

## ITEMS FROM MEXICO

# **CIMMYT — INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER** **Molecular Wheat Breeding, El Batan, Mexico.**

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## ***Marker-assisted selection in the CIMMYT wheat breeding programs.***

**Marker-assisted selection (MAS) summary 2010.** The number of data points produced to assist phenotypic selection with molecular markers in the CIMMYT wheat breeding programs remained constant in 2010 compared to previous years. During the selection cycles in Cd. Obregon and Toluca, about 28,000 and 18,000 DNA extractions, along with 49,700 and 39,000 marker data points, respectively, were provided. Thus, a total of about 46,000 DNA extractions and 88,700 marker data points were performed in the laboratories in El Batan and Cd. Obregon in 2010. Molecular markers were applied across all breeding programs. In the programs targeted to rain-fed and irrigated environments and the durum wheat and wide crosses program, parental lines to be used for crosses were initially characterized. Markers were subsequently used for allele enrichment in the top cross and F<sub>2</sub> generations in the program targeted to rain-fed environments and durum wheat program during selection. Marker or gene presence was confirmed in the F<sub>3</sub> to F<sub>7</sub> and advanced backcross generations. In the winter wheat program, the 18th FAWWON and various selected sets of germ plasm, e.g., a historical set of winter wheat cultivars, were screened with a subset of markers.

The markers applied in the wheat programs during 2010 are listed in Table 1. Markers linked to rust resistance genes were most frequently used in bread and durum wheat. The amplification of the markers commonly revealed the

**Table 1.** Markers applied for marker-assisted selection in the bread and durum wheat programs in 2010 at CIMMYT–Mexico.

Gene	Reference	Data points	Gene	Reference	Data points
Bread wheat			Durum wheat		
T1A·1R/T1B·1R	Weng et al. 2007	12,050	<i>Lr19/Sr25</i>	Zhang et al. 2008	9,059
<i>Lr19/Sr25</i>	William, personal communication	8,318	<i>Lr14a</i>	Herrera-Foessil et al. 2008	7,009
<i>Sr26</i>	Liu et al. 2010	3,964	<i>Lr47</i>	Dubcovsky et al. 1998	5,249
<i>Rht1, Rht2</i>	Ellis et al. 2002	3,720	<i>Sr22</i>	Khan et al. 2005	2,905
<i>Cre1</i>	Ogbonnaya et al. 2001	3,547	<i>Cre1</i>	Ogbonnaya et al. 2001	1,239
<i>Sr2</i>	Anderson et al. 2001, Spielmayr et al. 2010	3,179	<i>GPC-B1</i>	Distelfeld et al. 2006	974
<i>Vrn-A1</i>	Yan et al. 2004	1,772	<i>Vrn-A1, Vrn-B1</i>	Fu et al. 2005, Yan et al. 2004	704
<i>Ppd-D1</i>	Beales et al. 2007	1,472	<i>VPM</i>	Helguera et al 2003	700
<i>Vrn-B1, Vrn-D1</i>	Fu et al. 2005, Yan et al. 2004	1,472	<i>Fhb1</i>	Liu et al. 2008	500
<i>Lr34</i>	Lagudah et al. 2009	1,472	<i>Ppd-A1</i>	Bentley et al. 2010	176
<i>Sr24</i>	Mago et al. 2005	1,297	<i>Bo1</i>	Schnurbusch et al. 2007	171
<i>VPM</i>	Helguera et al. 2003	1,297	<i>Lr53</i>	Wellings, personal communication	172
<i>Cre3</i>	Martin et al. 2004	1,032	<i>Rln1</i>	Mather, personal communication	81
<i>Sr36</i>	Tsilo et al. 2007	1,032			
<i>Sr22</i>	Khan et al. 2005	1,032			
<i>Ppd-A1</i>	Bentley et al. 2010	265			
<i>SrCad</i>	Hiebert et al. 2010	89			

expected results, with some exceptions. Similar to previous years, the marker for *Cre1* showed segregation distortion in various populations. Less individuals than expected were observed containing the tolerance allele for *Cre1*. The comparison of marker data for *Cre1* and phenotypic screening in Turkey furthermore indicated that *Cre1* might not be effective in some Middle East and South Asian countries, which has to be confirmed in subsequent screenings in 2011. When characterizing parental materials, we noticed that the marker for VPM amplified in various synthetic derivatives, which are not expected to have the *Ae. ventricosa* fragment.

**New markers – optimization and validation.** New markers tested were linked to the genes *Ppd-A1*, *SrCad*, *Sr26*, *Sr2*, *Lr47* (co-dominant marker), and *H25*. For the first time, the marker diagnostic for *Ppd-A1* in durum wheat was tested in germ plasm targeted to rain-fed environments. The *Ppd-A1* allele G105 from durum wheat was confirmed to be present in the CIMMYT germ plasm, introduced via a synthetic hexaploid wheat and its derivatives. The stem rust resistance gene *SrCad* was confirmed in the Canadian sources AC Cadillac, AC Taber, and AC Vista. The gene was not present in a set of CIMMYT germ plasm tested to date. The new CAPS marker for *Sr2* (Spielmayr et al. 2010) was evaluated in the 1st Stem Rust Screening Nursery and germ plasm targeted to irrigated environments. The marker confirmed the presence of the gene in CIMMYT lines, however with exceptions. Examples are the cultivar Siete Cerros, released in 1966, and the Pastor, which were expected to carry *Sr2* but lacked the characteristic SNP detected in Hope. The cultivar Thatcher is not known to carry *Sr2* but amplified the corresponding allele with the CAPS marker. Thus, the marker does coincide with the presumed *Sr2* genotype in various, but not all, cases.

The marker linked to *H25* was used to validate the source of the gene and a set of parents that will be used for crosses in durum wheat. The only marker that could not be successfully optimized is the co-dominant marker for *Lr47*. Amplification was not able to clearly distinguish between lines carrying the genes and heterozygotes. Markers successfully tested will be further validated and subsequently used in the wheat breeding programs.

### SNP development.

Gene polymorphisms based on SNP or indels (insertion/deletions) have been converted to 'KASPar' SNP assays, a platform provided by the company KBioscience (<http://www.kbioscience.co.uk>) in order to move the marker technology at the Batan laboratories from slab gels to a higher throughput platform. SNP assays designed and validated on a larger set of CIMMYT germ plasm are given (Table 2). Primers required for the SNP assay were designed on the basis of available sequence information of the respective genes. Validation was performed with a set of lines known to carry or not carry the genes. SNP assays are to be used for MAS via outsourcing up to 5,000 samples to KBioscience. Outsourcing is expected to increase in 2011.

During the validation of the SNP assays in Batan, a number of advantages of the SNP assays in comparison of the previously used markers were observed. The SNP assays provided marker data three times faster and, based on initial cost analyses, at least two times more cost efficient and under the current conditions of the Batan laboratories. The amplification of the SNPs was simpler and more robust. A unique PCR program was used across all assays, and amplification was more stable with less missing data or weak amplifications. The assays required similar to SSR or STS markers, only standard DNA quality and reactions permitted varying DNA quantity across samples so that no DNA adjustments were required. The design of SNP assays for an additional set of genes was initiated during 2010 (Table 3) and will be validated in 2011.

The design of some SNP assays failed (VPM, PinA, PinB), mainly due to the amplification of primers in one of the nontargeted homologous genomes. The assay development will be repeated for those genes.

**Table 2.** Validated SNP markers with a set of lines known to carry or not carry the gene of interest.

Gene	SNP ID
<i>Lr34</i>	Lr34_TCCIND
<i>Glu-D1</i>	Glu-D1d_SNP
<i>GPC-B1</i>	GPC-B1_DUP
<i>Cre8</i>	Cre8_SNP
<i>Rht-B1</i>	Susan_RhtB1_SNP
<i>Rht-D1</i>	Susan_RhtD1_SNP
<i>Rln1</i> (DW)	Rlnn1_SNP/1

**Table 3.** SNP markers under development and validation at CIMMYT-Mexico.

Gene	SNP ID
<i>Fhb1</i>	Fhb1_UMN10_IND
<i>VPM</i>	VPM_SNP
<i>Rln1</i>	Rlnn1_SNP2
<i>Rln1</i>	Rlnn1_SNP3
<i>Glu-A1</i>	Glu-Ax1/x2*_SNP
<i>Glu-A1</i>	Glu-Ax2*_IND
<i>Glu-B1</i>	Glu-Bx17_IND
<i>Glu-B1</i>	Glu-By8_SNP
<i>Glu-B1</i>	Glu-By9_IND
<i>Glu-A3a</i> to <i>Glu-A3g</i>	Glu-A3a to GluA3g_SNP
<i>Glu-B3a</i> to <i>Glu-B3i</i>	Glu-B3a to GluB3i_SNP
<i>Sr36</i>	STM773-2_IND
<i>Lr19/Sr25</i>	WMC221_IND

## General Wheat Pathology, El Batan, Mexico.

Etienne Duveiller, Pawan K. Singh, and Norbert Schlang.

**Greenhouse evaluation of germ plasm for reaction to tan spot and *Stagonospora nodorum* blotch.**

**Wide-crosses material.** Successful evaluation of 86 entries (including four checks) for tan spot was possible and 38 entries were resistant and 48 were susceptible. For *Stagonospora nodorum* blotch, 84 entries (including four checks) were evaluated of which 25 were resistant and 59 were observed to be susceptible. There were nine entries giving resistant reactions to both diseases (Table 4, continued on p. 47).

<b>Table 4.</b> Disease reaction of the most promising breeding lines of the Wide-Crosses and Durum Programs to tan spot (TS) and <i>Stagonospora nodorum</i> blotch (SNB) under greenhouse tests.			
<b>GID</b>	<b>Cross/name</b>	<b>TS</b>	<b>SNB</b>
<b>Resistant Wide-Crosses Lines</b>			
6002836	GAN/ <i>Ae. tauschii</i> (408)//2*BERKUT	1.83	1.83
6123554	GAN/ <i>Ae. tauschii</i> (897)//OPATA/3/BERKUT	1.92	1.69
6123557	GAN/ <i>Ae. tauschii</i> (897)//OPATA/3/BERKUT	1.92	1.96
6123505	YAV_3/SCO//JO69/CRA/3/YAV79/4/ <i>Ae. tauschii</i> (498)/5/OPATA/6/PASTOR	1.71	1.99
6123562	GAN/ <i>Ae. tauschii</i> (897)//Opata/3/BERKUT	1.25	1.50
6123563	GAN/ <i>Ae. tauschii</i> (897)//Opata/3/BERKUT	1.38	1.50
6123569	YAV_3/SCO//JO69/CRA/3/YAV79/4/ <i>Ae. tauschii</i> (498)/5/2*OPATA	1.75	1.37
5929330	GAN/ <i>Ae. tauschii</i> (236)//CETA/ <i>Ae. tauschii</i> (895)/3/MAIZ/4/2*INQALAB 91	1.25	1.50
5929356	GAN/ <i>Ae. tauschii</i> (236)//CETA/ <i>Ae. tauschii</i> (895)/3/MAIZ/4/2*INQALAB 91	1.50	1.34
<b>Resistant Durum Lines</b>			
3829630	Svevo	1.85	1.53
5081890	Meridiano	1.72	1.33
5532383	SOOTY_9/RASCON_37//LLARETA INIA	1.72	1.57
5081011	1A.1D 5+10-6/3*MOJO//RCOL/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1	1.68	1.40
5545239	GUAYACAN INIA/POMA_2//SNITAN/4/D86135/ACO89//PORRON_4/3/SNITAN	1.77	1.71
5546969	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	1.97	1.90
5541716	SILK_3/DIPPER_6/3/ACO89/DUKEM_4/5*ACO89/4/PLATA_7/ILBOR_1//SOMAT_3	1.88	1.79
5828212	BCRIS/BICUM//LLARETA INIA/3/DUKEM_12/2*RASCON_21/4/1A.1D 5+10-6/2*WB881//1A.1D 5+10-6/3*MOJO/3/BISU_1/PATKA_3	1.83	1.94
5828385	NUS/SULA//5*NUS/4/SULA/RBCE_2/3/HUI//CIT71/CH*2/5/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1	1.88	1.83
5828419	PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBAD/5/AVO/HUI/7/PLATA_13/8/ RAFI97/9/MALMUK_1/SERRATOR_1/10/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/11/SHAG_21/DIPPER_2//PATA_2/6/ARAM_7//CREX/ALLA/5/ENTE/ MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69	1.75	1.50
5827254	LLARETA INIA/4/SKEST//HUI/TUB/3/SILVER/5/LHNKE/RASCON//CONA-D/6/ GREEN_32/CHEN_7//SILVER_14/3/DIPPER_2/BUSHEN_3/4/SNITAN	1.42	1.67
5828254	STOT//ALTAR84/ALD/3/THB/CEP7780//2*MUSK_4/6/ECO/CMH76A.722//BIT/3/ ALTAR84/4/AJAIA_2/5/KJOVE_1/7/RASCON_37/2*TARRO_2/4/ROK/FGO//STIL/3/ BISU_1/5/MALMUK_1/SERRATOR_1	1.93	1.63
5828341	ALBIA_1/ALTAR84//YAZI_1/4/CREX//BOY/YAV_1/3/PLATA_6/5/SOMAT_4/IN- TER_8/6/LIRO_2/CANELO_9	1.52	1.53
5828439	ALTAR84/BINTEPE85/3/STOT//ALTAR84/ALD/4/POD_11/YAZI_1/5/ VANRRIKSE_12/SNITAN/6/SOOTY_9/RASCON_37//WODUCK/CHAM_3	1.83	1.92

**Table 4.** Disease reaction of the most promising breeding lines of the Wide-Crosses and Durum Programs to tan spot (TS) and *Stagonospora nodorum* blotch (SNB) under greenhouse tests.

GID	Cross/name	TS	SNB
6004713	SOMAT_4/INTER_8/4/GODRIN/GUTROS//DUKEM/3/THKNEE_11/5/1A.1D5+10-6/2*WB881//1A.1D 5+10-6/3*MOJO/3/BISU_1/PATKA_3/4/GODRIN/GUTROS//DUKEM/3/THKNEE_11	1.75	1.72
6004721	ODIN_15/WITNEK_1//ISLON_1/5/TARRO_1/TISOMA_2//TARRO_1/3/COMB-DUCK_2//ALAS//4*COMB DUCK_2/4/SHAG_9/BUTO_17/6/VANRRRIKSE_6.2//1A-1D 2+12-5/3*WB881/5/TARRO_1/TISOMA_2//TARRO_1/3/COMBDUCK_2//ALAS//4*COMBDUCK_2/4/SHAG_9/BUTO_17	1.44	1.64
6005034	SWAHEN_2/KIRKI_8//PROZANA_1/4/ADAMAR_15//ALBIA_1/ALTAR 84/3/SNITAN/11/GUAYACANINIA/GUANAY/10/LD357E/2*TC60//JO69/3/FGO/4/GTA/5/SRN_1/6/TOTUS/7/ENTE/MEXI_2//HUI/4/YAV1/3/LD357E/2*TC60//JO69/8/SOM-BRA20/9/JUPAREC 2001	1.62	1.73
6004804	MOHAWK/5/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/3/SOMAT_3/4/SOOTY_9/RASCON_37	1.90	1.50
5549135	SNITAN/5/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/3/SOMAT_3/4/SOOTY_9/RASCON_37/6/SNITAN	1.42	1.99
5550695	TOPDY_18/FOCHA_1//ALTAR84/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/4/SOMAT_3/GREEN_22/5/VRKS_3/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13	1.76	1.90
6004507	USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV1/6/ARDENTE/7/HUI/YAV79/8/POD9/9/ADAMAR_15//ALBIA_1/ALTAR84/3/SNITAN/10/MINIMUS_6/PLATA_16//IMMER/3/SOOTY_9/RASCON_37	1.92	1.94
6004540	ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/4/TOSKA_26/RASCON_37//SNITAN/5/PLAYERO	1.42	1.85

**Durum material.** A total of 104 entries (including four checks) were screened for tan spot and 31 entries were resistant and 73 were susceptible. For *Stagonospora nodorum* blotch, a higher proportion of resistance was observed with 63 entries showing resistant reaction and 41 entries susceptible. A total of 22 entries had resistant reactions to both diseases (Table 4, continued on p. 46). Some of the parents of the mapping populations gave differential reaction, so genetic analysis of tan spot and *Stagonospora nodorum* blotch resistance in these populations will be attempted.

### *Evaluation of germ plasm for reaction to spot blotch.*

A total of 1,380 genotypes from the Bread Wheat Irrigated (EPCBWIR09-10, entries = 540), Bread Wheat Rainfed (C29SAWSN, entries = 382), Durum (D10PR-SETHLB, entries = 100), Nepal Program (HLB Resistance Stocks, entries = 100), and 1<sup>st</sup> CSISA Spot Blotch Trial (entries = 258) were evaluated for reaction to spot blotch under field conditions at Agua Fria. Additionally, inoculum was provided to the Wide Crosses Program to facilitate their efforts in developing spot blotch resistant germ plasm.

**Bread Wheat Irrigated Trial.** Spot blotch development in the nursery was good and consistent throughout the nursery. Twenty lines were early of which 19 entries were the checks Sonalika (18) and CIANO T 79 (1) and the breeding line 'Fret2\*2 / Kukuna\*2 / SNLG' (GID: 5993859) that had heading less than 63 days. Normal heading was found in 278 entries and 242 lines had late maturity. The AUDPC scores of this nursery ranged from 302.47 to 1,408.64 with a mean score of 632.38. Based on the selection criteria's from the EPCBWIR nursery, 190 breeding lines have been selected to be evaluated in 2011 in replicated trials. The ten most promising lines are given in the Table 5 (p. 48-49).

**Bread Wheat Rainfed Trial.** The check Sonalika (seven entries) was only early maturing and had heading less than 63 days. Normal heading was found in 280 entries and 95 lines had late maturity. The AUDPC scores of this nursery ranged from 388.89 to 1,330.86 with a mean score of 623.13. Based on the selection criteria's from the C29SAWSN nursery, 105 breeding lines have been selected to be evaluated in 2011 in replicated trials. The ten most promising lines from this nursery are given in the Table 5 (pp. 48-49).

**Table 5.** Disease reaction of the ten most promising breeding lines of different nurseries evaluated for spot blotch resistance at Agua Frias, Mexico, in 2010.

GID	Cross/name	AUPDC score
<b>Resistant Bread Wheat Irrigated (EPCBWIR09-10) lines.</b>		
5996123	SHA7/VEE#5//ARIV92/3/PBW343*2/KUKUNA	302.47
5996302	YUNMAI 48/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ	362.96
5849285	TILHI/SOKOLL	371.60
5996303	YUNMAI 48/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ	388.89
5994383	PBW343*2/KHVAKI//PARUS/3/PBW343/PASTOR	388.89
5996554	PBW343/PASTOR/4/YAR/ <i>Ae. tauschii</i> (783)//MILAN/3/BAV92/5/PBW343*2/KUKUNA	406.17
5995752	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/CROC1/ <i>Ae. tauschii</i> (205)//KAUZ/3/2*KAUZ*2/YACO//KAUZ	406.17
5996837	FRET2/KUKUNA//FRET2/3/YANAC/4/FRET2/KIRITATI	406.17
5996681	NSM*4/14-2/5/2*FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	414.81
5996430	ALTAR84/AE.SQ//OPATA/3/2*WH542/7/VEE#8//JUP/BJY/3/F3.71/TRM/4/BCN/5/KAUZ/6/MILAN/KAUZ/8/ATILIA*2/PBW65	414.81
<b>Resistant Bread Wheat Rainfed (C29SAWSN) lines.</b>		
6000943	SW89-5124*2/FASAN//2*UP262	388.89
6001233	BAV92/SERI	388.89
6001232	BAV92/SERI	401.85
5999827	VORB/4/CROC_1/ <i>Ae. tauschii</i> (205)//BORL95/3/KENNEDY	406.17
5999832	VORB/4/CROC_1/ <i>Ae. tauschii</i> (205)//BORL95/3/KENNEDY	406.17
6000906	SOKOLL*2/TROST	406.17
6000909	SOKOLL*2/TROST	406.17
6001064	SOKOLL/TRCH	406.17
6001175	SOKOLL//FRTL/2*PIFED	406.17
5999831	VORB/4/CROC_1/ <i>Ae. tauschii</i> (205)//BORL95/3/KENNEDY	414.81
<b>Resistant durum (D10PR-SETHLB) lines.</b>		
5828254	STOT//ALTAR84/ALD/3/THB/CEP7780//2*MUSK_4/6/ECO/CMH76A.722//BIT/3/ALTAR84/4/AJAIA_2/5/KJOVE_1/7/RASCON_37/2*TARRO_2/4/ROK/FGO//STIL/3/BISU_1/5/MALMUK1/SERRATOR1	388.89
6005064	ALTAR84/CMH82A.1062//ALTAR84/3/DIPPER/RISSA//ALTAR84/AOS/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/5/MINIMUS/COMBDUCK_2//CHAM_3/3/RCOL/4/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN	425.62
5081011	1A.1D 5+10-6/3*MOJO//RCOL/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1	427.78
6004809	MOHAWK/4/DUKEM_1//PATKA_7/YAZI_1/3/PATKA_7/YAZI_1	427.78
5548129	CAMAYO/GUANAY/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1	432.10
5828350	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/JUPAREC2001/10/SOMAT_3/PHAX_1//TILO_1/LOTUS_4/11/SOOTY_9/RASCON_37//WODUCK/CHAM_3	432.10
6004804	MOHAWK/5/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/3/SOMAT_3/4/SOOTY_9/RASCON_37	432.10
6004488	RASCON_37/GREEN_2/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9	434.26
5512003	AG 1-23/2*ACONCHI//2*UC1113	434.26
5543994	TADIZ/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9	436.42
<b>Resistant 1<sup>st</sup> CSISA Spot Blotch Trial (CSISA) lines.</b>		
911521	CHIRYA.3	303.91
5793174	TILHI/4/CROC_1/ <i>Ae. tauschii</i> (213)//PGO/3/CMH81.38/2*KAUZ	309.67
5793393	CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/SASIA/4/TROST	337.04



**Table 5.** Disease reaction of the ten most promising breeding lines of different nurseries evaluated for spot blotch resistance at Agua Frias, Mexico, in 2010.

GID	Cross/name	AUPDC score
5792804	SERI.1B*2/3/KAUZ*2/BOW//KAUZ*2/4/KRONSTAD F2004	341.36
5793392	CROC_1/Ae. tauschii (205)//KAUZ/3/SASIA/4/TROST	345.68
5792823	PBW343*2/KUKUNA//KRONSTAD F2004/3/PBW343*2/KUKUNA	348.56
5792874	SERI.1B*2/3/KAUZ*2/BOW//KAUZ*2/5/CNO79//PF70354/MUS/3/PASTOR/4/BAV92	350.00
5793111	TILHI/PALMERIN F2004	352.88
5793110	TILHI/PALMERIN F2004	355.76
5793395	CROC_1/Ae. tauschii (205)//KAUZ/3/SASIA/4/TROST	360.08

**1<sup>st</sup> CSISA Spot Blotch Trial.** This nursery consisted of 258 entries replicated four times of which three were inoculated with pathogen and the fourth replicate was protected by multiple application of fungicide Opus (epoxiconazole). Spot blotch development in the nursery was good and consistent throughout the nursery. The check Sonalika (three entries) was only early maturing and had heading less than 63 days. Normal heading was noted in 86 entries and 169 lines had late maturity. The AUDPC scores of this nursery ranged from 204.53 to 1,271.81 with a mean score of 520.46. In this nursery, the resistant check Chirya had a mean score of 278.34 and the susceptible check Sonalika had the score of 1,231.00. There was negative correlation ( $-0.56$ ) between spot blotch AUPDC scores and days-to-heading. Based on the rigorous selection criteria from the CSISA nursery, 50 breeding lines have been selected to be sent across different location worldwide and evaluated in 2012. Presently, the selected lines are being increased at Mexicali to be forming the 2<sup>nd</sup> CSISA Spot Blotch Nursery. The most promising ten lines from this nursery are given in Table 5 (pp. 48-49).

### *Septoria tritici* blotch research.

**Field screening of germ plasm for resistance to *Septoria tritici* blotch.** A total of 243 genotypes from the Bread Wheat-Irrigated (BWIR: 115 entries) and the Bread Wheat Rainfed (BWR: 128 entries) Program were evaluated for reaction to *Septoria tritici* blotch at two locations, Toluca and Boximo. At each location there was a randomized block design with two replicates. The disease assessment utilized a double-digit scale and multiple evaluations were conducted, which were later used to develop AUPDC score.

The development of *Septoria tritici* blotch at both the locations was similar. For the BWIR nursery, the range of *Septoria tritici* blotch AUDPC scores (mean of all reps/location) was between 201.81 and 993.43 with a mean score of 397.97. From this nursery, 50 lines were selected based on AUDPC scores and pedigree information, which may be part of the ISEPTON nursery. The most promising genotypes identified from this nursery are listed in Table 6 (p. 50). For the BWR nursery, the range of *Septoria tritici* blotch AUDPC scores (mean of all reps/location) was between 168.52 and 358.64 with a mean score of 291.13. From this nursery, 40 lines were selected that may be part of the ISEPTON nursery. The most promising genotypes identified from this nursery are listed in Table 6 (p. 50).

**20<sup>th</sup> International Septoria Observation Nursery.** The 20<sup>th</sup> International Septoria Observation Nursery (20<sup>th</sup> ISEPTON) comprised of 53 entries of genetically diverse genotypes was distributed to Ethiopia, Iran, Mexico, Morocco, Syria, Tunisia, and Uruguay (20 sets). The genotypes were selected based on low *Septoria tritici* blotch scores and availability of seed.

**Greenhouse screening protocol for *Septoria tritici* blotch.** Two experiments were conducted to develop protocols for induction of *Septoria tritici* blotch under greenhouse conditions. Each experiment was conducted as a randomized block design with two replicates. Each replicate consisted of five genotypes with known reaction to *Septoria tritici* blotch (Table 7, p. 50). The experimental unit consisted of five plants/entry that were planted in big pots. The planting was done on 24 August.

Inoculation for the first experiment was on 8 October. Inoculum was made from isolate P8. Spore inoculum from isolate P8 was made by culturing the fungus on medium of agar, malt, and levadura (4 g extract of levadura, 4 g extract of malt, 4 g sacarosa, 15 g agar, and 1,000 mL distilled water). The prepared medium with isolate P8 was left for

**Table 6.** Disease reaction of the ten most promising breeding lines from Bread Wheat-Irrigated (BWIR) and the Bread Wheat Rainfed (BWR) Programs to *Septoria tritici* blotch under field tests at Boximo and Toluca, Mexico.

GID	Genotype	AUPDC score
<b>Resistant BWIR lines.</b>		
5849246	CHEN/ <i>Ae. tauschii</i> (TAUS)//BCN/3/BAV92/4/INQALAB 91*2/KUKUNA	201.81
5995732	WBLL1*2/VIVITSI/4/D67.2/P66.270// <i>Ae. tauschii</i> (320)/3/CUNNINGHAM	217.17
5996488	BABAX/LR43//BABAX/6/MOR/VEE#5//DUCULA/3/DUCULA/4/MILAN/5/BAU/MILAN/7/SKAUZ/BAV92	217.81
5995748	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/2*KAUZ*2/YACO//KAUZ	218.45
5996074	MILAN/PASTOR/3/C80.1/3*BATAVIA//2*WBLL1	224.93
5996189	THB/KEA//PF85487/3/DUCULA/4/WBLL1*2/TUKURU	244.88
5995992	CNDO/R143//ENTE/MEXI_2/3/ <i>Ae. tauschii</i> (TAUS)/4/WEAVER/5/2*KAUZ/6/TIMBA	245.46
5996796	UP2338/3/HE1/3*CNO79//2*SERI/4/RABE/2*MO88	257.58
5994285	PBW343*2/KUKUNA*2//YANAC	264.26
5996195	THB/KEA//PF85487/3/DUCULA/4/WBLL1*2/TUKURU	266.22
<b>Resistant BWR lines.</b>		
5999769	BABAX/LR42//BABAX/3/VORB	168.52
5999771	BABAX/LR42//BABAX/3/VORB	172.84
5999774	BABAX/LR42//BABAX/3/VORB	183.64
5999775	BABAX/LR42//BABAX/3/VORB	183.64
5999807	VORB/4/D67.2/P66.270// <i>Ae. tauschii</i> (320)/3/CUNNINGHAM	199.85
5999926	PROINTA SUPERIOR/4/RL6043/4*NAC//PASTOR/3/BAV92/5/KLEIN SAGITARIO	207.41
5999956	POTCH 92/2*ROLF07	209.57
5999957	POTCH 92/2*ROLF07	225.77
5999970	POTCH 93/4/MILAN/KAUZ//PRINIA/3/BAV92/5/MILAN/KAUZ//PRINIA/3/BAV92	231.17
5999972	ACHTAR*3//KANZ/KS85-8-5/4/MILAN/KAUZ//PRINIA/3/BAV92/5/MILAN/KAUZ//PRINIA/3/BAV92	235.49

3 days for incubation at room temperature (18–22°C). The spores were harvested and a spore suspension prepared at a concentration of  $10^7$  conidia/mL. The plants were spray inoculated until run-off. Inoculated plants were left in a mist-chamber for 48 hours with continuous misting. Subsequently, the humidifiers were turned off, plants were left to dry, and then the plants were put in GH8 at a temperature of 18°C min and 28°C max. In the second experiment inoculation was on 29 October with isolate ST2. The rest of the protocol was similar to that in the first experiment. Disease evaluation was based on percentage of *Septoria tritici* blotch infection.

Murga, a known source of resistance gave no disease symptoms in both the experiments, whereas the other lines with moderate to high susceptibility to *Septoria tritici* blotch gave disease symptoms as expected (Table 7). More disease was observed in first experiment than the second experiment, indicating that plant age may play role in disease development. Additionally, differences in the development of disease in the two experiments can be attributed to the two isolates used and the greenhouse temperature; temperatures were a bit lower in the second experiment. However, we were able to induce *Septoria tritici* blotch under greenhouse conditions for the first time at the Main Station. The challenge now lies in optimizing and further reducing the time taken in evaluating the disease in greenhouse conditions.

**Table 7.** Percent infection of *Septoria tritici* blotch on the five lines evaluated under greenhouse conditions at El Batán, Mexico, in 2010.

Line	First experiment		Second experiment	
	1 November	8 November	16 November	22 November
HPO/TAN/VEE/3/2*PGO/4/Milan/5/5Seri 1	20	50	10	40
SAAR//PBW343*2/Kukuna/3/PBW343*2/Kukuna	50	70	10	50
Kauz//Altar 84/Aus/3/Milan/Kauz/4/Avites	20	50	20	50
Catbird	40	50	10	40

***Fusarium head blight research.***

**High-throughput field screening operations at El Batan, Mexico.** A total of 1.8 ha was planted at El Batan, Mexico, in mid-May 2010 to screen wheat and barley material under artificial field inoculation for FHB. Plots were inoculated with the help of precision CO<sub>2</sub> backpack sprayers equipped with a flat fan nozzle for liquid inoculum (50,000 conidia/mL) at a pressure of 40 psi and a rate of 39 mL of inoculum/m. The inoculum was of a mixture of five different *F. graminearum* isolates collected during the preceding year in naturally infected fields. Ten spikes/plot were tagged and spray inoculated at anthesis. The inoculation is repeated 2 days later. A programmable misting system maintains a humid microclimate, which is favorable for the disease development.

For preliminary material screened for the first time, only the absolute number of infected spikelets/spike was evaluated, and the average number of infected spikelets for all ten spikes calculated. For advanced material in replicated trials in the second and third year of screening, the percent of infected spikelets/spike was evaluated by counting the number of infected spikelets and the total number of spikelets for each spike. Subsequently, the FHB index was calculated using the following formula:

$$\text{FHB index (\%)} = \frac{\text{Severity}}{\text{Incidence}}$$

where severity = the average severity of all spikes that show infection (totally healthy spikes are not considered for calculation of severity) and incidence = the percent of spikes that show infection.

The difference in evaluation methods between the preliminary and advanced material is due to the fact that the number of preliminary materials is much higher than the number of advanced materials. Assessing FHB resistance for the preliminary materials would be too labor- and time-intensive. On the other hand, a difference only between 'resistant' and 'susceptible' for first year material proved not to be valuable, because it does not take into account that resistance to FHB is a quantitative trait. The evaluation of the absolute number of infected spikelets/spike (regardless the total number of spikelets) was found to be the middle ground between these two approaches.

In addition to the candidates and entries of the international nurseries and mapping populations, F<sub>3</sub>- and F<sub>4</sub>-derived head rows also were planted, which had been spaced planted in Obregón to select for agronomic type. This research is a significant contribution of the Fusarium program in resistance breeding efforts for FHB and how the information generated in former years aids the development of new promising lines.

**Bread wheat lines for irrigated areas: Results of PCFusarium White and Red Grain Nursery.** A total of 290 entries from the PCFusarium White Grain (1,076 entries) and PCFusarium Red Grain (246 entries) nurseries planted in 2009 were selected, assembled in the PCFusarium White and Red Grain Nursery (PCFusWGyRG), and tested again in the summer of 2010 at El Batan in replicated trials. Entries with FHB indices below 11 % are shown in Table 8 (pp. 51-54).

Interestingly, despite the normally lower levels of resistance for white-grained material, relatively high levels of resistance in terms of disease symptoms (FHB index) and mycotoxin contamination were observed for these types in this trial. This demonstrates that white-grained bread wheats with levels of resistance similar to that of red-grained materials are available, which is a breakthrough in bread wheat breeding.

**Table 8.** White- (W) and red-grained (R) bread wheat genotypes for irrigated areas in the PC Fusarium White and Red Grain Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of FHB index and DON contamination.

CID	GID	Cross	Grain color	FHB index (%)	DON (ppm)
4965	10004	Sumai #3 (resistant check)		1.7	0.5
520956	6123270	FN/2*mazar 99//GONDO/TNMU/3/FRANCOLIN #1	W	3.0	0.9
516901	6123192	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	3.6	2.3
516852	6122669	PFAU/WEAVER*2//BRAMBLING/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/Ae. tauschii (190)/8/PFAU/WEAVER//BRAMBLING	R	3.9	1.9
516093	6121931	HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1/6/GONDO	W	4.1	1.3



**Table 8.** White- (W) and red-grained (R) bread wheat genotypes for irrigated areas in the PC Fusarium White and Red Grain Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of FHB index and DON contamination.

CID	GID	Cross	Grain color	FHB index (%)	DON (ppm)
520950	6123240	SHA3/CBRD//TNMU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	W	4.1	4.4
516901	6123199	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	4.4	2.0
516068	6123620	CBRD/FILIN	R	4.9	1.8
520950	6123246	SHA3/CBRD//TNMU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	R	5.0	1.4
516900	6123179	PBW343/mazar 99*2/6/TURACO/5/CHIR3/4/SIREN//ALTAR 84/AE.SQUARROSA (205)/3/3*BUC	W	5.0	2.3
120634	2589783	Heilo (moderate resistant check)		5.4	1.7
516775	6122143	CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/mazar99/7/CHUM18/BORL95//CBRD/8/CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/mazar 99	W	5.5	6.0
516068	6123635	CBRD/FILIN	R	5.7	0.8
516068	6123623	CBRD/FILIN	R	6.3	1.3
516772	6122128	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/5/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/SASIA/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	W	6.4	7.0
516852	6122665	PFAU/WEAVER*2//BRAMBLING/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/PFAU/WEAVER//BRAMBLING	R	6.7	1.5
516852	6122662	PFAU/WEAVER*2//BRAMBLING/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/PFAU/WEAVER//BRAMBLING	R	6.8	2.3
516852	6122658	PFAU/WEAVER*2//BRAMBLING/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/PFAU/WEAVER//BRAMBLING	W	6.8	1.8
516104	6122002	WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ/5/GONDO	W	6.8	3.4
516901	6123187	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	6.9	1.3
516874	6122758	KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES/5/SHA3/SERI//SHA4/LIRA/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	R	7.0	0.8
516844	6122610	WBLL1/FRET2//mazar 99/3/SHA3/SERI//SHA4/LIRA/4/WBLL1/TACUPETO F2001//mazar 99	R	7.0	2.8
520950	6123245	SHA3/CBRD//TNMU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	R	7.1	2.8
520964	6123343	HEILO/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/AE.SQUARROSA (190)/8/VORB/FISCAL	R	7.2	1.7
516772	6122127	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/5/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/SASIA/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	W	7.3	5.9
516901	6123188	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	7.3	1.9
516901	6123191	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	7.4	3.1
516068	6123629	CBRD/FILIN	R	7.7	1.0
516068	6123617	CBRD/FILIN	R	7.8	0.7
520950	6123242	SHA3/CBRD//TNMU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	R	7.9	2.7
516775	6122145	CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/mazar99/7/CHUM18/BORL95//CBRD/8/CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/mazar 99	W	8.0	3.8

**Table 8.** White- (W) and red-grained (R) bread wheat genotypes for irrigated areas in the PC Fusarium White and Red Grain Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of FHB index and DON contamination.

CID	GID	Cross	Grain color	FHB index (%)	DON (ppm)
520949	6123236	NG8675/CBRD/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/WBLL1*2/CHAPIO	R	8.1	1.0
516068	6123625	CBRD/FILIN	R	8.1	1.6
516772	6122129	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/5/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/SASIA/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	W	8.1	2.5
516901	6123186	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	8.3	1.5
516871	6122748	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES*2/5/CHIL/CHUM18	W	8.3	9.8
516068	6123628	CBRD/FILIN	R	8.3	1.4
516843	6122590	WBLL1/FRET2//mazar 99*2/3/GONDO	W	8.4	1.7
516070	6123660	CHIL/CHUM18//GONDO	R	8.6	1.5
516871	6122741	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES*2/5/CHIL/CHUM18	W	8.6	9.5
516901	6123193	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	8.7	1.0
516901	6123195	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	8.7	1.7
516901	6123189	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	8.7	0.7
516901	6123196	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	8.9	0.8
520950	6123247	SHA3/CBRD//TNMU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	R	8.9	2.0
516772	6122123	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/5/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/SASIA/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	W	8.9	2.0
520949	6123231	NG8675/CBRD/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/WBLL1*2/CHAPIO	R	9.0	2.3
516900	6123185	PBW343/mazar 99*2/6/TURACO/5/CHIR3/4/SIREN//ALTAR 84/ <i>Ae. tauschii</i> (205)/3/3*BUC	R	9.0	1.4
516776	6122173	CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/mazar99*2/7/CNDO/R143//ENTE/MEXI_2/3/ <i>Ae. tauschii</i> (TAUS)/4/WEAVER/5/2*mazar 99	W	9.1	4.3
516852	6122654	PFAU/WEAVER*2//BRAMBLING/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/PFAU/WEAVER//BRAMBLING	W	9.2	3.6
516070	6123661	CHIL/CHUM18//GONDO	R	9.2	2.7
520949	6123235	NG8675/CBRD/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/WBLL1*2/CHAPIO	R	9.3	0.9
516107	6122040	WBLL1*2/KURUKU//HEILO	W	9.4	2.5
516772	6122104	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/5/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/SASIA/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	W	9.5	7.9
516901	6123200	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	R	9.6	0.9
516068	6123630	CBRD/FILIN	R	9.6	1.6
516901	6123198	PBW343/mazar 99*2/3/WUH1/VEE#5//CBRD	W	9.6	1.4
516789	6122272	WAXWING/KIRITATI*2/3/SHA3/SERI//SHA4/LIRA	R	9.6	4.0
516068	6123634	CBRD/FILIN	R	9.9	1.4
520948	6123221	CHIL/CHUM18//GONDO/3/WBLL1*2/KURUKU	R	10.0	2.1
520956	6123283	FN/2*mazar 99//GONDO/TNMU/3/FRANCOLIN #1	R	10.0	2.3
520947	6123209	CHIL/CHUM18//FN/2*mazar 99/3/PRL/2*mazar 99	R	10.1	2.5

**Table 8.** White- (W) and red-grained (R) bread wheat genotypes for irrigated areas in the PC Fusarium White and Red Grain Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of FHB index and DON contamination.

CID	GID	Cross	Grain color	FHB index (%)	DON (ppm)
516852	6122657	PFAU/WEAVER*2//BRAMBLING/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/AE.SQUARROSA (190)/8/PFAU/WEAVER//BRAMBLING	W	10.1	3.3
516107	6122042	WBLL1*2/KURUKU//HEILO	W	10.1	2.7
516068	6123616	CBRD/FILIN	R	10.2	1.1
516883	6123013	PRINIA/PASTOR//CHIL/CHUM18/3/PRINIA/PASTOR	R	10.4	1.2
516772	6122097	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/5/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/3/SASIA/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	W	10.4	3.8
520974	6123365	KAUZ/mazar 99//PBW343*2/3/HEILO	W	10.4	1.8
520950	6123243	SHA3/CBRD//TNMU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	R	10.5	2.9
516871	6122746	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES*2/5/CHIL/CHUM18	W	10.7	4.8
520949	6123229	NG8675/CBRD/7/IVAN/6/SABUF/5/BCN/4/RABI//GS/CRA/3/ <i>Ae. tauschii</i> (190)/8/WBLL1*2/CHAPIO	W	10.7	3.3
516883	6123007	PRINIA/PASTOR//CHIL/CHUM18/3/PRINIA/PASTOR	W	10.7	2.5
516098	6121958	KAUZ/mazar 99//PBW343/3/HEILO	W	10.7	2.9
516093	6121935	HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1/6/GONDO	W	10.8	2.4
516070	6121915	CHIL/CHUM18//GONDO	W	10.9	2.5
516068	6123631	CBRD/FILIN	R	10.9	2.9
1860	5536	GAMENYA (susceptible check)		92.5	8.1

**Bread wheat for marginal areas: Results of the 27<sup>th</sup> Semi-Arid Wheat Screening Nursery (SAWSN) and 20<sup>th</sup> High Rainfall Wheat Screening Nursery (HRWSN).** The 27<sup>th</sup> SAWSN and the 20<sup>th</sup> HRWSN were tested again in the 2010 summer cycle in El Batan. Entries with an FHB index less than 20% (27<sup>th</sup> SAWSN) and 18% (20<sup>th</sup> HRWSN) also were tested for DON contamination (Table 9, continued on p. 55, and Table 10, pp. 55-56).

**Table 9.** Bread wheat genotypes for marginal areas from the 27<sup>th</sup> Semi-Arid Wheat Screening Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of Fusarium head blight (FHB) index and DON contamination.

CID	GID	Cross	FHB index (%)	DON (ppm)
4965	10004	SUMAI #3	0.5	2.8
120634	2589783	HEILO	5.3	2.7
450346	5427852	SW94.2690/SUNCO	11.5	2.2
279807	3855011	VOROBAY	12.9	4.2
450346	5427842	SW94.2690/SUNCO	13.1	3.7
450352	5427939	VEE/MJI//2*TUI/3/mazar 99/4/BERKUT	13.2	3.1
473247	5435908	PASTOR//HXL7573/2*BAU/3/SOKOLL/WBLL1	13.3	2.1
450346	5427849	SW94.2690/SUNCO	13.5	2.8
437257	5423751	OASIS//TC14/2*SPER/3/ATTILA/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	13.5	3.7
452364	5428200	PASTOR/4/WEAVER/TSC//WEAVER/3/WEAVER/5/URES/PRL//BAV92	13.9	3.6
454534	5428538	<i>T. dicoccon</i> PI94625/ <i>Ae. tauschii</i> (372)//3*PASTOR	14.3	3.1
450346	5427856	SW94.2690/SUNCO	14.6	3.9
450352	5427940	VEE/MJI//2*TUI/3/mazar 99/4/BERKUT	14.7	2.0

**Table 9.** Bread wheat genotypes for marginal areas from the 27<sup>th</sup> Semi-Arid Wheat Screening Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of Fusarium head blight (FHB) index and DON contamination.

CID	GID	Cross	FHB index (%)	DON (ppm)
427650	5422808	OASIS//TC14/2*SPER/3/ATTILA/4/WBLL4	15.0	2.7
437245	5423717	A93324S.7197.29/4/KAUZ//ALTAR 84/AOS/3/KAUZ/5/PASTOR	16.2	4.3
450356	5427957	FILIN/3/CROC_1/ <i>Ae. tauschii</i> (205)//KAUZ/4/FILIN/5/VEE/MJI//2*TUI/3/mazar 99	16.5	3.7
450355	5427955	BERKUT/3/ATTILA*2//CHIL/BUC	16.7	3.2
437240	5423682	TAN//TEMPORALERA M 87/AGR/3/FRET2/4/URES/PRL//BAV92	17.1	4.9
435275	5423325	BABAX/LR42//BABAX/3/ER2000	17.3	4.8
473281	5436044	MEX94.27.1.20/3/SOKOLL//ATTILA/3*BCN	17.9	5.8
472868	5435731	SOKOLL/3/PASTOR//HXL7573/2*BAU	18.2	4.5
452470	5428491	PASTOR//HXL7573/2*BAU/3/CMH82.575/CMH82.801	18.3	3.5
437257	5423741	OASIS//TC14/2*SPER/3/ATTILA/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	18.4	2.2
454534	5428531	<i>T. dicoccon</i> PI94625/ <i>Ae. tauschii</i> (372)//3*PASTOR	18.4	3.2
460356	5429403	PASTOR//HXL7573/2*BAU/3/WBLL1	19.1	5.8
435388	5423482	MILAN/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	19.5	1.4
1860	5536	GAMENYA	60.3	0.2

**Table 10.** Bread wheat genotypes for marginal areas from the 20<sup>th</sup> High Rainfall Wheat Screening Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of Fusarium head blight (FHB) index and DON contamination.

CID	GID	Cross	FHB index (%)	DON (ppm)
4965	10004	Sumai #3 (resistant check)	0.5	0.3
4749	9774	Shanghai #8	4.1	0.9
451641	5685994	NING MAI 96035/FINSI//HEILO	5.3	2.8
120634	2589783	Heilo (moderate resistant check)	6.2	1.6
442354	5686022	ATTILA/HEILO	6.9	1.1
451641	5685999	NING MAI 96035/FINSI//HEILO	7.3	2.5
442354	5686027	ATTILA/HEILO	9.0	0.9
475170	5685928	CPI8/GEDIZ/3/GOO//ALB/CRA/4/ <i>Ae. tauschii</i> (208)/5/HAHN/2*WEAVER/6/SKAUZ/BAV92	9.7	2.6
444320	5686059	BURI/JARU//METSO	9.8	2.4
442354	5686023	ATTILA/HEILO	10.4	2.3
480883	5551988	WAXWING//PFAU/WEAVER	12.6	3.0
451641	5685998	NING MAI 96035/FINSI//HEILO	12.6	3.3
279807	3855011	VOROBAY	13.2	3.1
442354	5686025	ATTILA/HEILO	13.3	2.1
451641	5686001	NING MAI 96035/FINSI//HEILO	13.6	2.1
475170	5685929	CPI8/GEDIZ/3/GOO//ALB/CRA/4/ <i>Ae. tauschii</i> (208)/5/HAHN/2*WEAVER/6/SKAUZ/BAV92	16.1	2.6
476919	5535312	ND643//2*PRL/2*mazar 99	16.4	3.0
448397	5398611	BABAX/LR42//BABAX*2/3/KURUKU	17.3	3.5
444913	3826276	FUNDACEP 30	17.4	1.2

**Table 10.** Bread wheat genotypes for marginal areas from the 20<sup>th</sup> High Rainfall Wheat Screening Nursery tested for the 2<sup>nd</sup> year in the summer of 2010 and results of Fusarium head blight (FHB) index and DON contamination.

CID	GID	Cross	FHB index (%)	DON (ppm)
451809	5685991	IAS58/4/KAL/BB//CJ71/3/ALD/5/CNR/6/THB/CEP7780/7/TN MU/8/METSO	17.5	3.0
475170	5685927	CPI8/GEDIZ/3/GOO//ALB/CRA/4/Ae. <i>tauschii</i> (208)/5/HAHN/2*WEAVER/6/SKAUZ/BAV92	17.9	2.4
451641	5685996	NING MAI 96035/FINSI//HEILO	17.9	2.9
1860	5536	GAMENYA (susceptible check)	64.2	4.9

### *Wheat blast caused by Magnaporthe grisea.*

**Defining disease prone climatic conditions and wheat blast risk assessment.** Wheat blast or ‘brusone’, induced by *Magnaporthe grisea*, infects the spikes of wheat grown in subtropical climates. The disease has been recorded in the wheat cropping areas of Brazil since the mid 1980s and occurs in similar climatic conditions in Paraguay and Bolivia. No reports exist on the occurrence of wheat blast outside South America. Damage potential is high and can account for 10 to 100% crop losses. Control of the disease is limited by lack of effective fungicide spray schemes and resistant cultivars. This study estimated the potential risk of wheat blast to occur in other wheat-growing areas in the world based on a climate similarity approach. The assessment was based on categorizing blast sites in South America for moderate and high disease severity levels and their corresponding climate profiles. Climate similarity with wheat production areas in nontraditional, warmer areas on other continents was derived from the Worldclim database considering the coolest quarter in which wheat is grown and similarity comparisons with the areas of cultivation in the northern hemisphere were drawn from the warmest quarter of the year.

Our preliminary analysis revealed areas of wheat blast risk in significant parts of central India, Bangladesh, and parts of Ethiopia. The wheat-growing regions in South Africa or Australia did not match with the blast climate profile. Similarity also was identified with large areas of wheat production in the northern hemisphere, Eurasia, and North America. However, determining the similarity of sites using the Homologue software showed that northern Eurasia and North America did not match a year-round climate comparison with areas in South America where brusone is known to occur. Areas generally at the border of wheat-growing areas in the Indian subcontinent and in parts of Africa show a 40–60% to 60–80% similarity with affected areas in South America underlining that risk of wheat blast pathogen survival exists. From the limited knowledge available from the wheat blast pathogen, its survival in the cool or cold season is unlikely, diminishing the current risk of wheat blast in production zones of the northern hemisphere.

### *The first international workshop on wheat blast held in Passo Fundo, Brazil.*

To address wheat blast or ‘brusone’, which is responsible for 5–100% of wheat yield losses in regions of South America and has the potential to spread to other countries, the ‘Wheat blast: A potential threat to global wheat production’ workshop was held in Passo Fundo, Brazil, 3–5 May, 2010, followed by a field visit to the Brasília region. The workshop was organized by Embrapa Wheat, Embrapa Cerrados, and CIMMYT with the support of the project to ensure a participation of scientists from national programs besides Brazil. The workshop was attended by representatives from 11 countries. Wheat blast was identified for the first time in 1985 in the State of Paraná in southern Brazil, from where it quickly spread to neighboring countries. Four years later, blast caused serious damage (40–100%) in the wheat fields of Paraguay. In the lowlands of Bolivia, it was responsible for a loss of 90,000 ha of wheat between 1997 and 2000. In 2007, the disease was seen in summer-sown experimental wheat trials in Chaco, Argentina, and although researchers in Uruguay have not observed the disease in wheat, they have found the fungus on barley. The 2009 outbreak cut Brazilian wheat production by up to 30%.

Of great concern is that chemical control of wheat blast may not be working. Some farmers are using four fungicide applications with no results, which suggests the current chemicals are not effective against the fungus or are not properly applied. To date, resistant cultivars are unavailable and only limited tolerance can be found. Climate



change is adding to the problem. 'A more hot and humid climate favors fungal diseases such as wheat blast, which needs high temperatures of about 24–28°C and long periods of rain to occur,' explained researcher Gisele Torres of Embrapa Wheat. Changes in rainfall may create environmental conditions favorable to wheat blast in other parts of the world such as South Asia or Africa and was the main reason for inviting researchers from different wheat-producing countries on several continents to discuss wheat blast in Brazil.

The most important diseases that affect wheat production worldwide are leaf rust ( $5 \times 10^6$  ha), tan spot ( $4.5 \times 10^6$  ha), and Fusarium ( $4 \times 10^6$  ha). 'So far, new diseases like wheat blast in South America have been limited to a few countries,' said Man Mohan Kohli, ex-CIMMYT researcher once posted in South America. 'Similarly, the distribution of the stem rust Ug99 in Africa has been limited, but has been the object of studies by several research institutes around the world.' Efforts to improve wheat resistance to Ug99 and to reduce the risk of its spread to other countries show how international collaborative research and investment facilitates scientific response to new virulent pathotypes, or races of pathogens, that could become potentially devastating. Researchers from the following institutions participated in the workshop, which was supported by EMBRAPA and BMZ (Germany): Göttingen University (Germany), Kansas State University (United States), CIRAD (France), CIAT (Bolivia), INTA (Argentina), INIA (Uruguay), CIMMYT (Mexico), USDA/ARS (United States), MAG/DIA (Paraguay), and Wageningen University (Netherlands), as well as Brazil Embrapa Cerrados, Embrapa Wheat, Embrapa Labex Europa, BIOTRIGO, COODETEC, FUNDA-CEP, UPF, UNESP, and Fapa/Agrária.



### *Safe movement of germ plasm.*

The project 'Safe movement of germ plasm' was concluded in March 2010. Recommendations for 15 crops under the CGIAR mandate were published on line as part of the SGRP GPG2 Knowledge Portal. We corresponded with all CGIAR centers scientists working on seed crops to obtain the technical information on import/export permits, technical guidelines, and best practices in seed health for all CGIAR mandate seed crops. We revised and edited the materials receive from other centers. Please consult <http://cropgenebank.sgrp.cgiar.org>.

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## NATIONAL INSTITUTE FOR FORESTRY, AGRICULTURE, AND LIVESTOCK RESEARCH (INIFAP-CIRNO)

**Campo Experimental Valle del Yaqui, Apdo. Postal 155, km 12 Norman E. Borlaug, entre 800 y 900, Valle del Yaqui, Cd. Obregón, Sonora, México CP 85000.**

### *Identification of genes of agricultural importance in bread wheats for the state of Sonora, Mexico.*

José Luis Félix-Fuentes, Pedro Figueroa-López, Guillermo Fuentes-Dávila, Víctor Valenzuela-Herrera, Gabriela Chávez-Villalba, and José Alberto Mendoza-Lugo.

**Introduction.** Southern Sonora is characterized by having a large area sown with irrigated wheat every year. Farmers, through their economic contributions to agricultural research, demand wheats with high yield potential, quality, and

resistance to diseases; however, leaf rust caused by *Puccinia triticina* Eriks. is an endemic and highly destructive disease in this region. The pathogen has the capacity to mutate (Rajaram and Campos 1974), and multiply rapidly (Singh et al. 2001). A severe infection reduces the photosynthetic area, there is water loss which debilitates the radical system, plant growth stops, kernels are shriveled, and the plant may die (Roelfs 1978). This disease is the main cause of cultivar replacement and the increase in the use of fungicides making the wheat crop less profitable. A more recent threat to the wheat crop is the TTKS or Ug99, a variant of stem rust. Although there is no records of its presence in the American continent, research has been intensified looking for resistance genes for this and other diseases.

**Materials and methods.** Experimental plots were established at the Norman E. Borlaug Experimental Station, which belongs to the Northwest Regional Research Center of the National Institute for Forestry, Agriculture and Livestock Research (CENEB-CIRNO-INIFAP), during the crop season autumn–winter 2009–10. The station is located in block 910 of the Yaqui Valley at 27°22' latitude north and 109°55' longitude west, 37 masl. Seven commercial cultivars released by INIFAP were evaluated (Onavas F2009, Tepahui F2009, Villa Juarez F2009, Navojoa M2007, Roelfs F2007, Kronstad F2004, and Tacupeto F2001), as well as 29 advanced lines from the CIMMYT bread wheat breeding program, for the presence of genes *Lr34*, *Sr22*, *Sr24*, *Sr26*, and *Sr36* (Table 1, continued on p. 60). DNA was extracted from plant material following the method described by Saghai-Maroo et al. (1984). PCR reactions were carried out in the Biotechnology Laboratory of CIMMYT in El Batán, state of Mexico. For gene *Lr34*, a final volume of 9.5 µl were used for the reaction (6.5 µl of RED Sigma TAQ, 1.5 µl of primer CSLV34, and 1.5 µl of L34PLUS), and 5 µl of DNA for genes *Sr22* (CFA2123), *Sr24* (Sr24#12), *Sr26* (Sr26#43), and *Sr36* (STM773-2). PCR products obtained were separated by horizontal electrophoresis in 2.5 and 3.0% agarose gels, depending on the gene; separation was in TBE1X buffer, then stained with ethidium bromide, visualized under UV light, and documented with digital photography.

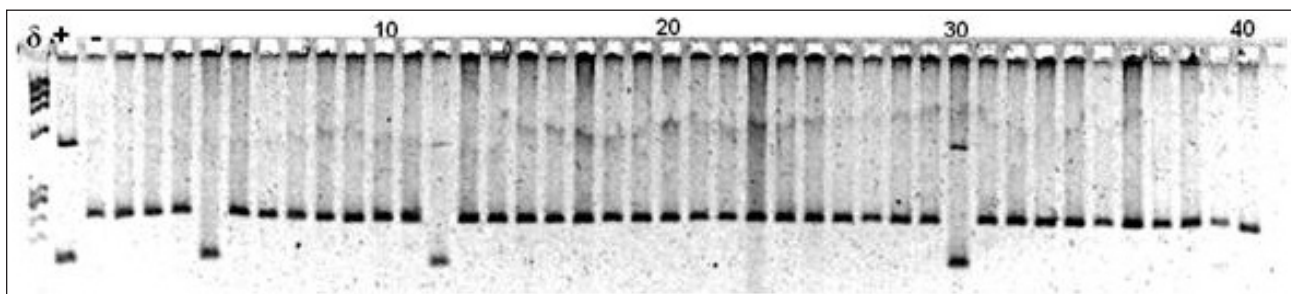
**Table 1.** Bread wheat advanced lines and commercial cultivars evaluated during the 2009–10 crop season in the Yaqui Valley, Sonora, Mexico.

#	Cultivar/line	Selection history
1	Chewink	CGSS03B00074T-099Y-099M-099Y-099M-6WGY-0B-3B
2	Navojoa M2007	CMSS97Y04045S-040Y-050M-040SY-030M-14SY-010M-0Y
3	Villa Juarez F2009	CGSS01B00062T-099Y-099M-099M-099Y-099M-12Y-0B
4	KEA/TAN/4/TSH/3/KAL/BB//TQFN/5/ Pavon/6/SW89.3064/7/Sokoll	CMSS04Y00153S-099Y-099ZTM-099Y-099M-5WGY-0B
5	Becard	CGSS01B00063T-099Y-099M-099M-099Y-099M-33WGY-0B
6	Onavas F2009	CGSS01B00069T-099Y-099M-099M-099Y-099M-20Y-0B
7	PBW343//CAR422/ANA/3/ELVIRA	CMSS02M00409S-030M-1Y-0M-040Y-10ZTB-0Y-02B-0Y
8	Babax/LR42//Babax*2/4/SNI/TRAP#1/3/ KAUZ*2/TRAP//KAUZ	CGSS01B00045T-099Y-099M-099M-099Y-099M-26Y-0B
9	Roelfs F2007	CGSS00B00169T-099TOPY-099M-099Y-099M-9CEL-0B
10	Wheat/Kronstad F2004	CGSS04Y00106S-099Y-099M-099Y-099M-9WGY-0B
11	Wheat/Kronstad F2004	CGSS04Y00106S-099Y-099M-099Y-099M-3WGY-0B
12	Tepahui F2009	CMSW00WM00150S-040M-040Y-030M-030ZLM-3ZTY-0M
13	Babax/LR42//Babax/3/ER2000	CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-24M-0Y-0SY
14	TOBA97/Pastor	CMSS97M05756S-040M-020Y-030M-015Y-3M-1Y-3M-0Y
15	PFAU/Milan/3/Babax/LR42//Babax	CMSS02M00056S-030M-28Y-0M-040Y-25ZTB-0Y-01B-0Y
16	Babax/LR42//Babax/3/ER2000	CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-30M-0Y-0SY
17	Wheat/Sokoll	CMSS04Y00201S-099Y-099ZTM-099Y-099M-11WGY-0B
18	Thelin/2*WBLL1	CGSS02Y00079T-099B-099B-099Y-099M-6Y-0B
19	TC870344/GUI//Temporalera M 87/ AGR/3/2*WBLL1	CMSA01Y00725T-040M-040P0Y-040M-030ZTM-040SY-10M-0Y-0SY
20	Waxwing*2/Kronstad F2004	CGSS04Y00020T-099M-099Y-099ZTM-099Y-099M-3WGY-0B
21	ROLF07/YANAC//Tacupeto F2001/Brambling	CGSS05B00121T-099TOPY-099M-099NJ-4WGY-0B
22	Kronstad F2004	CMSS92Y01425T-16Y-010M-010Y-010Y-1M-0Y-50EY-0Y
23	PFAU/MILAN//TROST/3/ PBW65/2*SERI.1B	CMSS04M01426S-0TOPY-099ZTM-099Y-099M-3RGY-0B

**Table 1.** Bread wheat advanced lines and commercial cultivars evaluated during the 2009–10 crop season in the Yaqui Valley, Sonora, Mexico.

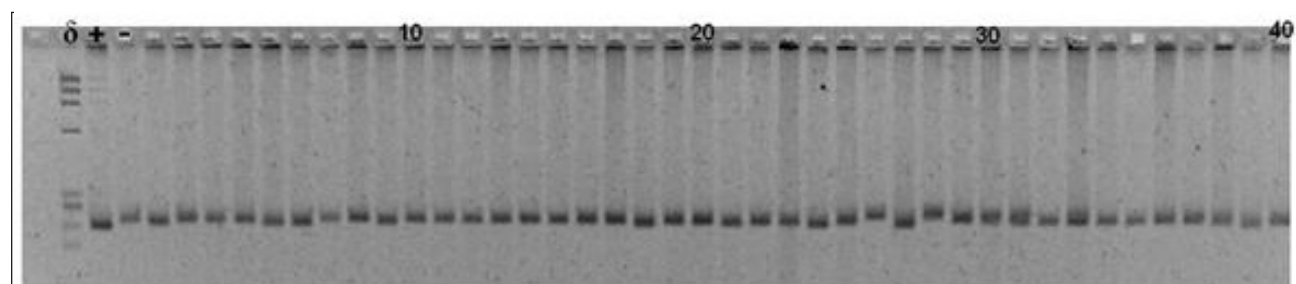
#	Cultivar/line	Selection history
24	Tacupeto F2001	CGSS95B00016F-099Y-099B-099Y-099B-15Y-0B
25	CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/WH576/7/WH 542/8/Waxwing	CMSS04Y00364S-099Y-099ZTM-099Y-099M-2WGY-0B
26	CHYZ//BOW/CROW/3/WBLL1/4/CROC_1/ <i>Ae. tauschii</i> (213)//PGO	CMSA02Y00509T-040M-040P0Y-040ZTM-040SY-040M-6ZTY-03M-0Y
27	Reolfs F2007	CGSS00B00169T-099TOPY-099M-099Y-099M-9CEL-0B
28	CHYZ//BOW/CROW/3/WBLL1/4/CROC_1/ <i>Ae. tauschii</i> (213)//PGO	CMSA02Y00509T-040M-040P0Y-040ZTM-040SY-040M-15ZTY-03M-0Y
29	OR 9437534/Sokoll/Sokoll	CMSA04Y01203T-040ZTM-040ZTY-040ZTM-040SY-5ZTM-04Y-0B
30	Sokoll/Excalibur	CMSA03Y00010S-3P0Y-0ZTY-010M-010SY-010M-9ZTY-03B-0Y
31	Babax/LR42//Babax/3/ER2000	CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-28M-0Y-0SY
32	CHEN/ <i>Ae. tauschii</i> (TAUS)//BCN/3/BAV92/4/Berkut	CMSA02Y00104S-040P0Y-040ZTM-040SY-040M-8ZTY-02M-0Y
33	Sokoll/Sunco/2*Pastor	CMSA04Y00294S-040ZTY-040ZTM-040SY-8ZTM-01Y-0B
34	CROC_1/ <i>Ae. tauschii</i> (213)//PGO/3/CMH81.38/2*KAUZ/4/Berkut	CMSA02Y00059S-040P0Y-040ZTM-040SY-040M-5ZTY-01M-0Y
35	VEE/MJI/2*TUI/3/Pastor/4/Berkut	CMSA01M00075S-040P0M-030ZTM-040SY-040M-13Y-0M-0SY
36	MTRWA92.161/Prinia/5/SERI*3//RL6010/4*YR/3/Pastor/4/BAV92	CMSA02M00279S-040ZTM-040ZTY-040ZTM-040SY-2ZTM-03Y-0B
37	KRONSTAD F2004	CMSS92Y01425T-16Y-010M-010Y-010Y-1M-0Y-50EY-0Y
38	CROC_1/ <i>Ae. tauschii</i> (213)//PGO/3/CMH81.38/2*KAUZ/4/Berkut	CMSA02Y00059S-040P0Y-040ZTM-040SY-040M-7ZTY-03M-0Y
39	Tacupeto F2001	CGSS95B00016F-099Y-099B-099Y-099B-15Y-0B
40	Navojoa M2007	CMSS97Y04045S-040Y-050M-040SY-030M-14SY-010M-0Y

**Results.** Amplification by PCR indicated that out of the 40 genotypes analyzed (taking into consideration the replication of three cultivars), only three were positive for gen *Lr34* (Fig. 1), which were ‘KEA/TAN/4/TSH/3/KAL/BB//TQFN/5/Pavon/6/SW89.3064/7/Sokoll’, ‘Sokoll / Excalibur’, and cultivar Tepahui F2009. Genes such as *Lr34* for nonspecific races called durable resistance or slow-rusting, are expressed in adult plants, and are related to grain yield decrease (Singh and Huerta 1997); on the other hand, other studies indicate that *Lr34* contributes to a significant increment in protein content (Labuschagne et al. 2002). However, the statistical analysis did not show a correlation with yield and protein due to the low number of positives in the amplification of *Lr34*. Gen SR22 was originally identified in the diploid wheat *T. monococcum* subsp. *monococcum* (Gerechter-Amitai 1971) and transferred to tetraploid and hexaploid wheat through interspecific hybridizations. Gene *Sr22* is effective against Ug99, however, its presence has a negative effect on

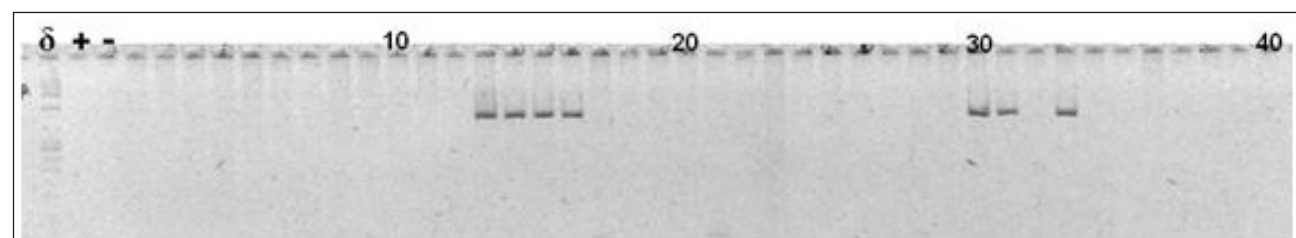
**Fig. 1.** PCR amplification for gene *Lr34* in bread wheat lines and commercial cultivars evaluated during the 2009–10 crop season in the Yaqui Valley, Sonora, Mexico. See Table 1 (pp. 59-60) for line identification.



grain yield. Based on results from PCR, the presence of *Sr22* was detected in Chewink, Becard, 'Thelin / 2\*WBLL1', 'ROLF07/Yanac//TACUPETOF2001/Brambling', and in the cultivars Tacupeto F2001, Roelfs F2007, and Onavas F2009 (Fig. 2). Gene *Sr24* confers resistance to most races of stem rust, including virulent race Ug99 (TTKSK) established in Eastern Africa and Ethiopia. Resistance of this gene during devastating epidemics of stem rust have been reported in South Africa and India (Mago et al. 2005), however, *Sr24* is not effective against a more recent variant of Ug99, designated as TTKST. Materials that possess *Sr24* are 'Babax/LR42//Babax/3/ER2000', 'TOBA97/Pastor', 'PFAU/Milan/3/Babax/LR42//Babax', 'Sokoll/Excalibur', and 'Sokoll/Sunco/2\*Pastor' (Fig. 3). *Sr26* was not found in the materials evaluated; this gene is one of the few with major resistance effective against race TTKSK and its derivatives TTKST, making it ideal for pyramiding resistance. Gene *Sr36* was not found during analysis of the materials evaluated. Previous studies indicate that *Sr36* confers resistance to Ug99, however, other variants of Ug99 affect this gene, so, it is recommended to use it to pyramid with other genes. Genetic resistance is considered the most important strategy for disease management in wheat. This resistance implies an aggregated value to materials when they are released as cultivars; therefore, different breeding programs invest a great deal of their resources to disease management, as a response to a possible event that might occur.



**Fig. 2.** PCR amplification for gene *Sr22* in bread wheat lines and commercial cultivars evaluated during the 2009–10 crop season in the Yaqui Valley, Sonora, Mexico. See Table 1 (pp. 59-60) for line identification.



**Fig. 3.** PCR amplification for gene *Sr24* in bread wheat lines and commercial cultivars evaluated during the 2009–10 crop season in the Yaqui Valley, Sonora, Mexico. See Table 1 (pp. 59-60) for line identification.

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### *Effect of tillage methods on wheat grain yield and fuel consumption in the Yaqui, Valley Sonora, Mexico.*

Juan Manuel Cortés-Jiménez, Alma Angélica Ortiz-Ávalos, and Guillermo Fuentes-Dávila.

**Introduction.** In The Yaqui Valley, Sonora, Mexico, about 100,000 ha are managed with equipment for conventional tillage, such as the plough or chisel. The cost of ploughing is \$56.50 (11.5 exchange rate), chiseling \$47.80, and disk harrowing \$30.40. In terms of economic impact, more importance now is focused on the energy cost of agriculture, and agricultural diesel is the primary source of energy for tillage practices. The cost increase derived from tillage and the commitments of the Kyoto Protocol are factors that make more important the use of efficient practices, taking into consideration their influence on competitiveness in agricultural activities. Moreover, greenhouse gases produced by the use of fossil fuels, such as diesel, are one of the most significant environmental problems to be addressed; therefore, agricultural tractors ought to be used more efficiently (Pérez de Ciriza 2004). Deep tillage is considered essential for yield improvement but, with the exception of deep-rooted plants, many crops yield well with 12–15 cm of tillage (Prasad 1996). Reduced tillage in wheat requires less equipment and energy in comparison to conventional tillage, where the plow is used and yields are very similar; an economic advantage to the farmer (Gemtos et al. 1999). However, occasionally plowing is recommended for weed control (Turley et al. 2003). Our objective was to determine the effect of conventional tillage on wheat grain production and diesel consumption in a clay soil in the Yaqui Valley, Sonora, Mexico.

**Materials and methods.** The study was conducted at the Norman E. Borlaug Experimental Station, which belongs to the Mexican National Institute for Forestry, Agriculture and Livestock Research (INIFAP), during the period 2006–07 to 2009–10. The station is located at 27°22' north latitude and 109°55' west longitude. The plot size was 5,760 m<sup>2</sup>. The soil was prepared with secondary tillage based on the use of disk harrowing during five years (2002 to 2006), and from the sixth year on, the plot was divided into three subplots of 1,920 m<sup>2</sup>. In each crop season, one of the subplots was prepared just with disk harrowing, another with disk harrowing followed by plowing, and the third with disk harrowing followed by chiseling. Plowing and chiseling were done to a depth of 40 cm and harrowing to 30 cm. In all cases, there was no summer rotation. Sowing date and agronomic management followed the recommendations of INIFAP for the region. During 2009 and 2010, diesel consumption was measured from the time the tractor started with a full tank in each treatment. Tractor brand and models for this study were New Holland 7610, John Deere 6403, and 4455.

**Results.** Plowing or chiseling did not produce a higher wheat grain yield as compared to disk harrowing in any of the years of evaluation (Table 2), which indicates that primary tillage based on plowing and chiseling only contributed to unnecessary increase in production costs. Only after four years of plowing, there was a slight increase in wheat grain yield; however, this increase was not sufficient to pay for the cost of this tillage method.

Diesel consumption for each tillage method evaluated and tractors used are reported in Table 3. The levels of consumption were consistent with those reported by manufacturers; however, some variations are expected depending on the type of tractor, equipment size, and operating conditions such as depth, speed, size, and shape of the field. In this study, diesel consumption for the disk harrowing method was half the amount used with chiseling, and from 26 to 32% with plowing, depending on the type of tractor.

**Table 2.** Wheat grain yield (t/ha) obtained in conventional and secondary tillage in the Yaqui Valley, Sonora, Mexico, during four crop seasons.

Tillage method	Crop season			
	2007	2008	2009	2010
Plowing	6.450	7.643	6.460	8.220
Chiseling	6.710	7.660	6.888	7.663
Disk harrowing	6.724	8.085	7.758	8.013

**Table 3.** Fuel consumption in conventional and secondary tillage methods in wheat in the Yaqui Valley, Sonora, Mexico (NH = New Holland; JD = John Deere tractors).

Tillage method	2009 season		2010 season	
	L/ha	Tractor	L/ha	Tractor
Plowing	24.3	NH 7610	32.2	JD 6403
Chiseling	16.3	JD 4455	16.4	JD 6403
Disk harrowing	7.9	NH 7610	8.5	NH 7610

**Conclusions.** The use of secondary tillage based on disk harrowing showed greater grain yield and profitability as compared with conventional tillage based on plowing or chiseling, under conditions of the Yaqui Valley, Sonora. The elimination of conventional tillage practices in wheat management, reduced diesel consumption and therefore the emission of greenhouse gases like carbon dioxide, without affecting grain yield.

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### *Evapotranspiration as a tool to predict quantity of water for wheat irrigation in the Yaqui Valley, Sonora, Mexico.*

Alma Angélica Ortiz-Avalos, Juan Manuel Cortés-Jiménez, Guillermo Fuentes-Dávila, and Xóchitl Marisela Bravo-Peña (Colegio de Estudios Científicos y Tecnológicos del Estado de Sonora, Periférico S/N, Esquina con Tamaulipas, Bacoampo, Sonora, México CP 85287).

**Abstract.** The evapotranspiration data used in this study was taken from the weather station network in the Yaqui Valley from 1 December, 2008, to 15 April, 2009, which corresponded to the wheat crop season. A database created in an Excel spreadsheet was imported into the Idrisi Kilimanjaro program, in order to convert it into a digital file, and through interpolation by the nearest neighboring method, the value of evapotranspiration was projected for the entire Yaqui Valley. The total value for the period of evaluation was 507 mm, however, evapotranspiration values were different throughout the whole region. Therefore, we concluded that it cannot be generalized the application of the same quantity of irrigation water to wheat across the Valley.

**Introduction.** Evapotranspiration is a key parameter for establishing the frequency and amount of water to be applied in an irrigated crop (Gurovich 1985). Evaporation is affected by climate, crop characteristics, and management (FAO 1998). In the Yaqui Valley, where wheat has occupied the largest area during the autumn-winter for many years, evapotranspiration is higher than precipitation, therefore, irrigation is necessary in order to make agriculture a profitable business (Cortés et al. 2009). The FAO (1998) recommends to study evapotranspiration in this type of regions to monitor crop water demand. The objective of this evaluation was to identify the evapotranspiration reference values in the Yaqui Valley through data recorded by the weather station network, and to determine whether these values could be used as a general criterion for irrigated wheat scheduling.

**Materials and methods.** Evapotranspiration data was taken from the weather station network in the Yaqui Valley, Sonora (PIEAES 2009) reported from 1 December, 2008, to 15 April, 2009. An Excel spreadsheet data base was created for each of the stations with their respective coordinates. The data base was saved as text (tab delimited) and imported into the Idrisi Kilimanjaro program, which created a map of points (known as vector) (Eastman 2003). The map was taken to a process of interpolation (nearest neighboring method), and it also was added the minimum and maximum limit in X, Y, of the Yaqui Valley, in order to get the map with the spatial distribution of evapotranspiration. The accumulated monthly evapotranspiration was used to make graphs.

**Results and discussion.** The evapotranspiration value is a very important tool for agricultural irrigation programming. However, it should be considered that even within the same region, values are not equal (Fig. 4, p. 64). The region where the highest evapotranspiration was recorded is located in block 2920 near the coast known as Siari Island. Evaporation is higher in coastal areas, because there is more area with bare soil and the evaporation from a soil under this condition is greater than a soil with a vegetative cover, because solar radiation is mitigated by the plant cover (Miliarum. com 2009).

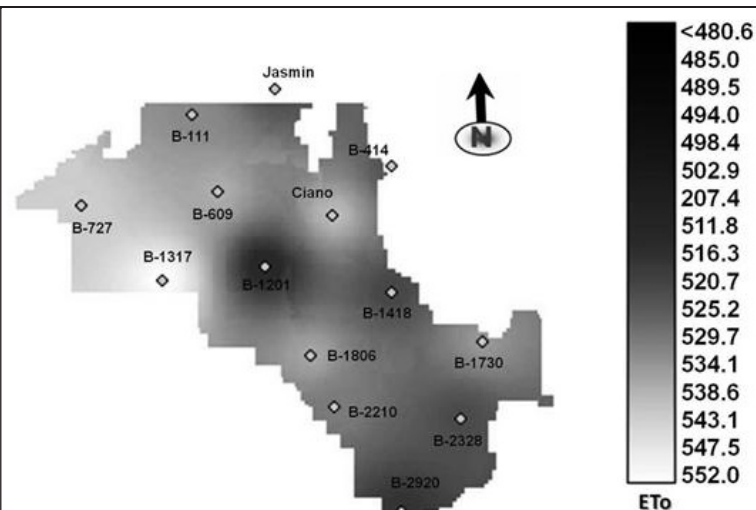
During the wheat season of evaluation, the highest value of evapotranspiration (143 mm) occurred in March (Fig. 5). However, the evaluation covered just 15 days in April, so if sowing was carried out after the first day of December, the physiological crop cycle would be shifted so that more days would be considered in April for the purpose of this study. Therefore, the value of evapotranspiration would increase as this month reported a total value of 162 mm.

In irrigated agriculture, optimizing water management is necessary to increase the efficiency of using water resources through technical procedures, which provide the necessary information to irrigate a crop with an optimal frequency and timing (Singh and Chauman 1996). Although evapotranspiration is a useful tool for irrigation scheduling, it can not predict its application, therefore, it is necessary to incorporate other values such as rainfall, crop type and phenological stage, type and quality of soil, soil moisture, and water quality (FAO 1998).

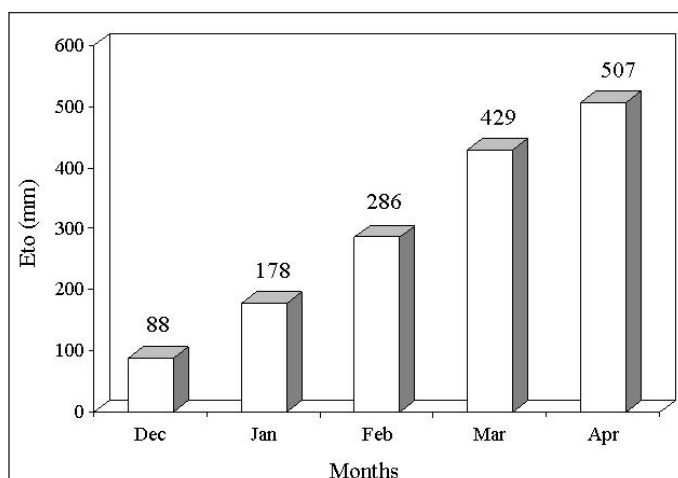
**Conclusions.** Results of the average spatial distribution of evapotranspiration for the Yaqui Valley are not the same across the region, so that the value of evapotranspiration can not be taken as a single criterion for irrigation scheduling.

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**Fig. 4.** Evapotranspiration (mm) recorded in the Yaqui Valley, Mexico, from November 2008 to April 2009.



**Fig. 5.** Evapotranspiration (mm) accumulated from 1 December, 2008, to 15 April, 2009, in the Yaqui Valley, Mexico.

**Effect of two biofertilizers on wheat grain yield in the Yaqui Valley, Sonora, Mexico.**

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**Abstract.** The use of biofertilizers is a practice that has generated great interest in recent years. In this process, the seed is inoculated with beneficial microorganisms that exist naturally in soil, thus increasing its concentration in the rhizosphere. In general, their effects reside in promoting plant growth, developing tolerance to moderate stress, and increasing the efficiency of nutrient absorption. In this study, the simple effects and interactions between nitrogen, phosphorus, *Glomus arbuscular*, and *Azospirillum brasilense* as fertilizers on wheat yield were evaluated. Results from simple interactions indicated that plots with a nitrogen application produced greater grain yield than untreated ones, a phosphorus application did not increase yield, and the highest yield was obtained with *Azospirillum* in plots treated with just biofertilizers. The highest grain yield from chemical fertilizer + biofertilizer interactions was obtained with the treatment nitrogen + the mixture *Glomus* + *Azospirillum*.

**Introduction.** Research and technology contributed to increase crop yields during the 1960s and 1970s, but the ecological price has been high (FAO 1995). The conventional agricultural model adopted by the middle of last century was based on a production system that was highly efficient, but dependent on elevated synthetic inputs (FIDA-RUTACATIE-FAO 2003), as well as the use of methods that caused soil erosion, salinization, pollution, desertification, and loss of biodiversity (FAO 1995). Twenty-first century agriculture in Mexico and the world will have to use science as an alternative to generate a revolution in agricultural production systems that overcome all areas (economy, productivity, and ecology) of the production systems used during the last century. Agriculture in Mexico is promoting the use of *Rhizobium etli* and *Azospirillum brasilense*, bacteria that fix atmospheric nitrogen in conjunction with the mycorrhizal fungus (*Glomus arbuscular*) are the basis for the production of the so-called biofertilizers (Morales 2007). Biofertilizer is a product that contains one or more soil microorganisms and can be applied to the seed or soil in order to increase their population; it can be associated directly or indirectly to the plant root system, encourage its interaction, and increase growth and reproduction of the host plant (Aguirre et al. 2010). These microorganism-biofertilizers are normally distributed in the soil, but its concentration is insufficient (between 103–104 cells/g of soil) to cause the desired beneficial effect on plants, hence, the importance of increasing their population size (between 106–108 cells/g of soil) (Dibut 2009). In addition, these biofertilizers are environmentally friendly and low cost.

In the Yaqui Valley, Sonora, fertilization represents the main cost of wheat production, which affects the profitability of this crop. In this study, the simple effects and interactions between nitrogen, phosphorus, *Glomus*, and *Azospirillum*, as fertilizers on wheat yield were evaluated.

**Materials and methods.** The study was carried out at the Norman E. Borlaug Experimental Station (INIFAP) during the 2008–09 crop season. A factorial experimental design was used with the following factors: A) nitrogen rates 0 and 200 kg/ha as urea; B) phosphorus rates 0 and 52 kg P<sub>2</sub>O<sub>5</sub>/ha in the form of monoammonium phosphate; and C) biofertilizers control, *Glomus*, *Azospirillum*, and *Glomus* + *Azospirillum*. Experimental plots were 4.8 m<sup>2</sup> and treatments had three replications. Mean comparisons used Tukey's test (0.05). Planting date and agronomic management of durum wheat cultivar Samayoa C2004 followed recommendations of INIFAP for the region.

**Results and discussion.** The single addition of 200 kg/ha of nitrogen produced on average 756 kg of grain/ha more than the control (Table 4); a greater yield was obtained in plots without phosphorus application than in treated plots. In the case of biofertilizers, the highest grain yield was obtained with the application of *Azospirillum*, which was 699 kg/ha more than the con-

**Table 4.** Effect of biofertilizers, phosphorus, and nitrogen on grain yield of the durum wheat cultivar Samayoa C2004 during the 2008–09 crop season at the Norman E. Borlaug Experimental Station. Grain yield was evaluated at 12% humidity content. Tukey ( $p = 0.05$ ) = 0.172.

Treatment	Grain yield (t/ha)				
	Rate of fertilizer N-P (kg/ha)				
	0-0	0-52	200-0	200-52	Average
Control	6.560	6.385	7.773	7.594	7.078 a
<i>Glomus</i>	6.895	6.573	7.600	7.452	7.130 a
<i>Azospirillum</i>	7.259	6.918	7.287	7.738	7.301 a
<i>Glomus</i> + <i>Azospirillum</i>	6.760	6.381	7.839	7.273	7.063 a
Average	6.869 b	6.564 b	7.625 a	7.514 a	

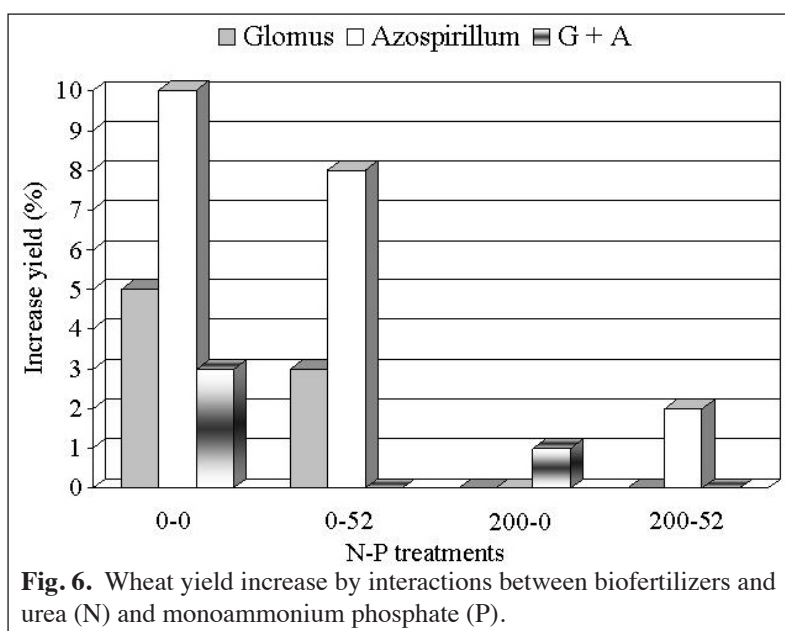


trol. The interaction that produced the highest yield was the mixture of *Glomus* + *Azospirillum* with a N-P rate of 200–0, respectively; however, the difference with respect to the control was only 66 kg/ha.

A greater response to biofertilizers was observed in treatments without chemical application (Fig. 6), plots treated with *Azospirillum* showed a yield increase of 9.6%, *Glomus* 4.9%, and 3.0% with the mixture *Glomus* + *Azospirillum*. Plots treated with nitrogen and the mixture *Glomus* + *Azospirillum* showed a yield increase of 0.8%, whereas those treated with nitrogen, phosphorus, and *Azospirillum* 1.9%. This type of response can be attributed the lack of fixation of atmospheric nitrogen by the biofertilizers, because nitrogen availability in the soil is high and therefore the symbiotic process is not established (Aguirre et al. 2010).

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### Characteristics and descriptions of phenotypic components of Huatabampo Oro C2009, a new durum wheat cultivar for southern Sonora, Mexico.

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**Introduction.** Before the 1990s, bread wheat was the dominant class in northwest Mexico. In the state of Sonora, bread wheat occupied more than 50% of the area dedicated to wheat from the agricultural season of 1983–84 to 1993–94. However, many wheat producers have turned to durum wheat since the implementation of the domestic quarantine No. 16 (SARH, 1987), which limited the cultivation of bread wheat in fields where Karnal bunt had been detected at levels greater than 2% infected grains. Other important factors were that durum wheat showed greater grain yield than bread wheat and that, during that period of time, this crop did not have problems with leaf rust. In addition, there were opportunities for export of durum wheat.

Durum wheat was consolidated as the dominant class grown in Sonora beginning with the agricultural season 1994–95. Altar C84 was the most cultivated cultivar up to 2002–03, despite the fact that its resistance to leaf rust had already been overcome by a wheat race, which caused production losses during 2000–01 and 2001–02. Seed production of cultivar Júpate C2001 (Camacho-Casas et al. 2004) (resistant to leaf rust) through the collaborative project between



the Mexican National Institute For Forestry, Agriculture, and Livestock Research (INIFAP) and the International Maize and Wheat Improvement Center (CIMMYT) with support by the farmer's union (PIEAES) of the Yaqui Valley, made it the most widely grown cultivar in southern Sonora from 2003–04 to 2008–09 (Table 5, Fuentes-Dávila et al. 2010a). Átil C2000, a high-yielding cultivar released in 2001 that became susceptible to leaf rust in 2001–02 (Figueroa-López et al. 2002), occupied 53,106.07 ha.

**Table 5.** Area (ha) grown with wheat during the 2008–09 agricultural season in southern Sonora, Mexico.

Cultivar	Area (ha)	% of total area
<b>Durum wheat</b>		
Júpare C2001	119,327.38	42.34
Átil C2000	53,106.07	18.84
Samayoa C2004	29,062.75	10.31
Banámichi C2004	13,652.76	4.84
Platinum	7,741.92	2.75
Aconchi C89	1,067.14	0.38
Altar C84	491.66	0.17
Rafi C97	478.20	0.17
Nácori C97	10.00	0.004
TOTAL	224,937.90	
<b>Bread wheat</b>		
Kronstad F2004	29,818.81	10.58
Tacupeto F2001	23,733.23	8.42
Tarachi F2000	1,615.60	0.57
Rayón F89	1,045.33	0.37
Abelino F2004	638.18	0.23
Navojoa M2007	9.60	0.003
Roelfs F2007	9.60	0.003
TOTAL	56,870.34	

Júpare C2001 did not comply with the expected protein content in the grain and color, which are very important parameters of quality. In addition, new races of leaf rust present during 2008–09 overcame its resistance, and the area occupied with this cultivar decreased significantly in 2009–10, while that for Átil C2000 increased (Table 6, Fuentes-Dávila et al. 2011). Therefore, options for cultivars resistant to leaf rust for this region must be increased so that they contribute to help the long-lasting use by wheat producers in Sonora and in northwest Mexico and at the same meet current minimum quality requirements for export.

**Table 6.** Area (ha) grown with wheat during the 2009–10 agricultural season in southern Sonora, Mexico.

Cultivar	Area (ha)	% of total area
<b>Durum wheat</b>		
Átil C2000	81,777	33.07
Júpare C2001	53,164	21.50
Samayoa C2004	23,318	9.43
Sáwali Oro C2008	4,761	1.93
CIRNO C2008	3,256	1.32
CEVY Oro C2008	3,233	1.31
Platinum	2,655	1.07
Patronato Oro C2008	2,325	0.94
Aconchi C89	1,019	0.41
RSM Imperial C2008	980	0.40
Banámichi C2004	826	0.33
RSM Chapultepec C2008	499	0.20
Rafi C97	351	0.14
Río Colorado	296	0.12
Nácori C97	241	0.10
Altar C84	105	0.04
TOTAL	178,806	
<b>Bread wheat</b>		
Tacupeto F2001	40,552	16.40
Kronstad F2004	25,021	10.12
Abelino F2004	736	0.30
RSM-Norman F2008	659	0.27
Rayón F89	636	0.26
Tarachi F2000	384	0.16
Roelfs F2007	248	0.10
Navojoa M2007	235	0.10
Monarca F2007	4	0.00
TOTAL	68,475	

**Pedigree, history selection and description of Huatabampo Oro C2009.** After evaluation of grain yield since the 2007–08 agricultural season at the Yaqui Valley Experimental Station (renamed as Norman E. Borlaug Experimental Station, CENEB, since March 2010), we proposed the release the experimental durum wheat line ‘GUAYACAN INIA/ POMA\_2//SNITAN/4/D86135/ACO89//PORRON\_4/3/SNITAN’ as cultivar Huatabampo Oro C2009 (Fuentes-Dávila et al. 2010b). Huatabampo Oro C2009 is a spring-type durum wheat cultivar that originated from hybridizations made in the Durum Wheat Breeding Program of CIMMYT. The cross number and history selection is CDSS02B00562S-0Y-0M-2Y-1M-04Y-0B. Shuttle breeding was carried out between the experimental stations of El Batán, state of Mexico (B) (19°30'N and 2,249 msnm); San Antonio Atizapán, state of Mexico (M) (19°17'N and 2,640 msnm); and the Yaqui Valley

(Y) (27°20'N and 40 msnm), in Sonora (Table 7).

The most important phenotypic characteristics of this cultivar, according to the International Union for the Protection of New Varieties of Plants (UPOV 1994), are given in Table 8 (p. 69). Cultivar Huatabampo Oro C2009 has an average of 78 days-to-heading with a range of 68 to 86. The cultivar has an average of 118 days to physiological maturity; however, the cycle may be shortened due to the lack of cold hours if planting is late, and may average 107 days when sowing is done at the end of December. Huatabampo Oro C2009 has an average height of 86 cm (Fig. 7), a maximum of 100 and minimum of 75. Plant growth habit is erect, and shows no or low frequency of recurved flag leaves.

Spike shape in profile view is tapering, density is medium, and the length excluding awns is medium; awns are longer than the spikes. Spike glaucosity is strong, and awns are distributed the whole length and have a brown color. At maturity, spikes become pigmented. Glume shape is ovoid (spikelet in mid-third of spike), and hairiness on the external surface is present. The shape of the shoulder is rounded and the width is narrow; length of the beak is short and slightly curved. Grain shape is elongated (Fig. 8), and the length of brush hair in dorsal view is medium. Grain coloration when treated with phenol is absent or very light.

**Acknowledgements.** The authors wish to thank Dr. Karim Ammar, Head of the Durum Wheat Breeding Program of the International Maize and Wheat Improvement Center (CIMMYT), for providing the advanced lines from which Huatabampo Oro C2009 originated.

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**Table 7.** Selection history and localities where cultivar Huatabampo Oro C2009 was evaluated. Yield trials at INIFAP were at the following plant dates: 15, 30 November, 15 December, and 1 January. For season, F–W = autumn–winter, S–S = spring–summer; For irrigation conditions, RR = regular rainfed, NI = normal irrigation.

Activity	Locality	Season	Irrigation conditions
Simple genetic cross	El Batán, Mexico	S–S / 2002	RR
F <sub>1</sub> generation	Cd. Obregon, Sonora	F–W / 2002–03	NI
F <sub>2</sub> generation	Cd. Obregon	F–W / 2003–04	NI
F <sub>3</sub> generation	Atizapan, Mexico	S–S / 2004	RR
F <sub>4</sub> generation	Cd. Obregon	F–W / 2004–05	NI
F <sub>5</sub> generation	Atizapan	S–S / 2005	RR
F <sub>6</sub> generation	Cd. Obregon	F–W / 2005–06	NI
F <sub>7</sub> generation yield trials by CIMMYT	El Batán	S–S / 2006	RR
Yield trials by INIFAP	Cd. Obregon	F–W / 2007–08	NI
		F–W / 2008–09	NI



**Fig. 7.** Huatabampo Oro C2009 durum wheat cultivar has an average height of 86 cm. Plants are erect and present no or very low frequency of recurved flag leaves.



**Fig. 8.** The grain shape of Huatabampo Oro C2009 durum wheat cultivar is elongated. In the dorsal view, pubescence is of medium length. Grain coloration after treatment with phenol is absent or very light.

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**Table 8.** Characteristics and description of phenotypic components of cultivar Huatabampo Oro C2009.

Structure	Characteristic	Description
Coleoptile	Anthocyanin coloration	Strong
First leaf	Anthocyanin coloration	Absent or very weak
Plant	Growth habit	Erect
	Frequency of plants with recurved flag leaves	Absent or very low
	Seasonal type	Spring
Spike	Time of emergence	Early
	Glaucosity	Strong
	Length (stem, ear and awns)	Medium
	Distribution of awns	Whole length
	Awns at tip of spike in relation to spike	Longer
	Length excluding awns	Medium
	Hairiness of margin of first rachis segment	Absent or very weak
	Color (at maturity)	Pigmented
	Shape in profile view	Tapering
	Density	Medium
Flag leaf	Glaucosity	Strong
	Glaucosity of blade	Weak
Awn	Anthocyanin coloration	Absent or very weak
	Color	Brown
Culm	Hairiness of uppermost node	Weak
	Glaucosity of neck	Medium
Lower glume	Shape (spikelet in mid-third of ear)	Ovoid
	Shape of shoulder	Rounded
	Shoulder width	Narrow
	Length of beak	Short
	Shape of beak	Slightly curved
Straw	Hairiness on external surface	Present
	Pith in cross section (half way between base of ear and stem node below)	Medium
Grain	Shape	Elongated
	Length of brushhair in dorsal view	Medium
	Coloration with phenol	Absent or very light

### *Evaluation of grain yield of durum wheat cultivar Movas C2009.*

José Luis Félix-Fuentes, Guillermo Fuentes-Dávila, Pedro Figueroa-López, Víctor Valenzuela-Herrera, Gabriela Chávez-Villalba, and José Alberto Mendoza-Lugo.

**Introduction.** Northwest Mexico, comprised by the states of Sonora, Sinaloa, and South and North Baja California, is the main wheat-producing region of Mexico with approximately 460,000 ha. In this region, wheat producers have a high

demand for cultivars with important agronomic and quality characteristics; this, in turn, forces and maintains dynamic breeding programs that evaluate experimental germ plasm under different environments. Every crop season, wheat lines that show stability in main parameters, such as grain yield, quality, and disease resistance, are proposed for commercial release. After several crop seasons of evaluation, the experimental spring durum wheat CIMMYT line 'CMH83.2578/4/D88059//WARD/ YAV79/3/ACO89/5/2\*SOOTY\_9/RASCON\_37/6/1A.1D5+106/3\*MOJO/3/AJAIA\_12/ F3LOCAL (SEL.ETHIO. 135.85)//PLATA\_13' was released as the commercial cultivar Movas C2009 (Félix-Fuentes et al. 2010). The cross number and selection history is CDSS02B00720S-0Y-0M-8Y-1M-04Y-0B. Evaluations of grain yield of Movas C2009 and the check cultivar Júpare C2001 are presented here.

**Materials and methods.** This study was at the Norman E. Borlaug Experimental Station (CENEB), which belongs to the Northwest Regional Research Center (CIRNO) of the Mexican National Institute for Forestry, Agriculture and Livestock Research (INIFAP), located in block 910 of the Yaqui Valley (27°22' latitude north, 109°55' longitude west, at 38 masl). Grain yield of Movas C2009 and the check cultivar Júpare C2001 was evaluated in four sowing dates with two and three complementary irrigations during the crop season autumn–winter 2008–09 (Table 9), with two and four complementary irrigations during the 2009–10 crop season (Table 10), and with drip irrigation (full irrigation) during crop seasons 2005–06 to 2008–09 on one sowing date (1 December), in block 810 at CIM-

MYT area. Experimental plots were 5-m long on two beds with two rows; space between beds was 0.8 m. Sowing dates were 15 November, 1 and 15 December, and 1 January, in dry clay soil using 100 kg of seed/ha. Fertilization consisted of 100 units of N (as urea) and 100 units of P (as monomium phosphate) before seeding. The trial was irrigated right after seeding and later during the season complementary irrigations were provided as indicated

(Tables 9 and 10). Also, 100 units of N were applied before the first complementary irrigation and 50 before the second. The herbicide Situi® xl at 25 g/ha of commercial product was sprayed over the trial 30 days after sowing. Statistical analysis was performed using SAS, and mean comparison with Tukey's test (0.05).

**Results and discussion.** The results of the evaluation during the 2008–09 crop season with two and three complementary irrigations indicated that the best sowing date, in order to obtain the highest yield potential of both cultivars Movas C2009 and Júpare C2001, was 1 December, which produced an average of 6.1 ton/ha, followed by the first sowing date with 5.8 (Table 11, p. 71). In general, sowing between 15 November and 1 December 1 allows the accumulation of more cold units (CU) that render better grain yield by wheat cultivars in the Yaqui Valley. Félix-Valencia et al. (2009)

**Table 9.** Dates of application of the two and three complementary irrigations for cultivars Movas C2009 and Júpare C2001 at four sowing dates during the autumn–winter crop season 2008–09, at the Norman E. Borlaug Experimental Station in Sonora, Mexico (D = sowing, IR = two and three complementary irrigations, days after sowing are indicated in parentheses following date).

1D 2IR	6 January (50)	17 February (92)	
1D 3IR	31 December (44)	5 February (80)	2 March (107)
2D 2IR	23 January (53)	3 March (90)	
2D 3IR	14 January (44)	18 February (79)	12 March (103)
3D 2IR	6 February (53)	10 March (87)	
3D 3IR	28 February (44)	4 March (81)	27 March (104)
4D 2IR	26 February (56)	26 March (86)	
4D 3IR	13 February (43)	10 March (67)	3 April (93)

**Table 10.** Dates of application of the two and three complementary irrigations for cultivars Movas C2009 and Júpare C2001 at four sowing dates during the autumn–winter crop season 2009–10, at the Norman E. Borlaug Experimental Station in Sonora, Mexico (D = sowing, IR = two and three complementary irrigations, days after sowing are indicated in parentheses following date).

1D 2IR	6 January (50)	18 February (93)		
1D 4IR	24 December (37)	22 January (67)	18 February (93)	5 March (110)
2D 2IR	10 January (50)	3 March (90)		
2D 4IR	8 January (38)	9 February (70)	4 March (95)	19 March (110)
3D 2IR	10 February (57)	23 March (100)		
3D 4IR	22 January (38)	24 February (71)	19 March (96)	29 March (106)
4D 2IR	23 February (54)	26 March (91)		
4D 4IR	11 February (42)	17 March (76)	29 March (91)	15 April (107)



reported that with an accumulation of 340 CU, wheat grain yield would be approximately 4,630 kg/ha, and for each increment of 100 CU, yield will increase by 330 kilograms. The average grain yield of Movas C2009 in four sowing dates with two complementary irrigations registered 0.7

ton/ha greater than that of the check cultivar Júpare C2001, although the highest yield difference was recorded in the 1st sowing date with 0.9 ton/ha (Table 12). The average difference in grain yield was 0.8 ton/ha in favor of Movas C2009 with three complementary irrigations, and the highest difference was recorded again in the 1st sowing date with 2.6 ton/ha. The effect generated by water stress on a wheat crop depends on the phenological stage of the plant, pre- and post-anthesis being the most susceptible to this abiotic factor. During the evaluation in 2008–09, the average temperature during this stage was 16°C (Fig. 9). Most of the assimilates that are stored in the grain are generated during grain filling, therefore, a preanthesis reserve does not increase with water stress, as expressed as the proportion of dry weight of the crop during anthesis, but increases as yield proportion.

**Table 11.** Average grain yield of cultivars Movas C2009 and Júpare C2001 with two and three complementary irrigations during autumn–winter 2008–09 crop season, at the Norman E. Borlaug Experimental Station in Sonora, Mexico. For grain yield, columns with the same letter are statistically similar (Tukey,  $p = 0.05$ ).

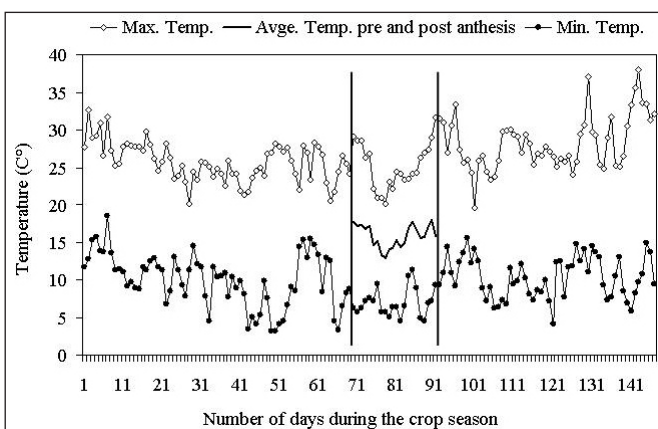
Sowing date	Grain yield (ha)
1st	5.8 ab
2nd	6.1 a
3rd	5.4 bc
4th	5.1 c

**Table 12.** Grain yield of cultivars Movas C2009 and Júpare C2001 in four sowing dates with two and three complementary irrigations during autumn–winter 2008–09 crop season, at the Norman E. Borlaug Experimental Station in Sonora, Mexico.

Number / date of irrigation	Cultivar	
	Movas C2009	Júpare C2001
<b>Two irrigations</b>		
15 November	6.8	5.9
1 December	6.2	5.4
15 December	6.0	5.6
1 January	5.3	4.7
Average	6.1	5.4
<b>Three irrigations</b>		
15 November	6.7	4.1
1 December	7.0	5.9
15 December	4.4	5.7
1 January	5.4	4.8
Average	5.9	5.1

**Table 13.** Grain yield of cultivars Movas C2009 and Júpare C2001 in four sowing dates with two and four complementary irrigations during autumn–winter 2009–10 crop season, at the Norman E. Borlaug Experimental Station in Sonora, Mexico.

Number / date of irrigation	Cultivar	
	Movas C2009	Júpare C2001
<b>Two irrigations</b>		
15 November	6.6	6.6
1 December	7.1	6.5
15 December	6.4	5.5
1 January	6.3	5.3
Average	6.6	6.0
<b>Four irrigations</b>		
15 November	7.0	6.7
1 December	8.4	7.9
15 December	7.7	7.3
1 January	7.2	5.7
Average	7.6	6.9



**Fig. 9.** Maximum, minimum, and average temperature during pre- and post-anthesis during the 2008–09 autumn–winter wheat season at the Norman E. Borlaug Experimental Station, Sonora, Mexico.

Movas C2009 expressed its grain yield potential with four complementary irrigations during the 2009–10 crop season with an average of 7.6 ton/ha and a maximum of 8.4 in the second sowing date (Table 13). The yield difference ranged from 1 to 1.7 t/ha when Movas C2009 had two or three complementary irrigations during crop seasons 2008–09 and 2009–10. Movas C2009 showed a higher grain yield than that of Júpare C2001, with an average difference of 0.65 t/ha with two and four complementary irrigations during 2009–10.

The difference in grain yield for Movas C2009 between the average of the first two sowing dates and the average of the third and fourth ones, was 0.850 t/ha with two irrigations in 2008–09 and 0.500 in 2009–10 in favor of the first two sowing dates. The same trend was found in 2008–09 with three irrigations (1.950 t/ha difference) and in 2009–10 with four ir-



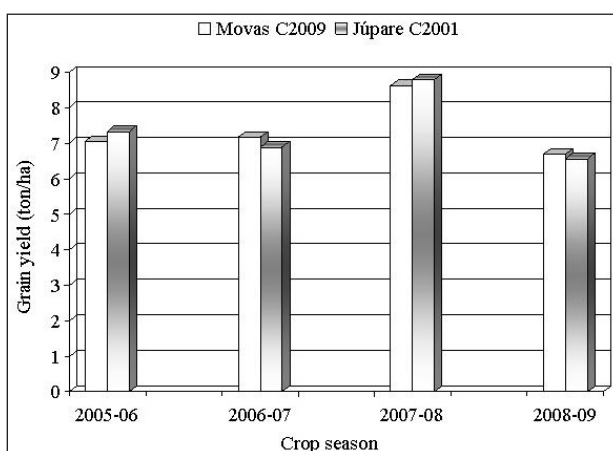
rigations (0.250 t/ha). The low grain yield obtained on the dates considered as late (third and fourth) can be attributed to the high temperatures registered in the region when plants were in a vegetative stage and under this stress and represents a decrease in grain number. Fokar et al. (1998) and Savin et al. (1997) have reported significant variation in reduction of grain number and weight/spike under heat stress. The environmental stress may be different but most have a common effect on the hydric status of the plant (Bohnert et al. 1995).

Moderate water stress in a wheat plant causes a foliar reduction and, according to Abbate et al. (1997), anthesis takes place earlier than normal. Anthesis is delayed when a more severe stress occurs, being able to be modified on the day spike growth ends, however, Abbate and Cantarero (2001) reported that the duration of spike growth is not affected in a significant way by drought. The way in which a plant responds under such conditions depends on the species, because the mechanisms that confer tolerance to stress in many instances have evolved in a specific way for certain plant groups. Ortiz (2009) reported that only the first complementary irrigation can be delayed without affecting normal plant development; this irrigation is applied during tillering, 35 to 40 days after sowing. The second irrigation is applied during heading or flowering, 74 to 85 days after sowing, and can affect grain yield if delayed. The third and fourth irrigations are applied during the milky stage; the number of days to reach this stage is about 100 days, depending on the sowing date.

The grain yield of Movas C2009 and the check cultivar Júpare C2001 was similar during the different crop seasons of evaluation under drip irrigation (Fig. 10). Movas C2009 showed a greater grain yield than that of Júpare C2001 in a range of 0.14 to 0.28 t/ha during 2008–09 and 2006–07, respectively. The highest yield by Movas C2009 was 7.17 t/ha during crop seasons 2007–08 and 2005–06. Grain yield of Júpare C2001 was greater than that of Movas C2009, 0.170 to 0.290 t/ha, respectively. The highest yield by Júpare C2001 was 8.79 t/ha. Although this type of irrigation maintains a hydric status in the soil, which avoids water stress in the plant, environmental conditions vary from season to season and may have an effect on grain yield, as it was shown in contrasting crop seasons 2007–08 and 2008–09; grain yield difference in Movas C2009 in both seasons was 1.92 t/ha and 2.23 t/ha for Júpare C2001.

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**Fig. 10.** Grain yield of cultivars Movas C2009 and Júpare C2001 under drip irrigation in block 810 at CIMMYT, during the autumn–winter 2005–06 to 2008–09 crop seasons in the Yaqui Valley, Sonora, Mexico.

***Effect of green manure crops and inoculation with *Glomus intraradices* on the quality and yield of wheat in the Yaqui Valley, Sonora, Mexico.***

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**Abstract.** The effect of inoculating wheat seed with *Glomus intraradices* and the interaction with incorporation of maize (*Zea mays*), *Sesbania exaltata*, *Clitoria ternatea*, and sorghum (*Sorghum bicolor*) as green manure on wheat grain yield and quality was studied. Green manure treatments were compared with a control treatment that consisted of a fallow plot during the summer. A randomized complete block split-plot design with three replications was used to evaluate the treatments. Significant statistical differences were detected for grain yield, between green manure treatments, and the interaction between green manure and inoculation treatments. Grain yield was 7.690, 7.653, 7.590, 7.433, and 7.115 t/ha for *Clitoria*, sorghum, *Sesbania*, the control, and maize, respectively. There was a significant and positive interaction between *Glomus* and sorghum. The average grain yield of the biofertilizer treatment was 7.632 t/ha and 7.36 for the control. Wheat grain yield was 7.394 t/ha when green manure crops were established under irrigation, and 7.597 t/ha under rainfed conditions. For grain protein, the only significant difference was between irrigation treatments for green manure crops; a greater grain protein content (10.32%) was found in treatments where green manure crops were irrigated than those where green manure crops grew under rainfed conditions (9.67%). An average of 10.16% was obtained when seed was inoculated with *Glomus*, and 9.83% when it was not.

**Introduction.** The use of biological fertilizers is a practice of great interest in the last few years. The practice consists in inoculating seed with beneficial, natural soil microorganisms, increasing its concentration in the rhizosphere (Ferraris and Couretot 2006). Macías (2004) evaluated the use of biofertilizers in wheat during three crop seasons in northern Sinaloa, Mexico, and reported a 700 to 1,280 kg/ha increase with the use of the rhizobacterium *Azospirillum brasilense*, and from 300 to 820 kg/ha with the use of the fungal mycorrhiza *Glomus intraradices*, with respect to a control without nitrogen fertilization. In soil in the Yaqui Valley with 166 kg/ha of nitric nitrogen and 30 kg/ha of phosphorus available, Cortés (2000) did not find significant differences between the inoculation with *A. brasilense* and *G. intraradices*, fertilization with the formula NPK 200-52-0, and the absolute control; grain yield was 6.406, 6.696, and 6.128 t/ha, respectively. When *G. intraradices* or *A. brasilense* were used separately, grain yield was lower than that of the absolute control. Treatment with the rhizobacterium accumulated 28.3 kg/ha of additional nitrogen in relation to the absolute control. According to the information available, associations with *A. brasilense* are capable of fixing from 12 to 313 kg of nitrogen per ha per year depending on the conditions. In the case of the *Glomus* spp., it is generally accepted that this type of microorganisms increases the absorption of those nutrients that have very low mobility in the soil, such as phosphorus (Marschner 1986). Ferraris and Couretot (2006) reported an additive behavior without the interaction of inoculation by chemical fertilization in relation to yield, which coincides with the results obtained in northwest Mexico (Manjarrez 2002; Manjarrez et al. 2002; Macías 2002).

On the other hand, green manure is a type of cover crop grown primarily to add nutrients and organic matter to the soil. Typically, a green manure crop is grown for a specific period and then plowed under at the flowering stage and incorporated into the soil. In general, green manure crops are decomposed in and on the soil and are an ideal food-stuff for soil microorganisms (Kulmans and Vásquez 1999). They also increase the resistance to abrupt pH modification, provide substances such as phenols that contribute to plant respiration, and facilitate greater absorption of phosphorus and a better plant health (Guerrero 1993). Incorporation of green manure crops also is very important in crop rotation, because they increase production, incorporate residues, improve the soil cover, and interrupt the life cycles of pests, diseases, and weeds (Altieri and Nicholls 2000). The use of green manure is an option that will depend upon the objectives proposed, the area, weather conditions, and the main crop to be cultivated. In the case of the Yaqui Valley, it is possible to establish a green manure leguminous crop after wheat harvest, from July to September, in order to take advantage of the rainy period, by which the production of green material rises and nitrogen is delivered into the soil (García and Martínez 2011). This study evaluated the effect of inoculating wheat seed of durum cultivar CIRNO C2008 with the fungal mycorrhiza *G. intraradices* and the incorporation of green manure crops during the summer on grain yield and quality of the same cultivar.

**Materials and methods.** A study on the effect of green manure crops maize, *S. exaltata*, *C. ternatea*, sorghum, and a control treatment on wheat grain yield and quality was carried out at the Norman E. Borlaug Experimental Station during 2009–10. A randomized complete block split-plot design with three replications was used to evaluate treatments. The main plot corresponded to the green manure crops, the subplot to the irrigation treatments in the green manure crops, and the sub-subplot to seed inoculation with *G. intraradices*. The experimental plot consisted of four beds with two 50-m

rows each with a separation of 0.80 m (160 m<sup>2</sup>), whereas the experimental unit consisted of two 3-m long beds. Mean comparison was performed with Tukey's multiple range test ( $p = 0.01$  and  $0.05$ ). Weed control was carried out manually.

Crops were established in the month of June and incorporated as green manure in September of 2009. They were irrigated for germination and, later, half the area of each plot was irrigated twice on 30 July and 14 August, and the other half was left under rainfed conditions. The durum wheat cultivar CIRNO C2008 was sown in humid soil on 7 December, 2009, in those plots where the green manure crops had previously been incorporated. The seed that was inoculated with *G. intraradices* was treated at the rate of 1.0 kg/ha/30 kg of seed. Three complementary furrow irrigations were applied 46, 75, and 94 days after sowing.

**Results and discussion.** Significant statistical differences were detected between the green manure treatments, and the interaction between green manure and inoculation treatments for grain yield. In all cases, greater yield was detected in plots where the seed was inoculated with *G. intraradices*, except when maize was established as green manure crop under rainfed conditions. Incorporation of leguminous crops grown under irrigation or rainfed conditions, produced greater wheat grain yield with or without inoculation with the mycorrhiza; this phenomenon was not observed with incorporation of gramineous crops. In the case of maize, its incorporation as green manure caused a reduction in grain yield under all the different conditions of evaluation, whereas sorghum caused a reduction in yield when CIRNO C2008 was not inoculated with *G. intraradices*, but it significantly increased when inoculated with the mycorrhiza. The treatment with the greatest average wheat grain yield (7.690 t/ha) was obtained with the incorporation of *C. ternatea*, whereas the lowest yield was obtained with incorporation of maize. The significant statistical interaction between green manure crops and inoculation treatments indicated that inoculation with *G. intraradices* produced greater wheat grain yield, only when the green manure crop incorporated was sorghum (Table 14).

**Table 14.** The effect of green manure crops and inoculation with *Glomus intraradices* on the grain yield (t/ha) of durum wheat cultivar CIRNO C2008. Inoculation x green manure crop, Tukey 0.05 = 0.536; green manure crop, Tukey 0.05 = 0.473.

Green manure crop	Without <i>G. intraradices</i>		With <i>G. intraradices</i>		Mean
	Irrigated	Rainfed	Irrigated	Rainfed	
Sorghum	7.127 a	7.167 a	8.153 b	8.163 b	7.653 a
<i>Clitoria</i>	7.523 a	7.700 a	7.587 a	7.950 a	7.690 a
Control	7.290 a	7.497 a	7.320 a	7.623 a	7.433 ab
<i>Sesbania</i>	7.363 a	7.660 a	7.367 a	7.970 a	7.590 ab
Maize	7.017 a	7.257 a	7.197 a	6.990 a	7.115 b
Mean	7.264 a	7.456 a	7.525 a	7.739 a	

For grain protein, the only significant difference was between irrigation treatments for green manure crops; there was a positive effect when crops were established under irrigation compared to rainfed conditions, because the percentage of protein increased (Table 15). During this first study, the grain yield obtained without fertilizers, including the control, indicated a great amount of residual nitrogen in the soil from trials carried out in previous wheat seasons. This also indicates the low efficiency of wheat for taking up this element. The greater wheat grain yield obtained when green manure crops

were established under rainfed conditions could be explained by the fact that under this condition they produce a small amount of biomass, which in turn requires less time to be mineralized, and the nitrogen becomes immovable for a shorter period of time.

**Table 15.** The effect of green manure crops and inoculation with *Glomus intraradices* on the grain protein content (%) of the durum wheat cultivar CIRNO C2008. Inoculation x irrigation, Tukey 0.05 = 0.634.

Green manure crop	Without <i>G. intraradices</i>		With <i>G. intraradices</i>		Mean
	Irrigated	Rainfed	Irrigated	Rainfed	
Sorghum	9.94	9.71	10.12	10.07	9.96
<i>Clitoria</i>	10.12	9.25	10.45	10.08	9.97
Control	10.44	9.85	10.71	9.82	10.24
<i>Sesbania</i>	9.91	8.08	10.28	9.87	9.54
Maize	10.68	10.25	10.46	9.67	10.27
Mean	10.22 a	9.43 b	10.41 a	9.90 a	

**Conclusions.** The incorporation of leguminous crops as green manure helps to increase wheat grain yield. The use of mycorrhizae such as *G. intraradices* as seed inoculants must continue being investigated in order to determine the interactions that provide its optimum use on wheat, as well as the use of irrigation on the production of green manure.

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***Evaluation of the biological effectiveness of BTN+ in rainfed wheat.***

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**Introduction.** Intensive agricultural activities constantly deteriorate soil fertility, therefore, the theories of minimum tillage and the use of plant residues after harvest aim to partially reestablishing the fertile condition of soils. Soil bacteria form part of this biological complex and have a key role in production of organic matter. The soil is an ecosystem that harbors five main groups of microorganisms: bacteria, actinomycetes, fungi, algae, and protozoa are considered inhabitants of the community. Bacteria have a wide biochemical diversity, so they are the most abundant of the groups. The bacterial population in the soil is large, although individuals measure a few micrometers in length.

The commercial product BTN+ is distributed and commercialized by the company GrowGreen Mexico, a subsidiary of Bio Tech Nutrients LLC, from Las Vegas, NV, U.S., and it is publicized as 'plant feed'. BTN+ is composed of carbon, hydrogen, oxygen, micronutrients, humic acid, fulvic acid, kelp, soil microbia, and enzymes. BTN+ utilizes energized carbon and bacteria, which according to the company, reduce salts in the soil and consequently reduce the soil electrical conductivity (EC), making nutrients available to the plant. Our objective was to evaluate the biological effectiveness of BTN+ on wheat cultivar Arandas F90 under rainfed conditions.

**Materials and methods.** A randomized complete block design with three treatments and six replication was used for this study, using bread wheat cultivar Arandas F90 under rainfed conditions. The study was carried out at the Centro-Altos de Jalisco Experimental Station, in Tepatitlan, Jalisco, Mexico, during the summer 2009. The soil type where the experiment was established was a loam-clay, pH 5.0–5.6, with a deficient organic matter content of 0.84–0.90%. The



sowing date was 9 July, 2009, once the rainfall period was established. The treatments were as follows: 1. BTN+, 2. fertilization formula according to INIFAP's technical recommendation, and 3. control without any fertilization (Table 16).

Foliar applications were made with a manual sprayer with a 20 L capacity and a Tee Jeet 8004 flat nozzle using a rate proportional to 200 L/ha of water. For the INIFAP treatment, the fertilization formula

180-60-00 was obtained by a physical mixture of 130.5 kg of the formula 18-46-00 + 145 kg of urea. The experimental plot was 8.0 m x 8.0 m with a proportional quantity of fertilizer (835.2 g + 928 g of 18-46-00 + urea/experimental plot (64 m<sup>2</sup>), for the first application, and 1,248 g of urea for the second application. The experimental unit was 4.0 m x 4.0 m (16 m<sup>2</sup>), according to the protocol.

The variables evaluated were days to flowering, days to physiological maturity, and grain yield (kg/ha). Harvest was carried out with a Pullman stationary thresher. Three soil samples were taken randomly during sowing; they were made up of six sub-samples obtained at 0–15 cm depth, which represents the arable horizon.

### Results and discussion

**sion.** Although the experiment was established once the rainfall period started, three weeks later there was a two week interval of drought, which somewhat effected the overall development of the wheat plant, with a consequent delay in the application of treatments. Because of this drought, weed control practices were limited, but days to flowering, heading, height, and physiological maturity were the same, because the same cultivar was used in all treatments; therefore, data on those parameters is not presented.

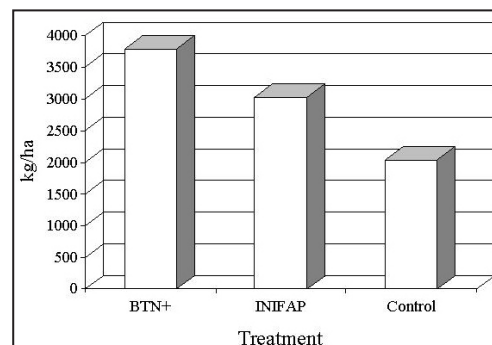
Grain yield with BTN+ ranged from 2,468.75 to 4,859.38 kg/ha, INIFAP's treatment ranged from 1,531.25 to 5,500, and the control was 937.50 to 3,250.00 (Table 17). BTN+ showed the highest yield in four of the six replications; whereas INIFAP's treatment was highest in two, which included the overall highest yield of 5,500 kg/ha in the sixth replication. The yield average of the six replications ranged from 2,468.75 to 3,765.63 kg/ha. Average grain yield of the BTN+ treatment was 3,791.67 kg/ha (Fig. 11), but it was not statistically different from INIFAP's treatment (3,028.65) (Table 18, p. 77). Average yield of the control was 2,041.67 kg/ha, statistically different from the BTN+ treatment, but not from the INIFAP treatment. The grain yield of the control

**Table 16.** Application of BTN+ and INIFAP recommended fertilizer formula on bread wheat cultivar Arandas F90 at the Centro-Altos de Jalisco Experimental Station, in Tepatitlan, Jalisco, Mexico, during summer 2009.

Treatment	Application	Date
BTN+	1 <sup>st</sup> application: 41 L/ha of the liquid product, sprayed during sowing and on the seed.	9 July
	2 <sup>nd</sup> application: 18 L/ha of Carbon Burst solution to the foliage.	14 August
	3 <sup>rd</sup> application: 25 oz/ha (750 mL/ha) of fungicide Quadris two weeks after the 2 <sup>nd</sup> application.	27 August
	4 <sup>th</sup> application: two weeks later, 18 L/ha of Carbon Burst + 10 oz (300 mL) of Quadris.	14 September
INIFAP's technical recommendation (160-60-00)	The formula 80-60-00 was applied during sowing.	9 July
	Complementary application 80-00-00	9 August
Control	No fertilizer application.	

**Table 17.** Grain yield (kg/ha) of the bread wheat cultivar Arandas F90 under different nutrient treatments, at the Centro-Altos de Jalisco Experimental Station, in Tepatitlan, Jalisco, Mexico, during summer 2009.

Treatment	Replication					
	I	II	III	IV	V	VI
BTN+	3,687.50	4,859.38	4,218.75	3,765.63	2,468.75	3,750.00
INIFAP (160-60-00)	3,250.00	3,187.50	1,531.25	1,765.63	2,937.50	5,500.00
Control	937.50	3,250.00	2,187.50	2,000.00	2,000.00	1,875.00
Mean	2,625.00	3,765.63	2,645.83	2,510.42	2,468.75	3,708.33



**Fig. 11.** Average grain yield of the bread wheat cultivar Arandas F90 under three different nutrient treatments at the Centro-Altos de Jalisco Experimental Station in Tepatitlan, Jalisco, Mexico, during summer 2009.

indicated a normal soil fertility, either due to residue from the previous crop or other factors not considered in this study.

The study of the rhizosphere is complicated, because three important components converge: soil, plants, and microorganisms. Microorganisms are highly

influenced by plant exudates, soil pH, and the physico-chemical condition. Exudates reported include carbohydrates of different types, nucleotides, flavonoids, enzymes, plant hormones, and aminoacids. These compounds are generated by the photosynthetic and metabolic activity of the plant (carbon compounds,  $H^+$ , inorganic ions, organic acids, or reducing agents). To conclude that BTN+ was the best treatment for wheat grain yield under rainfed conditions in Tepatlitan, Jalisco, Mexico would be biased, because it is not known its composition and the specific effects on the wheat plant or on the microorganisms present in the soil at the experimental station. Although, the average yield obtained with the BTN+ treatment was the highest, we do not know which factors or elements are induced or those that are inhibited or eliminated. On the other hand, the highest yield in this study was obtained with the INIFAP treatment (5,500 kg/ha).

Because several aspects were not included in this study, such as the pH behavior in the soil through time in the different treatments, the identification of population dynamics of the soil microorganisms more representative of the location, or the characterization with greater precision of the plant phenology under the different treatments, repeating the experiment taking into consideration the parameters that were not recorded in this study would be important.

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**Table 18.** Analysis of variance and mean comparison of grain yield (kg/ha) of the bread wheat cultivar Arandas F90 under different nutrient treatments at the Centro-Altos de Jalisco Experimental Station, in Tepatlitan, Jalisco, Mexico, during summer 2009.

SV	df	SS	MS	Fc	Pr>F	
Treatments	2	9,237,657.335	4,818,828.668	4.50	0.0403	*
Replications	5	5,589,586.046	1,117,917.209	1.09	0.4225	NS
Error	10	10,255,506.730	1,025,550.670			
Total	17	25,082,750.110				
Treatment	kg/ha	Significance				
BTN+	3,791.67	a				
INIFAP	3,028.65	ab				
Control	2,041.67	b				