibility in the Fusarium–toxin analysis subproject of the INIA-Spain-Procisur-CIMMYT project.

Advances in the development of NIRS calibrations. In 2008, NIRS was used in both Obregon (breeding programs; Conservation Agriculture; Agronomy-Harvest Plus) and El Batan for hardness, moisture, grain protein, and straw-N.

Durum wheat breeding.

Karim Ammar.

Summary. The competitiveness and global relevance of the germ plasm produced in the last two years have been clearly and successfully enhanced. We have been able to develop and identify lines combining high yield potential, good performance under water-limited conditions, and good-to-excellent functional quality attributes. The situation with regards to low yellow color in CIMMYT's germ plasm has been turned around, with 75–80% of the lines evaluated in the last two years showing acceptable-to-excellent color. More importantly, our use of as many sources of resistance to leaf rust as possible, since the appearance of the BBG/BN race in 2001, has provided us with sufficient genetic variability to be able to withstand unaffected the loss of one source of resistance (*Lr27+Lr31*) with the appearance of a new race BBG/BP in 2008. This loss did not affect our capacity to distribute highly improved germ plasm in sufficient numbers. Marker-assisted selection has enabled us to start pyramiding leaf rust resistance genes not present in durum wheat (*Lr19* and *Lr47*) and accumulating them on top of other effective genes present in durum wheat, including *Lr14a* for which reliable flanking markers are now available. Marker use also has allowed us to transfer stem rust resistance genes into durum backgrounds and will help us address more effectively, in the medium term, the stem rust vulnerability of our germ plasm in Ethiopia. Finally, our interaction with the Tunisian NARS has enhanced our capacity to effectively ad-

dress the susceptibility of our germ plasm to *Septoria tritici*.

Stem rust screening in Kenya and Ethiopia. For the second year (2008), we have sent an extensive collection of advanced lines (candidates for next international nurseries), crossing parents, and special genetics stocks to be screened in the off-season for their reaction to stem rust at the EARI Debre-Zeit station in Ethiopia. This year, the epidemic development of the disease was hampered by drought and established late, resulting in the data being unreliably positive, with a very high proportion of lines with low infection reactions (Table 2). In comparison, the 2007 off-season was characterized by an intense epidemic and resulted in an extremely low frequency of lines showing low infection reactions (~2.2%). In addition, we are considering the reaction from our secondary screening at Njoro in Kenya were a subset of the promising lines from the 2007 Debre-Zeit screening were evaluated in 2008. Although all of the lines with low reactions at Debre Zeit in 2007 were resistant in Njoro, many of those resistant in Njoro did not hold their resistance in Debre-Zeit, which is consistent with the belief that the main stem rust race in Kenya is $Ug99_{vir\ Sr24+}$, whereas in Ethiopia, there must be additional races specifically virulent on durum wheat (avirulent on bread wheat) that overcome most of the resistance effective in Kenya, confirming the absolute need to work in Ethiopia, not Kenya, for durum wheat. Based on all the results and information at hand, we were able to identify lines that may show some promise in terms of widely effective resistance to stem rust, in both Ethiopia and Kenya (Table 2).

***Septoria tritici* screening in Tunisia.** A relatively lower incidence of *S. tritici* was seen at the Tunisian hot spot of Béja (INRAT) in 2008. Nevertheless, the epidemic was intense enough to differentiate highly susceptible lines from real promising lines. The frequency of promising lines evaluated in 2008 (below 5 in the 1-digit scale used) was very similar to that screened in 2007 under a more intense epidemic and again was extremely low (less than 4%). The last two years of screening, including

Table 2. Some promising lines for resistance to stem rust in Ethiopia and Kenya. BBG/BP refers to the most recent race that appeared in Mexico in 2008 against which these lines were tested in El Batan during the summer cycle. R = resistant, S = susceptible, SR = slow rusting, T = trace, M = moderate, MS = moderately susceptible, MR = moderately resistant.

Cid	Sid	Cross	Selection history	Leaf rust BBG/BP	Debre Zeit, Ethiopia 2007	Debre Zeit, Ethiopia 2008	Njoro, Kenya 2008
477707	47	CMH83.2578/4/D88059/WARD/YAV79/3/ACO89/5/2*SOOTY_9/ RASCON_37/6/1A.1D 5+10-6/3*MOJO/3/AJAIA_12/F3LOCAL (SEL. ETHIO.135.85)//PLATA_13	CDSS02B00720S-0Y-0M-8Y-1M-04Y-0B	R	T	10S	10S
421913	70	CBC 509 CHILE/SOMAT_3.1/3/RASCON_37/TARRO_2//RASCON_37	CDSS00B00444T-0TOPY-0B-13Y-0M-0Y-1M-0Y	R	5MS	10MR	5R/MR
148658	71	HUALITA	CDWS91M377-9M-030Y-030M-1Y-0M-0BRL-1Y-0B	R	5MR/MS	15M/MS	1R
456178	39	KUCUK_2/PATA_2/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1	CDSS02Y00306S-0Y-0M-26Y-0Y	R	20R/MR	15MS	1R
477769	10	RCOL/POHO_1/3/DIPPER_2/BUSHEN_3//SNITAN	CDSS02B00782T-0TOPB-0Y-0M-1Y-3M-04Y-0B	S	5MR/MS	10MR	1R
173245	37	SVANE_1/AKAKI_4	CDSS94Y00096S-5M-0Y-0B-1Y-0B-0BLR-1Y-0B	SR	0	10M	1R
137790	143	THKNEE_9/MOJO_2	CDSS93B00037S-25M-0Y-0B-0Y-5B-1Y-0B-0BLR-2Y-0B	SR	10MS	10MR	1R
173731	44	CPAN.6018/2*RAJ1555//2*PORRON_4	CDSS94Y00582M-E-3M-0Y-0B-2Y-0B-0BLR-2Y-0B	SR	15R/MR	15MS	1R

2008, were, however, useful to identify lines that consistently show some promise as sources of resistance within our germ plasm. Thirteen such lines (Table 3) have been and continue to be used extensively in crosses with the best resistance sources from the Tunisian program.

Table 3. Promising lines for reaction to *Septoria tritici* based on data from Béja, Tunisia (INRAT). Reactions of the most resistant lines are in grey.

CID	SID	Cross	Selection history	2007	2008
148658	71	HUALITA	CDWS91M377-9M-030Y-030M-1Y-0M-0BLR-1Y-0B	—	2
403149	249	BCR/GUEROU_1/3/MINIMUS_6/PLATA_16//IMMER	CDSS99B00319S-0M-0Y-121Y-0M-0Y-0B	2	3
283822	56	USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79//8/POD_9	CDSS96Y00484S-3Y-0M-0Y-1B-0Y-0B-0B-0BLR-2Y-0B	2	3
261495	18	SOMAT_4/SILVER_1	CDSS95B00182S-2Y-0M-0Y-2B-0Y-0B-0B	4	3
417954	142	SOMAT_3.1//WODUCK/CHAM_3/5/AJAIA_16//HORA/JRO/3/GAN/4/ZAR	CDSS00Y01093T-0TOPB-2Y-0BLR-3Y-0B-0Y-0B	4	3
403142	269	AINZEN_1/6/CHM82A.1062/3/GGOVZ394//SBA81/PLC/4/AAZ_1/CREX/5/HUI//CIT71/CII	CDSS99B00312S-0M-0Y-51Y-0M-0Y-1B-0Y	4	3
327961	41	AJAIA_3/SILVER_16//AJAIA_13/YAZI	CDSS97Y00618S-1Y-0M-0Y-0B-0B-2Y-0BLR-1Y-0B	4	4
328423	51	PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR 84/3/HUI/POC//BUB/RUFO/4/FNFOOT	CDSS97Y01080T-0TOPM-3Y-0M-0Y-0B-0B-2Y-0BLR-4Y-0B	5	4
328178	58	LD357E/2*TC60//JO69/3/FGO/4/GTA/5/SRN_1/6/TOTUS/7/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69/8/SOMBRA_20/9/STOT//ALTAR 84/ALD	CDSS97Y00835S-0TOPM-4Y-0M-0Y-0B-0B-3Y-0BLR-4Y-0B	5	4
283798	47	SORA/2*PLATA_12//SRN_3/NIGRIS_4	CDSS96Y00460S-4Y-0M-0Y-1B-0Y-0B-0B-0BLR-2Y-0B	5	4
328510	30	RASCON_37/2*TARRO_2/4/ROK/FGO//STIL/3/BISU_1/5/MALMUK_1/SERRATOR_1	CDSS97Y01167T-0TOPM-2Y-0M-0Y-0B-0B-1Y-0BLR-4Y-0B	5	5
404000	32	CBC 509 CHILE/4/SKEST//HUI/TUB/3/SILVER/5/GREEN_14/YAV_10/AUK	CDSS99B01170T-0TOPY-0M-0Y-4Y-0M-0Y-2M-0Y	5	5
261494	50	SOMAT_4/INTER_8	CDSS95B00181S-0M-1Y-0B-1Y-0B-0Y-0B-0BLR-2Y-0B	5	5

3rd International Stem Rust Resistance Screening Nursery (3rdSRRSN).

Ravi P. Singh, Julio Huerta-Espino, Sridhar Bhavani, Sybil Herrera-Foessel, Davinder Singh, and Pawan K. Singh.

The presence of effective race-specific and adult-plant resistance was characterized by testing selected advanced breeding lines in the seedling stage with Ug99 and Ug99 + *Sr24* races at the USDA–ARS Cereal Disease Laboratory, St. Paul, MN, USA. Seedling tests with leaf rust races also were conducted in greenhouses in Mexico to determine the presence of those alien stem rust-resistance genes that are linked to leaf rust-resistance genes in the same translocation. Molecular markers also were applied for genes such as *Sr24*, *Sr25*, and *Sr26* to confirm their presence. These studies form the basis of resistance genes given in Table 4. One-hundred five entries (plus checks) were included in the 3rdSRRSN based on 2006–07 and 2007 screening results from Njoro, Kenya.

Table 4. Stem rust resistance (based on 2006–07 and 2007 screening results at Njoro, Kenya) of entries included in the 30th Elite Selection Wheat Yield Trial (30thESWYT), the 42nd International Bread Wheat Screening Nursery (42ndIBWSN), and the 3rd Stem Rust Resistance Screening Nursery (3rdSRRSN).

Nursery	30thESWYT		42ndIBWSN		3rdSRRSN	
Category	**# entries**	**% entries**	**# entries**	**% entries**	**# entries**	**% entries**
Adult-plant resistance						
R (10–15% severity)	1	2.2	4	2.5	0	0.0
R–MR (15–20% severity)	11	24.4	13	8.0	18	17.1
MR (30% severity)	15	33.3	27	16.7	38	36.2
MR–MS (40% severity)	7	15.6	36	22.2	0	0.0
MS (50–60% severity)	2	4.4	38	23.5	0	0.0
S (100% severity)	0	0.0	21	13.0	0	0.0
Race-specific resistance						
Sr25	6	13.3	4	2.5	11	10.5
Sr24 + Sr36	0	0.0	0	0.0	4	3.8
Sr33	1	2.2	1	0.6	0	0.0
SrTmp	1	2.2	3	1.9	4	3.8
SrSynt	0	0.0	0	0.0	4	3.8
SrSha7	0	0.0	0	0.0	4	3.8
SrND643	0	0.0	1	0.6	11	10.5
SrHUW234	1	2.2	3	1.9	2	1.9
Sr unknown	0	0.0	2	1.2	9	8.6
Unclassified	0	0.0	9	5.6	0	0.0

USAID–Ug99 Resistant Varieties Seed Multiplication Project.

Fifteen, Ug99 wheat lines were multiplied at El Batan, Mexico, during the 2008 crop season in a 3.3-ha plot. Ten normal and three early maturing lines were selected for the seed project based on their performance in the 3rd Elite Bread Wheat Yield Trial (3rd EBWYT) in various countries (Table 5, p. 116). The early maturing line Francolin#1, although not included in the 3rd EBWYT, performed very well in the northeastern Gangetic Plains in on-farm trials and was, therefore, selected form multiplication and shipment to Bangladesh, Nepal, and India.

A total of 13 tons of seed was produced and processed and packaged. Seed quantities shipped to various countries are summarized in Table 5 (p. 116). Egypt has already made significant progress in multiplying five Ug99-resistant

Table 5. Ug99-resistant wheat lines included in the USAID–Seed Project and seed quantities shipped (shipment to India pending Import Permit).

CIMMYT name	Cross	Maturity	Country and seed quantity (kg)							
			Bangladesh	Nepal	Pakistan	Turkey	Afghanistan	Egypt	Ethiopia	India
DANPHE #1	KIRITATI//2*PBW65/2*SERI.1B	Normal		100					100	
KINDE #1	PBW343*2/KUKUNA//KIRITATI	Normal								100
PICAFLOR #1	KIRITATI//SERI/RAYON	Early	100	100			50		100	100
PAURAQUE #1	WAXWING*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	Early	100	100						100
GRACKLE #1	WAXWING*2/KUKUNA	Normal						25		
BECARD #1	WBLL1*2/KIRITATI	Normal		100						
MUNAL #1	WAXWING*2/KIRITATI	Normal		100	300	100	50		100	
FRANCOLIN #1	WAXWING*2/VIVITSI	Early	100	100						100

entries selected from 2nd EBWYT, hence smaller quantities of new lines were sent. The remaining seed is stored to cater any future needs.

Evaluation of stem rust resistance in wheat materials from different countries during 2008 in Kenya.

A main-season, stem rust screening nursery (June–October) was planned and finalized jointly by KARI, CIMMYT–Kenya, and international collaborators. More than 18,000 lines of spring wheat, 2,600 lines of winter wheat, and 700 lines of barley from 20 countries were planted and screened (Table 6). The plots were established well apart from some of the late-sown material, which did not perform well, probably for a range of reasons, particularly the late arrival of seed and poor seed quality. Artificial rust epidemics were created using inoculum collected from previous-year screening nurseries. Rust infection was excellent and disease pressure was quite heavy. The infection type on the controls/differentials showed virulence for genes *Sr31* and *Sr24* in the screening nursery indicating the likely presence of Ug99 and its variant Ug99 + *Sr24* in the screening site. *Sr36* was partially effective, probably because of the low frequency of Sr36 virulence in the pathogen population. Lines with notable resistance included *Sr25* derivatives, several tall Giza (Egypt) lines, derivatives of the Chinese wheat Sha7, Canadian materials (Thatcher background plus *Lr34*), some ICARDA and CIMMYT lines, and several Egyptian and CIMMYT durum wheats. A varied response of materials with *Sr2* also was evident.

Table 6. Number of wheat lines screened and resistant lines selected from different countries at KARI Njoro (Kenya) during the main season 2008.

Country	No. of lines screened		Resistant lines selected
	Spring	Winter	
Australia	1,862	9	18
Argentina	112	—	12
Canada	1,400	2	21
CIMMYT	3,049	657	151
Egypt	228	—	12
ICARDA	5,908	111	16
India	318	—	4
Iran	371	179	3
Israel	10	—	—
Kazakhstan	259	—	13
Kenya	1,305	—	40
Nepal	125	—	1
Pakistan	135	—	—
South Africa	140	—	11
Sudan	70	—	—
Turkey	130	270	7
Uruguay	290	—	13
USDA	2,433	1,450	-
Total	18,145	2,678	322

Communications/logistics were established with relevant scientists/originators for scoring their material. More than 20 scientists from different countries visited their germ plasm materials and assistance was provided for data taking and selections. The low frequency of resistant materials remained a common feature among wheat materials from many countries with more than 80% of the screened germ plasm susceptible. The data has been documented and sent to the collaborators. From the resistant material, an elite set of 322 lines was selected to further characterize and determine the inheritance of resistance or for use as a source of resistance in crossing programs.

Cloning of Lr34/Yr18 and the development of diagnostic marker.

The highlight of 2008 has been the cloning of the pleiotropic leaf rust/yellow rust/powdery mildew resistance gene *Lr34/Yr18/Pm38* and acceptance of a paper in *Science*. The success of the cloning involved a strong collaboration between CIMMYT, CSIRO, and the University of Zurich, where CIMMYT's main role was generating deletion mutants and phenotyping mapping populations. *Lr34/Yr18/Pm38* turned out to be a new kind of resistance gene.

The abstract of *Science* paper is as follows: "Durable disease resistance in crops has great relevance for agriculture and breeding, but is not understood well at the molecular level. Durable resistance is often partial and controlled by several genes. *Lr34* is an important genetic component of resistance to three of the most devastating fungal pathogens in wheat: leaf rust, stripe rust, and powdery mildew. *Lr34*-based resistance has been durable for more than 50 years, is deployed globally, and specifically acts in the adult-plant stage. Here, we show that *Lr34* encodes an ATP-binding cassette transporter of the pleiotropic drug resistance subfamily. Wheat alleles of *Lr34* conferring resistance or susceptibility differ by three sequence polymorphisms which are conserved in all three breeding lineages with *Lr34* in the global wheat gene pool. The *Lr34* gene stimulates senescence-like processes in the flag leaf tips and edges."

The cloning success also has resulted in the development of a diagnostic molecular marker by CSIRO, which is under validation.

Development and characterization of an RIL mapping population for a single, slow-rusting resistance gene on chromosome 7BL.

An F_5 RIL mapping population of about 400 lines was developed from two sister lines and phenotyped at Cd. Obregon, Mexico, for fine mapping of a new, slow-rusting (adult-plant) leaf rust-resistance gene located in chromosome 7BL. The leaf rust severity response of the resistant parent (two sister-lines) was 15MS, whereas the susceptible parent showed 100S. Segregation confirmed involvement of a single, slow-rusting resistance gene. The population is planted for the second year evaluation during 2008–09 to confirm the phenotypic responses. Molecular mapping studies confirmed the location of this gene to 7BL (Fig. 1). The chromosomal region where the gene is located corresponds to a gene-rich area where a cluster of defense-response genes and the seedling-resistance gene locus *Lr14a* are located.

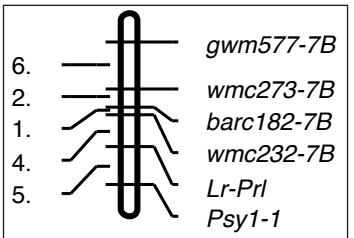

Fig. 1. Linkage map with the slow-rusting resistance gene (*Lr-Prl*) and its association with four microsatellite markers, and the CAPS marker *Psy1-1* associated with yellow pigment, based on a population of the first sister-line (198 F_5 lines).

Development of durum wheat germ plasm with slow-rusting resistance to leaf rust.

A total of 1,843 advanced lines of durum wheat, obtained from 28 three-way and four-way crosses of slow-rusting durum wheats carrying 2–3 minor additive genes, were grown during 2007, and 106 lines with enhanced resistance and desirable agronomic and grain characteristics were chosen for leaf rust and grain yield in nonreplicated trials. An additional 62 lines with race-specific resistance also were selected. Slow-rusting lines with high levels of resistance and acceptable yield performance comparable to that of Jupare C2001 were identified. Leaf rust severities of the lines were considerably higher at El Batan compared to 2007–08. The best identified durum wheat lines are being used at present for continued breeding to develop lines with high, stable levels of durable resistance to leaf rust.

Association mapping of leaf, yellow and stem rust resistance in an historical Elite Selection Wheat Yield Trial (ESWYT) set.

A total of 170 entries from five historical ESWYT trials (ESWYT 1, 6, 10, 20, and 24) were evaluated for leaf, yellow, and stem rust resistance in El Batan and Toluca, Mexico, in 2007, and in Kenya in the off and main season in 2008 under high disease pressure to races MBJ/SP and MCJ/SP (for leaf rust), PBW343 (for yellow rust), and Ug99 + *Sr24* (for stem rust). This same ESWYT set had been used previously to identify regions associated with leaf, yellow, and stem rust; powdery mildew; and grain yield based on historical data that had been collected between 1979 and 2004. The final rust-severity ratings taken for the three rusts and the area under the disease progress curve for leaf rust and the coefficient of infection for stem rust together with already available genotypic data and chromosome maps were used for an association analysis. Chromosomal regions were identified with markers associated to leaf, yellow, and stem rust resistance genes that are effective to the predominant races of relevance today and the number of significant markers in each region (Table 7). The same trial was sown in 2008–09 for a second year of leaf rust data and will be sown in Toluca, Mexico, during 2009. A gene-postulation test for leaf rust resistance was carried out in 2008 in the greenhouse to confirm the regions identified through association genetic analysis and investigate the power of this tool to identify regions with known genes that are present in each line. Seedlings of the same 170 entries were inoculated with 13 different races of *P. triticina* and infection-type response were compared to the differential sets of isogenic lines with known leaf rust-resistance genes. The leaf rust-resistance genes identified through gene postulation were *Lr1*, *Lr3*, *Lr10*, *Lr14a*, *Lr13*, *Lr16*, *Lr17*, *Lr19*, *Lr24*, and *Lr27 + Lr31*. Additional unknown seedling resistance genes were present in some of the lines. The infection-type response from each of the 13 races were transformed to quantitative data and association analysis made from the response from each race; the analysis is still in process. From the known seedling genes identified in the greenhouse test, only *Lr19* and *Lr24* are effective to the predominant races used in the field trial. Regions whit slow-rusting resistance genes, such as *Lr34*, were confirmed from the association analysis based on field data. Further analysis will help identify regions with unknown slow-rusting resistance genes.

Table 7. Chromosomal regions possessing DArT markers associated with resistance to current races of leaf (LR) and yellow (YR) rust in Mexico and stem rust race Ug99 (SR) in Kenya. The number of markers associated in each chromosome arm given in parenthesis.

Chromosome	Short arm	Long arm	Unknown arm
1A	LR(1), YR(1), SR(2)	LR(3), YR(1), SR(1)	YR(1), SR(1)
1B	LR(15), YR(2)	YR(2), SR(1)	LR(3), SR(1)
1D		YR(6), SR(2)	SR(1)
2A	YR(2)	SR(1)	SR(2)
2B	SR(3)	LR(4), SR(4)	LR(1), SR(1)
2D	LR(1)		YR(1)
3A		LR(1), SR(2)	
3B	LR(1), YR(8), SR(4)	LR(2), YR(4), SR(4)	LR(1), SR(1)
3D			
4A		LR(2), YR(5), SR(1)	YR(3), SR(1)
4B	LR(3), SR(1)	LR(1), YR(1), SR(2)	YR(2), SR(2)
4D	LR(1)		
5A	YR(1)	LR(1)	YR(1), SR(1)
5B	LR(1), YR(2), SR(1)	LR(1), YR(2), SR(3)	LR(1)
5D			
6A	SR(1)	LR(7), SR(4)	
6B	LR(1), YR(5), SR(3)	SR(1)	YR(1), SR(1)
7A	LR(2), YR(1), SR(3)	LR(3), SR(1)	SR(1)
7B	SR(2)	LR(2), YR(4), SR(3)	YR(1)
7D	LR(2), YR(2), SR(2)		LR(1), YR(1), SR(7)

Stem rust resistance: Development of mapping populations.

Development of 15 mapping populations was completed during 2008 (Table 8). These populations were planted as single replicates at Njoro, Kenya, during the 2008–09 season for first-year, stem rust phenotyping and in screenhouse at El Batan, Mexico, for seed multiplication. Three or four populations will be selected based on the phenotyping results for second-year phenotyping in replicated trials and molecular characterization.

Table 8. A summary of the populations developed for mapping uncharacterized sources of adult-plant resistance to stem rust and planted for phenotyping at Njoro, Kenya, during 2008–09.

PBW343 / parents with adult-plant resistance	Generation	No. of RILs
JUCHI	F_6	225
KIRITATI	F_6	225
PAVON76	F_6	225
DUCULA/2*PRINIA	F_6	225
PGO/SERI//BAV92	F_6	225
Kenya Nyangumi	F_6	225
Kenya Kudu	F_6	225
Kenya Swara	F_6	225
Kenya Fahari	F_6	225
KINGBIRD	F_5	200
CNDO/R143//ENTE/MEXI_2/3/*Ae. tauschii* (TAUS)/4/WEAVER/5/ 2*KAUZ /6/FRET2	F_5	150
PFAU/WEAVER*2//KIRITATI	F_5	150
PGO//CROC_1/*Ae. tauschii* (224)/3/2*BORL95/4/CIRCUS	F_5	150
BABAX/3/OASIS/SKAUZ//4*BCN/4/PASTOR	F_5	150
HE1/3*CNO79//2*SERI/3/ATTILA/4/WH 542	F_5	150
HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	F_5	150

Mapping of stem rust resistance: Identification of genomic regions governing seedling resistance to Ug99.

Five populations, where a resistant parent possibly carried previously an uncharacterized race-specific resistance gene to Ug99 race of stem rust pathogen, were used in molecular mapping (Table 9). Segregating F_3 and F_4 populations were characterized for seedling stem rust response in the greenhouse of the USDA–ARS, St. Paul, MN, USA, by Dr. Yue Jin. The populations also were characterized in the field at Njoro, Kenya, during 2007–08 and 2008.

Table 9. Wheat lines with uncharacterized race-specific resistance genes to stem rust race Ug99 of included in molecular mapping of resistance (IT = infection type).

Resistance source	IT	Susceptible parent	IT
MILAN/SHA7/3/THB/CEP7780//SHA4/LIRA/4/SHA4/CHIL (F_3 population)	2	PBW343	33+
NINGMAI 9415.16//SHA4/CHIL/3/NINGMAI 50 (F_3 population)	2–	PBW343	33+
CHEN/*Ae. tauschii*//2*EAVER/3/OASIS/5*BORL95 (F_3 population)	2–	PBW343	33+
CHEN/*Ae. tauschii* (TAUS)//BCN/3/CMH81.38/2*KAUZ (F_4 population)	3–	PBW343	33+
NING9415/3/URES/BOW//OPATA/4/NINGMAI 7 (F_4 population)	2–	PBW343	33+

A bulk-segregant analysis was used to identify marker-trait associations. Bulks were constituted by pooling DNA of 10 individual families each from nonsegregating resistant and nonsegregating susceptible classes. We used 213 microsatellite primers uniformly spread over the A, B, and D genomes. Markers that exhibited polymorphism among the resistant and susceptible bulks and parents were genotyped on the unscrambled HR and HS families and preliminary mapping analysis was performed. Recombination fractions were calculated with the MAP MANAGER Version QTXb20 using the Kosambi mapping function.

Greenhouse evaluation for resistance to tan spot and Stagonospora nodorum blotch.

Two sets of material from the Irrigated Bread Wheat Program included i) an irrigated, bread wheat set of 105 lines (the same lines also were included in the second-year *Fusarium* testing) and ii) an historical ESWYT set of 170 entries used for association mapping. Three experiments were conducted in the greenhouse for each disease. Each experiment was conducted as a randomized block design with two replicates. Each replicate consisted of the complete set of genotypes planted in trays. The experimental unit consisted of four plants/entry and 48 entries were planted in each tray.

The *Pyrenophora tritici-repentis* race 1 isolate Ptr-1 was used to induce tan spot. Race 1 is highly virulent and the most prevalent race worldwide. The *Phaeosphaeria nodorum* isolate SN-4 was used to induce Stagonospora nodorum blotch. Two-week-old seedlings were inoculated and rated eight days later for disease reaction based on a 1–5 scale. A mean rating of less than 2 was considered resistant, and those higher than 2 were considered to be susceptible.

Irrigated bread wheat set. For tan spot 35 entries were resistant while 70 were susceptible and in case of Stagonospora nodorum blotch 18 entries were resistant and the remaining 87 entries were susceptible. Many entries were resistant to one disease and susceptible to the other or vice-versa, however, nine entries were resistant to both the diseases (Table 10, p. 116).

Historical Elite Selection Wheat Yield Trial (ESWYT) set. This set was comprised of 170 wheat lines derived from five CIMMYT elite spring wheat yield trials (ESWYT 1 (1979), ESWYT 6 (1984), ESWYT 10 (1988), ESWYT 20 (1999), and ESWYT 20 (2004)). Eighty-nine genotypes were resistant and 81 were susceptible to tan spot; 33 entries were resistant and the remaining 137 entries were susceptible to *Stagonospora nodorum* blotch. Many entries were resistant to one disease and susceptible to the other or vice-versa, however, 26 entries were resistant to both the leaf spotting diseases (Table 10, p. 121).

Association mapping of tan spot resistance.

The molecular data generated earlier on the historical ESWYT set of 170 wheat lines and tan spot resistance data presented above were used for association mapping analysis. Results reveal that genomic regions on short arm of chromosomes 1A, 1B, and 6B and long arm of chromosomes 4A, 6A, 2B, 3B, 5B, and 7B may play important role in conferring resistance to tan spot induced by *P. tritici-repentis* race 1. Some of the above genomic regions contributing to tan spot resistance have been previously identified; however, novel genomic regions were identified in this study. Findings of this study reveal that CIMMYT wheat germ plasm is likely to contain novel sources of resistance to tan spot.

General wheat pathology.

Etienne Duveiller, M. Mezzalama, J. Murakami, N. Lozano, F. Lopez, J. Segura, A. Djurle, N. Schlang, P. Singh, M. Preciado, and M-E. Leymus.

Fusarium head blight research. Fusarium head blight or scab is one of the most destructive fungal diseases affecting wheat. The disease reduces kernel weight, yield, and flour extraction rates particularly in warm and humid wheat-growing areas. Fusarium species causing FHB produce mycotoxins that contaminate the grain and have been shown to be harmful to human and animal health. The mycotoxins of primary concern are the trichothecenes the most common of which in scabby grain is deoxynivalenol (DON) produced by *F. graminearum* and *F. culmorum*.

Table 10. Disease reaction of genotypes resistant to tan spot (TS) and *Stagonospora nodorum* blotch (SNB) in seedling evaluation under greenhouse conditions. Plants were rated on a 1–5 scale, and the data presented is mean of three experiments each with two replicates.

CID #	SID #	Cross	TS	SNB
Irrigated bread wheat set				
480918	25	PBW343*2/KUKUNA/3/PASTOR//CHIL/PRL	1.58	1.75
465822	91	CHEN/AE.SQ//2*OPATA/3/TILHI/4/ATTILA/2*PASTOR	1.67	1.60
482087	21	CNDO/R143//ENTE/MEXI_2/3/*Ae. tauschii* (TAUS)/4/WEAVER/5/2*KAUZ/6/PRL/2*PASTOR/7/FISCAL	1.64	1.88
459285	75	THELIN/3/BABAX/LR42//BABAX/4/BABAX/LR42//BABAX	1.78	1.61
448391	74	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	1.58	1.88
448436	114	PFAU/WEAVER*2//TRANSFER#12,P88.272.2	1.63	1.72
373440	145	80456/YANGMAI 5//SHA5/WEAVER/3/PRINIA	1.25	1.63
90292	248	NG8675/CBRD	1.58	1.75
90248	173	SHA3/CBRD	1.53	1.46
Historical Elite Selection Wheat Yield Trial set				
7760	9	DOVE	1.92	1.99
7668	42	SUNBIRD	1.58	1.72
7668	6	SUNBIRD	1.76	1.49
7691	18	GENARO T 81	1.28	1.58
8256	8	TTR/BOW	1.69	1.76
8918	10	SAP/MON	1.74	1.97
7691	319	VEERY	1.28	1.67
9704	5	SASIA	1.67	1.72
8176	7	SIBIA	1.56	1.78
7507	8	FASAN	1.38	1.63
53292	49	CARACARA	1.38	1.92
7691	50	SERI M 82	1.40	1.74
8195	5	RAYON F 89	1.56	1.71
7896	254	BACANORA T 88	1.38	1.99
43379	332	TOROCAHUI S2004	1.75	1.63
67414	39	IRENA/KAUZ	1.33	1.83
122467	76	OASIS/5*BORL95	1.85	1.83
65950	13	KAUZ*2/YACO//KAUZ	1.92	1.76
160593	23	SUPER SERI #2	1.86	1.83
160593	43	SERI*5//AGA/6*YR	1.58	1.86
98843	59	BUC/PRL//WEAVER	1.94	1.96
114906	319	CHEN/*Ae. tauschii* (TAUS)//BCN/3/KAUZ	1.42	1.92
118879	206	CROC_1/*Ae. tauschii* (205)//KAUZ/3/ATTILA	1.24	1.58
118879	209	CROC_1/*Ae. tauschii* (205)//KAUZ/3/ATTILA	1.35	1.58
120854	182	CHOIX/STAR/3/HE1/3*CNO79//2*SERI	1.56	1.55
134029	124	SW89.5181/KAUZ	1.63	1.95
		6B-662	1.92	2.38
		6B-365	3.40	3.37
		Glenlea	3.71	3.42
		Saloumini	1.54	1.58

CIMMYT started a breeding program for FHB resistance in the early 1980s with the routine screening of conventional and distantly related Triticeae germ plasm. In 1989, CIMMYT and China initiated a shuttle-breeding and germ plasm exchange program focusing on the integration of FHB resistance from Chinese wheats into high-yielding CIMMYT germ plasm. As a result, many Chinese derivatives have been included in the CIMMYT international nurseries that are distributed around the world.

Field screening. Until 2005, CIMMYT conducted field screening activities at the experiment station of Toluca, Mexico (2,640 masl), where the humid environmental conditions during the summer are particularly favorable to the development of the disease but, nevertheless, unverifiable and not possible to control. Since 2006, we modified our FHB screening system for greater accuracy and precision by shifting our operations to El Batan, Mexico, implementing an automated, programmable misting system, and using precision CO_2 sprayers for liquid inoculum application. The system allows the systematic and detailed screening of up to 9,000 plots (1–1.5-m double row) per year in the fields. The materials tested each year include advanced materials from the irrigated and rainfed CIMMYT wheat breeding programs, synthetic derivatives and wide crosses, elite triticale materials, multiple mapping populations, and introductions of new FHB-resistant materials. In 2008, in addition to the screening program, three trials were included under this screening system:

- a trial to confirm and assess the mycotoxin content of 36 advanced lines that have been evaluated in two previous years and tested for type-II resistance in the greenhouse in 2008,
- a trial to evaluate the effect of exposure to the misting system on DON content in two resistant and two susceptible lines depending on the harvest time (i.e., immediately after ripening vs. harvesting the entire screening field, which only can be done after late entries have been scored), and
- an experiment to assess the correlation between DON content and incidence/severity of FHB and its spatial distribution in the field.

Greenhouse screening. Mexican *F. graminearum* strains and other *Fusarium* species isolated from farmers fields and causing head blight were characterized. Suitable isolates to use in field screening, evaluating aggressiveness, and for chemotype and species verification were determined. Type-II resistance in wheat lines that have shown low FHB index and low mycotoxin content in the field were conducted.

DON evaluation. Quantification of DON in the most promising lines used the RIDASCREEN® FAST DON ELISA (R-Biopham AG, Germany). We also evaluated alternative methods for DON quantification including (qPCR).

Molecular pathology and marker-assisted selection. This work involved identifying Mexican *Fusarium* species and chemotype determination, evaluating alternative methods for DON quantification including (qPCR), and using MAS (3BS markers) in selected crosses made by the breeders.

International seed exchange network. Distributed the eleventh Scab Resistance Screening Nursery (11th SRSN) in 2008 and coördinated the Fusarium International Preliminary Spring Wheat Nursery (FIPSWN) and the Fusarium International Elite Spring Wheat Nursery (FIESWN) proposed by the 'Global Fusarium Initiative'.

Monitoring of long-term agronomy trials. This program is collaborating with CIMMYT's wheat agronomy group to investigate the long-term effects of conservation agriculture practices and rotation on FHB incidence, severity, and DON accumulation. Two years of data are already available.

Distribution of the 11th Scab Resistance Screening Nursery (SRSN). The SRSN was started at CIMMYT in 1985. These nurseries have consisted of the best FHB-resistant material identified through CIMMYT's FHB-screening trials and have been distributed to interested programs around the world upon request. In 2008, 54 sets of the 11th SRSN were distributed worldwide under the Standard Material Transfer Agreement adopted by the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture. This nursery includes the 47 best-performing, CIMMYT bread wheat lines and can be requested by anyone interested in improving wheat for resistance to FHB. Characteristics of the lines, including FHB index, DON content, and Fusarium damaged kernels (FDK) are reported in Table 11 (p. 123).

Spot blotch screening in Agua Fria, Puebla, Mexico. Spot blotch, caused by *Cochliobolus sativus*, emerged as a major threat to wheat production in the warmer, nontraditional wheat-growing areas in the late 1980s. This foliar disease causes significant yield losses annually (15–20% on average in South Asia) endangering the livelihoods of millions of small farmers. Effective measures in the field are needed to mitigate the impact of spot blotch on food security in af-

Table 11. List of bread wheat lines included in the 11th Scab Resistance Screening Nursery distributed by CIMMYT during 2008 with data on field performance in the previous year.

Entry	Cross	FHB Index	DON (ppm)	FDK %
6401	NG8675/CBRD//SHA5/WEAVER	7.2	0.8	12.5
6402	80456/YANGMAI 5//SHA5/WEAVER	5.1	1.4	17.5
6403	EMB16/CBRD//CBRD	14.4	—	.—
6404	MAYOOR//TK SN1081/*Ae. tauschii* (222)/4/CS/LE.RA//CS/3/PVN/5/PRINIA	9.4	2.0	8.0
6405	GONDO/CBRD	5.1	0.8	25.0
6406	YANGMAI 5*2/4/MOR/VEE#5//DUCULA/3/DUCULA	13.1	4.8	65.0
6407	SUM3/3/CS/LE.RA//CS/4/YANGMAI 158	12.0	1.5	30.0
6408	BAU/MILAN//CBRD	9.1	1.1	40.0
6409	SHA3/SERI//G.C.W 1/SERI/3/SHA3/SERI//YANG87-142	10.3	1.1	50.0
6410	80456/YANGMAI 5//SHA5/WEAVER/3/PRINIA	6.8	1.1	19.0
6411	80456/YANGMAI 5/3/PF70354/BOW//DUCULA/4/DULUS	7.0	2.1	25.0
6412	WUH1/VEE#5//CBRD	10.2	0.6	20.0
6413	SHA4/CHIL/4/CAR422/ANA//TRAP#1/3/STAR	10.3	2.3	50.0
6414	EMB16/CBRD//CBRD	4.6	0.5	4.0
6415	GAMENYA	91.9	8.0	—
6416	TNMU/6/CEP80111/CEP81165/5/MRNG/4/YKT406/3/AG/ASN//ATR	14.8	0.8	3.3
6417	FALCIN/*Ae. tauschii* (312)/3/THB/CEP7780//SHA4/LIRA	44.7	—	—
6418	SHANGHAI	13.9	1.2	11.3
6419	FRTR/MTA	5.5	1.2	1.0
6420	HEILO	11.7	2.5	33.3
6421	SUMAI #3	3.9	0.3	8.0
6422	SUMAI #3,AUT	2.8	—	—
6423	NG8675/CBRD//MILAN/3/NG8675/CBRD	9.1	0.4	5.3
6424	NING MAI 9558	10.4	3.9	20.0
6425	TINAMOU	10.4	1.5	7.3
6426	TRAP#1/BOW//TAIGU DERIVATIVE	9.8	0.7	7.0
6427	SHA3/CBRD	6.3	1.1	2.0
6428	SUM3/3/CS/LE.RA//CS/4/YANGMAI 158	8.9	0.5	8.0
6429	TRAP#1/BOW//TAIGU DERIVATIVE	9.8	0.7	8.0
6430	EMB27/KLORI	9.6	0.5	1.7
6431	GONDO/TNMU	10.0	3.1	14.7
6432	IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/*Ae. tauschii* (190)	10.4	1.0	3.3
6433	IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/*Ae. tauschii* (190)	14.0	1.6	12.0
6434	BR23/EMB27	5.8	0.5	4.0
6435	YANGMAI 5	6.9	2.1	15.3
6436	ATTILA/TNMU//TNMU	3.5	1.0	10.0
6437	SHA5/WEAVER//GONDO	2.1	0.5	45.0
6438	RUSS/7/OPATA/6/68.111/RGB-U//WARD/3/FGO/4/RABI/5/*Ae. tauschii* (878)	3.9	0.9	20.0
6439	SHA5/WEAVER//80456/YANGMAI 5	4.2	0.6	6.0
6440	RUSS/7/OPATA/6/68.111/RGB-U//WARD/3/FGO/4/RABI/5/*Ae. tauschii* (878)	5.1	0.7	40.0
6441	VERDE/7/OPATA/6/68.111/RGB-U//WARD/3/FGO/4/RABI/5/*Ae. tauschii* (878)	5.1	2.5	4.0
6442	CROC_1/*Ae. tauschii* (205)//KAUZ/3/PRL/SARA//TSI/VEE#5	6.5	0.7	8.0
6443	SRN/*Ae. tauschii* (358)//MILAN/SHA7	5.3	1.5	30.0
6444	GONDO	5.3	0.5	70.0
6445	PBW343/WBLL1//PANDION	4.0	1.3	4.0
6446	SKAUZ/BAV92//CHUM18/7*BCN	4.8	3.4	35.0
6447	CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92	5.1	5.5	20.0

fected areas. A review of three decades of work on spot blotch in wheat has been prepared and accepted for publication in *Journal of Phytopathology* (in press). The review summarizes the global knowledge on genetic improvement and crop-management strategies to minimize yield losses based on latest field research. Recent studies have shown that spot blotch severity is highly influenced by stress factors affecting crop physiology, which in turn affects host tolerance and resistance to the pathogen. Soil nutrient and water stress aggravate spot blotch-induced grain yield losses. Heat stress, which is gradually increasing in Asia, causes higher levels of disease damage. Genetic improvement is the cornerstone of a sustainable control of spot blotch in all affected regions. Resistance is essentially based on Chinese and South American sources and interspecific crosses with broadly adapted semidwarf germ plasm. A list of genotypes consistently reported in the last 10 years to have at least partial resistance to spot blotch, along with their inheritance of resistance, has been compiled to help breeding programs. Because the fungus is aggressive under conditions of high relative humidity and heat, which in turn influences plant susceptibility, a synthesis of the different tools for scoring disease severity is given. Because resistance is incomplete, the ultimate goal is the accumulation of minor genes for resistance in adapted, high-yielding genotypes. The use of resistant cultivars, timely seeding, adequate fertilization, crop rotation, and the judicious use of fungicides can be part of an integrated pest-management strategy for controlling yield losses due to spot blotch.

If the base of genetic resistance has to be expanded including through the use of new interspecific crosses or synthetic derivatives, field screening against spot blotch in Mexico should not be overlooked. This was confirmed again in Agua Fria, Mexico, in March 2008 at a CIMMYT maize station at the limit of Puebla and Veracruz where several hundreds advanced lines from the GREU program were tested. Typical spot blotch symptoms could be observed and scoring was conducted easily in second half of February. The Global Wheat Program resumed activities in Agua Fria in December, 2008, for future activities supporting the CSISA project in South Asia. The wheat pathology laboratory produced about 150-kg sorghum grain based inoculum that has been incubated for approximately six weeks at room temperature after been inoculated with three local *C. sativus* strains.

Screening for tan spot resistance in El Batan and Oaxaca, Mexico. Tan spot is considered to be the most important foliar wheat disease associated with zero tillage, because the fungus can over-winter on stubble. Screening for resistance in the field is cumbersome and difficult; the production of inoculum in sufficient quantity is complicated and slow because conidia are important for the disease development but are only induced under specific light requirements. Tan spot development is relatively slow in El Batan and symptoms are difficult to assess, because plants are submitted to earlier attacks by other foliar pathogens such as rusts. In Mexico, at least two races (1 and 2, based on host specific toxins) are known to exist. In 2008, systematic field screening in pathology plots continued at El Batan using race 1, the most commonly found race globally. A range of approximately 120 wheat entries known to show differences in resistance were field-tested from June to late September.

The inoculum-production protocol was revised and the rate of conidia production in the laboratory was improved. We confirmed the difficulty of establishing tan spot epidemics at El Batan. With the arrival of Dr. P. Singh, more effort has been done on seedling screening in the greenhouse. With support from SIDA/Sweden, we also have increased efforts towards setting up a high-throughput system for screening under hydroponics. This system still needs some adjustment but should help us select resistant materials based on seedling evaluations such as those done in Queensland, Australia. In collaboration with INIFAP, screening for resistance under natural epidemics continued for a second year in Yanhuitlan (Oaxaca) a location where CIMMYT used to screen efficiently for tan spot resistance until 1997. The performance of promising entries in El Batan and Oaxaca in 2008 is given in Table 12 (p. 125).

Leaf samples affected by tan spot were positively identified in the Oaxaca area, Tlaxcala, Guanajuato, and the State of Mexico in 2008 expanding our isolates collection and allowing us to refine our study of the race structure in the country. These strains will be characterized in early 2009 under a project sponsored by the Swedish Government. The objective is to make screening for tan spot resistance in wheat more effective in CIMMYT's global wheat-breeding program.

Table 12. Field results (double-digit score) of some of the most promising genotypes under tan spot epidemics at El Batan and Oaxaca (Mixteca), Mexico, in 2008.

CID	SID	Cross name	Oaxaca 2008				El Batan 2008			
			Rep 1		Rep 2		Rep 1		Rep 2	
			D1	D2	D1	D2	D1	D2	D1	D2
7572	0	MILAN Resistant Check	0	0	2	1	4	2	3	2
463293	51	AC8528/FRET2	1	1	0	0	4	2	4	2
20026	580	MILAN/SHA7	0	0	0	0	4	2	5	2
73478	615	SHA3/SERI//G.C.W 1/SERI	0	0	0	0	4	2	5	2
213007	798	ALD/COC//URES/3/MILAN/SHA7	0	0	0	0	5	2	4	2
13594	182	MILAN/AMSEL	1	1	0	0	4	2	6	2
213008	761	ALD/COC//URES/3/FCN	2	1	1	1	4	2	5	2
213007	788	ALD/COC//URES/3/MILAN/SHA7	1	1	0	0	5	2	5	2
213024	781	MILAN/SHA7/3/ALD/COC//URES	0	0	1	1	3	2	5	3
5230	0	TOROPI	3	2	2	1	4	2	4	2
303317	131	EMB16/CBRD	0	0	1	1	6	2	6	2
66483	1	M3	0	0	0	0	5	2	5	3
213024	783	MILAN/SHA7/3/ALD/COC//URES	0	0	0	0	5	2	5	3
213008	760	ALD/COC//URES/3/FCN	1	1	1	1	7	2	5	2
373305	625	EMB16/CBRD//CBRD	2	1	4	2	4	2	5	2
287012	0	INIA BOYERO	3	2	2	1	6	2	4	2
21597	4193	CATBIRD	0	0	1	1	5	3	7	2
21035	0	SABUF	0	0	0	0	5	3	5	3
481810	110	PFAU/MILAN/4/VEE/TRAP#1//ANGRA/3/PASTOR	0	0	0	0	6	3	6	2
213023	761	GUAM92/FCN	1	1	0	0	3	2	8	3
435388	110	MILAN/10/ZIY98*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	1	1	1	1	4	2	7	3
8050	89	ITAPUA 40-OBLIGADO	2	1	2	2	3	2	7	3
424190	1	KLEIN DON ENRIQUE	1	1	4	2	5	2	5	3
213006	809	ALD/COC//URES/3/GUAM92	1	1	2	2	5	3	7	2
440369	186	MAYOOR//TK SN1081/*Ae. tauschii* (222)/3/CBRD	1	1	1	1	6	2	7	3
7919	1625	TINAMOU	3	1	3	2	6	2	7	2
435183	89	FOW/JA903//PASTOR	1	1	2	1	8	2	8	2
450351	72	ZIY98*2/PBW65//BERKUT	1	1	0	0	5	3	7	3
67414	56	IRENA/KAUZ	1	1	0	0	6	2	8	3
425914	83	SLVS//ZIY98*2/M10 (MUTATED C-306)	1	1	0	0	7	3	5	3
469796	1	INIA CHURRINCHE	2	1	4	2	7	2	7	2
7027	5	CIANO T79 Susceptible Check	6	2	6	2	8	4	8	4

CIMMYT bread wheat for semiarid Mexico.

Yann Manès.

Performance of material coming from physiological crossing. Of the 205 candidates to the 27th Semi-arid Wheat Screening Nursery (SAWSN) evaluated in northwest Mexico, 48 (23%) came from crosses made by the physiology group combining complementary, drought-adaptive physiological traits (PT). When this group was compared with those based on conventional crossing, they showed similar yields in irrigated environments but outperformed significantly the conventional group in the drought trials each year for three consecutive years (Table 13). Based on these results, PT lines constitute 25% of the genotypes of the 27th SAWSN and 32% of the 17th SAWYT, which will be evaluated by many national wheat programs in developing countries.

Table 13. Evaluation of crosses made by combining complementary, drouth-adaptive physiologica traits (PT) and conventional crosses for three consecutive years (2006–08) in the 27th Semi-arid Wheat Screening Nursery (SAWSN) evaluated in northwest Mexico.

Candidates to 27th SAWSN	Number of lines	Full irrigation Obregon 2008 Group ave % Tacupeto	Drought Obregon 2008 Group ave % Vorobey	Drought Obregon 2007 Group ave % Vorobey	Drought Obregon 2006 Group ave % Tacupeto
Conventional crosses	157	95.1	90.4	95.5	103.1
PT crosses	48	94	92.8	97.9	107.7
LSD 5%		Not significant	2.4	2.4	4.6

The physiological data generated by Matthew Reynolds' group in drought trials on these 48 lines and their parents, planted in the same evaluation trials, has confirmed that some lines have cumulated most of the good physiological attributes of their parents, which was seen in elite x elite crosses and in crosses involving Mexican landraces.

This data is very encouraging for the use of physiological information on designing crosses. The CIMMYT rainfed-wheat breeding program now applies systematically this approach. The Physiology Wheat Group evaluates in detail part of the rainfed crossing block, mainly new elite lines sent to semiarid international nurseries, and returns to us the most outstanding lines, indicating for each the main physiological attributes. We then use crosses combining the physiological information with yield, disease resistance, and end-user quality. Of crucial importance to maximize the chances of success is the way breeding populations are managed during the selection. The traits for stress involved in the model that underlies the physiological crossing are likely to be controlled quantitatively by many genes. Large breeding populations are necessary to maintain enough variability during the mass-selection phase and reach the yield-testing stage with enough lines to have a good probability of identifing the few that will have accumulated many, positive yield alleles. This new strategy of wheat breeding involves fewer crosses written from more parental information and larger populations generated. Without talking of converting an entire wheat -breeding program, one could envision allocating a significant part of this resource to a few crosses and, for the rest of the program, keep selecting from a large number of crosses that always will remain necessary to explore the germ plasm.

Evolution of a semiarid, bread wheat breeding scheme. The last year of three years of yield testing, PYT, YT, and candidates was 2007–08. PYT and YT have been selected similarly with one yield plot under full irrigation and replicated yield trials under drought and selected lines as candidates to the 28th SAWSN. Next year and onward, we will have two years of yield testing, 1 = PYT, second = candidate. This will save one year in the breeding scheme.

We also are working at reducing the timeframe of the early generation phase. Formerly at CIMMYT, selected bulks were running until the F_6, then $F_{6:7}$ head-rows were derived, and selected to Advanced Lines (ALs) or PYT from Obregon and Toluca. One if the first changes made in 2007 was to debulk all F_5s and F_6s from Toluca to give $F_{5:6}$ and $F_{6:7}$ head-rows in Obregon. In 2007, we also debulked the best looking F_4 crosses. We had in total 18,618 F_5, F_6, and F_7 head-rows in Obregon from which we selected 3,716 ALs (selection rate 20%) from which we selected 2,147 PYTs. This process allows all lines promoted to PYT to be selected for good agronomic type and leaf and stem rust resistance in Obregon and for good agronomic type, and leaf and stripe rust and *S. tritici* resistance in Toluca and El Batan. Given

that most $F_{4:5}$ rows selected in Obregon in 2008 showed good uniformity, we pursued the process, and this year debulked all F_4s and F_5s to head-rows in Obregon.

Table 14 shows the evolution of the breeding scheme. We have saved one and a half years in the breeding scheme, reducing the whole cycle from 7 to 5.5 years. This process reduces the bulk phase. The advantages of the selected bulk scheme are clear in term of simplicity and cost-saving, however it also brings some risks:

1. drifting towards tallness because of loss of height reference when selecting plants within the bulks (unless planting specific checks) and
2. drifting towards lateness, when strong selection for disease resistance is made, unless special attention is given to grain filling and earliness (which we try to do).

Table 14. Evolution of the new CIMMYT, Mexico, breeding scheme (Ob = Obregon, To = Toluca, and Ba = El Batan nursery sites; YT = yield trial, AL - advanced line).

Year	Station	Old scheme	New scheme	Station	Old scheme	New scheme
1	Obregon	Crossing	Crossing	Toluca	Crossing	Crossing
1	Toluca	F_1	F_1	Obregon	F_1	F_1
2	Obregon	F_2	F_2	Toluca	F_2	F_2
2	Toluca	F_3	F_3	Obregon	F_3	F_3
3	Obregon	F_4	F_4	Toluca	F_4	F_4
3	Toluca	F_5	F_5	Obregon	F_5	Head-rows
4	Obregon	F_6	Head-rows	Toluca/El Batan	F_6	ALs head-rows
4	Toluca/El Batan	ALs	ALs head-rows	Obregon	Head-rows	PYT
5	Obregon	PYT	PYT	Toluca/El Batan	ALs	
5	Toluca/El Batan			Obregon	PYT	YTC
6	Obregon	YT	YTC	Toluca/El Batan		
6	Toluca/El Batan			Obregon	YT	
7	Obregon	YTC		Toluca/Ba		
7	Toluca			Obregon	YTC	

The breeder cannot select all the plants himself in the bulks. He needs, however, to check all crosses before individual plant selection starts and decide to either discard crosses when no good plants can be found or make sure many plants are selected in the good crosses, to maintain good genetic variability, especially for quantitative traits such as yield and quality, and give enough options to the breeder for head-row selection. If this work is not done, the risk is that all crosses will be treated in the same way, giving too much importance to bad or mediocre crosses and not enough emphasis on the best ones.

Another innovation of the scheme is a pedigree step at the AL phase. From the head-rows selected in Obregon, we derive a family of four head-rows planted in El Batan. Bulks from head-rows are sown and selected in Toluca. The head-rows of the best families selected in Toluca are selected in El Batan, giving one more generation to select for uniformity and exploiting additional genetic variation in the good-looking families. With this two-step process of head-row selection, we may pursue the reduction of the selected bulk phase, debulking also from the F_3 next year the best looking F_3 populations or back-crosses (equivalent to F_4), further reducing the breeding cycle by six months.

ME6 (high-latitude) crossing and breeding strategy. Until 2007, crossing for the ME6 was split equally between crossing for North Kazakhstan and western Siberia (KASIB) and crossing for the other ME6 regions, e.g., China's Heilonjiang province and Canada. The wheat-growing area in Heilonjiang is quite a small, less than a 10^6 ha, in comparison to the KASIB area, about twenty millions. Canadian wheat breeders have very stringent market quality requirements, therefore the CIMMYT ME6 breeding material would have very little chance of development in Canada. For these two reasons, we have stopped ME6 crossing for other regions than KASIB and doubled the breeding effort for KASIB. We now make about 100 back or top-crosses per cycle, about 200 crosses per year for North Kazakhstan and Siberia. The High Latitude Wheat Screening Nursery will be discontinued.

Like the ME4, a large part of the ME6 crosses is dedicated to resistance to Ug99. However, as opposed to ME4, ME6 Ug99 breeding focuses more on the use of major genes because of the risk of Ug99 spreading in KASIB seems lower than in South Asia, so major genes could bring an acceptable solution at the moment, and because most KASIB cultivars are highly susceptible to stem rust, and breeding with APR would be very difficult in Kenya with photoperiod-sensitive, ME6 material.

KASIB yield data analysis presented at the KASIB meeting held in Pavlodar in August ,2008, showed that there is little 'G x E' in the region, making it possible to find high-yielding lines/cultivars with broad adaptation. These lines will have priority use for crossing. The correlation analysis showed that some sites predict better global performance than others, in particular Omsk in Siberia and Karabalyk in North Kazakhstan. Until 2008, material selected in Mexico was sent only to Shortandy. From 2009, it will be sent to Omsk and to Karabalyk as well. Shuttle materials will be selected from the data and observations collected at these two sites, and then sent to all breeders of the KASIB network.

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Reaction of durum wheats to black point in southern Sonora, Mexico.

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Introduction. More than 100 species of fungi, including *Alternaria*, *Fusarium*, and *Helminthosporium* spp., can be isolated from newly harvested wheat grain. These fungi are most important in humid field environments, where they infect seed when relative humidity exceeds 90% and seed moisture content exceeds 20%. Rainfall during seed maturation favors black point (BP), as well as humid weather prevailing for a few days prior to harvest (Prescott et al. 1986). Expanding green kernels are most susceptible. Premature seed senescence also promotes BP because many of the fungi are saprophytic (Wiese 1987). *Alternaria alternata* and *Bipolaris sorokiniana* are generally considered the primary causal agents of the disease (Mathur and Cunfer 1993). Infected ears may look normal, but there may be elliptical, brown to dark brown lesions on the inner side of the glumes. The disease is more pronounced as brown to dark brown or blackish, localized discolored areas, usually around the embryo end of seeds (Adlakha and Joshi 1974; Hanson and Christensen 1953; Rana and Gupta 1982; cited by Mathur and Cunfer 1993). The discoloration also may occur near the brush, in the crease or any part of the seed and may be light or dark or with a distinct margin. Severe infection causes discoloration and shriveling of the whole seed (Adlakha and Joshi 1974). In southern Sonora, Mexico, black point is an endemic disease of durum and bread wheat, although incidence is variable from year to year. Wheat-breeding programs select for disease resistance during seed evaluation after harvest, however, there is not a formal project on BP in Sonora. The objectives of this work were to evaluate the reaction of durum wheat elite advanced lines, pre- and candidate lines for commercial release, and commercial cultivars to BP after harvest in year 2008.

Materials and methods. The materials evaluated consisted of various nurseries. The evaluation was by visual inspection taking in to consideration the relative amount of affected grains in the sample, but without considering the area or the percentage of affected area. The rating scale was as follows: 0 = healthy grains, 1 = low incidence of black point, 2 = moderate, and 3 = high incidence. The following nurseries were evaluated: a) Advanced Yield Trial consisting of 171 entries planted on 15 November, 2007, in block 810, in a clay soil with pH 7.5; 100 g per entry were analyzed; b) pre-candidate lines for commercial release consisting of 62 entries, planted on 27 December, 2007, in block 910, in a heavy sandy clay loam soil, pH 7.5; grains from five spikes were evaluated; c1) commercial cultivars, four groups with five replications (four spikes each) of Altar C84 and Júpare C2001 planted on 22 November, 2007, in block 710, in a clay soil with pH 7.8; c2) commercial cultivars Altar C84, Nacori C97, Rafi C97, Atil C2000, Júpare C2001, Samayoa C2004, and Banamichi C2004, planted on 15 November, 2007, in block 810, 100 g were evaluated; c3) commercial cultivars Júpare