RGON: A REGIONAL STRATEGY FOR FUSARIUM HEAD BLIGHT IMPROVEMENT

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ABSTRACT

In the hard winter wheat region of the Great Plains, Fusarium head blight (FHB) is a sporadic disease. Drought is more common than rain at flowering, however, within the region, rain at and after flowering often occurs in some parts of the region leading to severe FHB in localized areas. Hence the need to identify lines with FHB tolerance is needed, but most plant breeding programs have insufficient plant pathology support and financial support to actively pursue FHB tolerance.

The Regional Germplasm Observation Nursery (RGON) is a USDA coordinated nursery that screens early generation experimental lines for a number of diseases, insects, and abiotic stresses. Every public and private wheat breeding effort in the Great Plains submits between 10 and 40 lines for this collaborative screening effort. The USDA-University of Nebraska wheat improvement effort, with support of US Scab Initiative efforts, proposes testing this nursery for FHB tolerance. The advantages of screening this nursery are: 1) all of the germplasm that is developed and eventually released in the hard winter wheat region will be screened for FHB tolerance, 2) public and private programs have equal access for entering lines into the nursery and for accessing the data, 3) germplasm within the RGON often has Chinese (used to enhance noodle and steamed bread quality) and eastern European (the genetic basis form much of the Great Plains winter wheats) parents from regions where FHB tolerance has been identified, 4) lines that show promise in the initial screen can be further tested for confirmation of the initial data, and 5) the identified germplasm is freely shared.

DETECTION OF QTL LINKED TO FHB RESISTANCE IN SUMAI 3-DERIVED LINES

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ABSTRACT

During the past decade *Fusarium* Head Blight (FHB) has caused severe grain yield and quality losses of wheat in the Northern Great Plains. Given the complexity of breeding for FHB resistance, molecular markers associated with this trait will be valuable in accelerating efforts to breed new resistant varieties. The objective of this study was to identify quantitative trait loci (QTL) for FHB resistance in wheat (*Triticum aestivum* L.) using a set of lines obtained by several cycles of crossing to North Dakota adapted genotypes and deriving their resistance from Sumai 3. Microsatellite markers spanning the wheat genome were used to screen parents and derived lines. Polymorphisms for parental alleles were compared to disease scores for Type II resistance. The probability of linkage between markers and introgressed resistance genes was calculated using a binomial probability formula. Two markers were significantly associated with FHB resistance QTL: Xgwm533 and Xgwm274. (This poster was presented at the 2000 ASA Meetings, Minneapolis, MN, November 5-9, 2000).

TOWARD TRANSFERRING SCAB RESISTANCE FROM A DIPLOID WILD GRASS, *LOPHOPYRUM ELONGATUM*, INTO DURUM WHEAT

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INTRODUCTION

Scab, also known as Fusarium head blight (FHB), pink mold, and tombstone scab – caused by the fungal pathogen *Fusarium graminearum* – is responsible for extensive damage of wheat in humid and semi-humid regions of the world. We earlier found a diploid wild grass, *Lophopyrum elongatum* (2*n*=2*x*=14; EE genome) – a wild relative of wheat, to be an excellent source of resistance to FHB. We therefore hybridized this grass with some commercial durum cultivars and raised BC_1 and subsequent generations. Chromosomal constitution of the advanced hybrid derivatives and their resistance to FHB are described.

MATERIALS AND METHODS

Two durum wheat lines [Langdon, and a Langdon disomic substitution line 5D(5B)] were hybridized as female parents with *Lophopyrum elongatum* following the protocols established earlier (Jauhar and Peterson 1996; 2000a). BC_1 plants were produced from the F_1 hybrids by crossing them to the recurrent durum parent except in the case of Langdon 5D(5B)-derived F_1s, which were backcrossed to Langdon. Advanced backcross generations were produced by subsequent backcrossing.

Fusarium screening was conducted on lines which had seed fertility of 80% or greater according to Jauhar and Peterson (2000a). FHB scores were taken according to the guidelines established by Stack and McMullen (1994).

Cytogenetic studies were conducted on lines showing good resistance (33% or less). Both somatic and meiotic chromosomes where characterized by conventional staining and fluorescent genomic *in situ* hybridization (GISH) as described in Jauhar et al. (1999). Fluorescent GISH was conducted according to Jauhar and Peterson (2000a) except that *L. elongatum* genomic DNA was used as the labeled probe.

RESULTS AND DISCUSSION

We produced several advanced hybrid derivatives from durum × *L. elongatum* crosses. Some of these derivatives were cytologically characterized. The hybrid material with 80% or higher seed fertility was screened for scab resistance. Figure 1 shows the meiotic chromosomes of PRE-17E(127), a BC_1F_2. This hybrid derivative with several chromosomes of the grass parent (Fig. 1B) exhibited good resistance over multiple screenings (Table 1), and was therefore used as a common parent to several advanced lines developed and screened for scab resistance. Efforts were focused on stabilizing the chromosomal constitution and retain scab resistance in several promising hybrid derivatives.

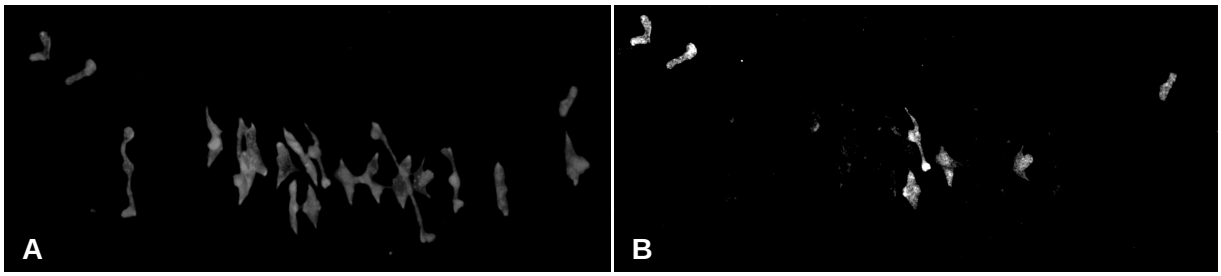

Figure 1. GISH of PRE-17E(127) – a selected hybrid derivative that showed good resistance to FHB. This line was the progenitor of all experimental lines screened in this study. **A.** PI counterstain showing 18II + 3I. **B.** Same cell as A probed with total genomic *L. elongatum* DNA labeled with biotin-14-dATP and detected with FITC. *L. elongatum* chromosomes (4 II + 3I) are clearly visible.

Table 1. Fusarium Head Blight Screening Results from Advanced Hybrid Derivatives.

		Percent infection of plant (average of three spikes)								
Cross / Line	**Plant No.**	**0-7**	**>7-15**	**>15-21**	**>21-33**	**>33-50**	**>50-67**	**>67-80**	**>80-100**	**Mean**
GHBC98-7[a]	4	3	1							7.92
GHBC98-14[a]	13	1	4	3	2	1	1		1	28.62
GHBC98-15[a]	15	3	6		2	3	1			22.02
GHBC98-16[a]	1				1					33.00
GHBC98-17[a]	6		1	2	1	1			1	38.00
GHBC98-18[a]	6	1		1	3	1				28.61
GHBC98-34[a]	16	2	7	3	4					15.98
GHBC98-68[a]	1		1							12.33
GHBC98-76[a]	11	1	7	3						13.76
PRE-17E(127)[b]	12		2	3	5			1	2	30.08
B-6[c]	10	1	6	1	1		1			17.60
B-7[d]	9	2	4	1	2					13.33
Langdon	9		1	1			1	2	4	68.33

[a] Unique crosses between PRE-17E(127) and Langdon [(Langdon/*L. elongatum*//Langdon)F_2/Langdon].

[b] Selected plant showing good resistance to FHB (Jauhar and Peterson, 1998) [(Langdon/*L. elongatum*//Langdon)F_2], derived from line B-6.

[c] BC_1 [Langdon/*L. elongatum*//Langdon] having good fertility, this is the BC_1 parent of PRE-17E(127).

[d] BC_1 [Langdon/*L. elongatum*//Langdon] derived lines from this plant are still in progress.

A general observation was that with the loss of *L. elongatum* chromatin, resistance is also lost. Line B-6 and B-7 both have good levels of resistance but as they were progressively backcrossed and selfed, resistance was lost (Table 1). However, as attempts were made to stabilize the lines through selfing and selection, some resistance is maintained. Figure 2A

shows meiosis of a line from Table 1 that had four *L. elongatum* chromosomes (univalents). This line scored 2% infection. Figure 2B is the selfed progeny from the previous plant having one *L. elongatum* chromosome present (as a univalent) and scored 21% infection. These observations support the assumption that FHB resistance is multigenic with genes occurring on different chromosomes. It is interesting that some of the monosomic addition lines of durum with a single grass chromosome (Fig. 2B) showed considerable resistance, although lower than when multiple grass chromosomes were present. However, several lines scored the same or even worse than the Langdon check. These lines have yet to be characterized cytologically, although some preliminary chromosome work has shown these lines to have the normal durum complement.

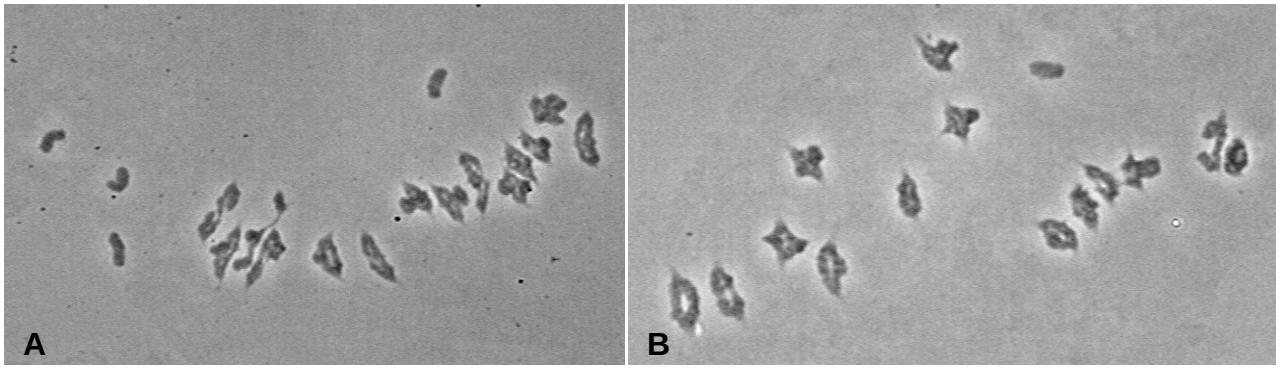

Figure 2. Meiotic chromosomes (under phase contrast) of advanced derivatives that had low infection of FHB. **A.** GHBC98-14 selection from Table 1 which had low infection (2%). This cell has 14 II of durum and 4 I from *L. elongatum*. **B.** Line GHBC98-14-14 selfed progeny from plant in Figure 2A, 14 II of durum and 1I from *L. elongatum*. It is interesting that even with a single grass chromosome this particular plant had a high level of resistance (only 21% infection).

Thus far, we have not been able to obtain disomic addition lines of durum with a pair of grass chromosomes, although we have selfed monosomic addition lines. Earlier, we have shown integration of *L. elongatum* chromatin into the durum genome (Jauhar and Peterson 2000b). Whether these integrations are maintained or whether new integrations have occurred has to be determined. We have not been able to obtain any 28-chromosome hybrid derived durum with an acceptable level of scab resistance. Nevertheless, our studies show that wide hybridization holds considerable promise for breeding scab resistance into wheat. Chromosome-mediated alien gene transfers will continue to play an important role in the germplasm enhancement of wheat (Jauhar and Chibbar 1999).

ACKNOWLEDGEMENTS

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GREENHOUSE BASED EVALUATION OF ASIAN AND ITALIAN WINTER WHEAT GERMPLASM FOR TYPE I RESISTANCE TO FUSARIUM HEAD BLIGHT

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INTRODUCTION

Fusarium graminearum Schwabe (teleomorph *Gibberella zeae* (Schwein.), also known as scab, is a devastating disease of wheat and barley in warm and humid regions of the world. In addition to reductions in grain yield, kernel color at harvest, and test weight, associated deoxynivalenol (DON) accumulation in the grain prevents it from being marketed. Host resistance has long been considered the most practical and effective means of control (Schroeder and Christensen, 1963; Martin and Johnston, 1982), but breeding has been hindered by a lack of effective resistance genes and by the complexity of the resistance in identified sources (Mesterházy, 1997). No source of complete resistance is known, and current sources provide only partial resistance, often in unadapted types. The identification of different sources of resistance and their incorporation into adapted wheat varieties is critical to the continued improvement of Fusarium head blight resistance in winter wheat. Mesterházy, (1995) identified five different types of resistance including reduced incidence (type I), reduced spread of the pathogen in the head following initial infection (type II), kernel retention (type III), low toxin accumulation (type IV) and tolerance (type V). Type II resistance, measured by point-inoculation in a single central floret is the most common type of resistance available and several sources have been identified and widely used in breeding programs. Good sources of type I resistance are fewer in number, partly because of the lack of precision and control associated with its evaluation and the potentially confounding effects of spread in the head subsequent to inoculation.

OBJECTIVES

This research was designed to evaluate a greenhouse-based technique for assessing type I resistance to *Fusarium graminearum.* A secondary object of this study was to complete a replicated verification of type II and III resistances in Asian and Italian germplasm.

MATERIALS AND METHODS

Germplasm identified for evaluation of type I resistance was Asian and Italian winter wheat accessions, previously evaluated at Missouri in the greenhouse (type II) and field (scab index) for reaction to artificial inoculations with *Fusarium graminearum.* Forty-two accessions were evaluated. Type II and scab index data for these accessions are provided on the website of the National Scab Initiative at .

Disease Resistance Screening: Forty vernalized seedlings of each accession were planted in the greenhouse for evaluation of type I and type II resistance. For each type of resistance, accessions were planted as two reps of 10 plants with replications separated in time by two weeks.

Type II Evaluation: At first anthesis, plants were inoculated with 10µL of a macroconidial suspension of *Fusarium graminearum* concentrated to 50,000 macroconidia/mL. Inoculum was placed in a single central floret using an Oxford 8100™ repeat dispensing syringe. For all inoculations, a single isolate was used which had been previously determined to be the most aggressive Missouri isolate on our most resistant cultivar, Ernie. Plants were incubated in a mist chamber (100% relative humidity) for 72 h post-inoculation to promote disease development and then returned to the greenhouse bench. Ratings for Type II resistance (disease spread in the spike) were made at 21 d after inoculation.

Type I Evaluation: At anthesis, heads were inoculated with a macroconidial suspension of *Fusarium graminearum* concentrated to 50,000 macroconidia/mL. Inoculum was sprayed directly on the head using a Pulmo-Aide nebulizer as the power source and an atomizer (model 163, DeVilbiss Sunrise Medical, Somerset, PA 15501-0635, USA). Inoculum was delivered to each head, spraying one side and then the other. Plants were incubated in a mist chamber (100% relative humidity) for 72 h post-inoculation to promote disease development and then returned to the greenhouse bench. At 10 d post-inoculation heads were rated for symptoms of Fusarium head blight. Total spikelets in the head were recorded followed by the number of spikelets in the head showing disease. The type I rating for each head was determined as the number of spikelets with disease divided by the total number of spikelets on the head. Ratings were taken again at 21 d post-inoculation to determine the scab index (incidence x severity) for the head. The type I rating (10 d) was taken as a measure of incidence. The 21-d rating (total number of infected spikelets/total spikelets in the inoculated head) provided an estimate of severity on the inoculated head. These data were compared to field based scab index data.

RESULTS AND DISCUSSION

Table 1 provides information on country of origin, improvement status and disease resistance data for Asian and Italian accessions with low scab reactions following two cycles of greenhouse and one cycle of field screening. Fusarium head blight index is the mean of the ratio of infected spikelets/total spikelets in the inoculated head, expressed as a percent. The field-based scab index is calculated as the product of incidence (mean percentage of plants in a 3 ft row, showing disease symptoms) and severity (mean percentage of the head showing disease symptoms). All lines had good kernel retention and quality under inoculation.

Significant differences among cultivars for greenhouse-based incidence are apparent from data collected to date. The experiment is currently ongoing and data collection is not yet complete. Final data will be presented at the 2000 Scab Forum in Cincinnati in December.

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Table 1. Disease resistant data for Asian and Italian accessions having low scab reactions after two cycles of greenhouse and one cycle of field screening.

Missouri ID	Accession	Origin	Improvement Status	Greenhouse Type II	Field Scab Index
				----------%	----------
4	Cltr 5087	China	Cultivated	10	9
5	Cltr 7159	China	Landrace	9	36
12	Cltr 8299	Italy	Landrace	10	48
51	Cltr 9400	China	Landrace	15	53
52	Cltr 9401	China	Landrace	12	53
70	Cltr 9428	China	Landrace	13	76
71	Cltr 9429	China	Landrace	7	14
77	Cltr 9445	China	Landrace	6	28
91	Cltr 9488	China	Landrace	8	90
92	Cltr 9490	China	Landrace	9	20
93	Cltr 9506	China	Landrace	12	15
94	Cltr 9507	China	Landrace	10	36
102	Cltr 9521	China	Landrace	11	45
122	Cltr 10198	China	Cultivated	13	15
124	Cltr 10205	China	Cultivated	13	34
126	Cltr 10216	China	Cultivated	15	12
128	Cltr 10264	China	Cultivated	13	45
147	Cltr 10335	China	Cultivated	16	35
151	Cltr 10353	China	Cultivated	11	2
193	Cltr 10491	China	Cultivated	14	48
198	Cltr 10504	China	Cultivated	7	80
202	Cltr 10509	China	Cultivated	4	32
206	Cltr 10520	China	Cultivated	14	38
209	Cltr 10524	China	Cultivated	14	35
217	Cltr 10574	China	Cultivated	5	32
242	Cltr 10623	China	Cultivated	15	42
244	Cltr 10627	China	Cultivated	9	30
295	Cltr 10783	China	Cultivated	10	48
348	Cltr 11155	China	Landrace	8	43
355	Cltr 15162	Italy	Cultivar	16	29
368	PI 94576	Italy	Landrace	13	70
371	PI 118726	China	Breeding	7	70
419	PI 132858	Italy	Cultivar	10	39
433	PI 155271	Japan	Cultivar	7	36
451	PI 157593	South Korea	Cultivar	9	27
463	PI 157910	Italy	Cultivar	9	60
473	PI 174639	Italy	Landrace	8	66
Checks	Ernie	Missouri	Cultivar	20	14
	Sumai 3	China		15	-
	Wangshuibai	China		10	24
	Patterson	Indiana	Cultivar	83	52

BROADENING THE GENETIC BASE FOR SCAB RESISTANCE THROUGH A CIMMYT/NATIONAL SCAB INITIATIVE PARTNERSHIP

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INTRODUCTION

Fusarium graminearum Schwabe (teleomorph *Gibberella zeae* (Schwein.), also known as scab, is a major disease limiting production of wheat and barley in warm and humid regions of the world. From the first description of scab in 1884 by W. G. Smith in England, epidemics were soon reported in many parts of the world. In a recent as yet unpublished review, Bob Stack reports that by 1917, scab had been recognized in 31 states of the United States, throughout many parts of Europe, in Russia and in Japan. Although present throughout much of the 20th century, scab has become an increasingly important problem in the north-central region of the United States because of the increased emphasis on conservation tillage, increased corn acreage and/or rotations with corn, the lack of effective cultural and/or fungicide control , and the lack of effective sources of genetic resistance. In addition to reduced kernel density and color at harvest, associated deoxynivalenol (DON) accumulation in the grain prevents it from being marketed.

Host plant resistance has long been recognized as the most practical and economical means of controlling scab in both wheat and barley, however, breeding has been hindered by a lack of genetically diverse, effective resistance genes. No source of complete resistance is known and current sources provide only partial resistance.

The narrow genetic base for scab resistance globally is clear from the widespread use of a limited number of good sources of resistance predominantly found in spring wheat. Although several sources of resistance are known, Sumai 3, developed at the Suzhou Institute of Agricultural Science in Jiangsu Province from the cross of two moderately susceptible lines, Funo and Taiwanxiaomai, has been most widely used. It is characterized by: high levels of stable resistance, low incidence, reduced spread and low toxin levels in grain colonized by the pathogen. Despite its relatively poor agronomic type, Sumai 3 has proven to have among the best combining ability of sources known and therefore, has been extensively used in breeding programs in China. Currently, there are more than 120 derivatives of Sumai 3 in production in China occupying a significant proportion of the 30 million hectares of wheat under cultivation. Narrowing the genetic base globally is the fact that Sumai 3 has been introduced into and widely used in Japan, Mexico, Canada, the United States and Europe.

OBJECTIVES

The National Wheat and Barley Scab Initiative's Germplasm Introduction and Evaluation programmatic area has as its focus, the broadening of the genetic base of scab resistance through four main objectives. These include: conducting an aggressive, world-wide search

for new sources of resistance through systematic screening of national wheat and barley germplasm collections; global acquisition of germplasm with known sources of scab resistance; global exchange of germplasm through the international nursery system; dissemination of information on resistance through internet databases.

The acquisition and testing of known sources of resistance is being conducted through a collaborative agreement between CIMMYT and the National Scab Initiative. Through this effort, CIMMYT has proposed to: provide agronomically suitable scab resistant germplasm to US collaborators through pre-breeding activities using synthetic wheats and major U.S. cultivars, conduct a world-wide search for and acquisition of suitable scab resistant wheat and barley germplasm and to make this germplasm available to U.S. Wheat and Barley Scab Initiative scientists, and to test germplasm through the International Nursery System.

MATERIALS AND METHODS

Targeted screening of accessions from geographical areas where environmental conditions are conducive to scab development or where scab resistance has been identified has been ongoing for the past 3 years under initiative funding. In addition to winter wheat screening being conducted at the University of Missouri, Columbia, and by Dr. Paul Murphy at North Carolina State University, spring wheat accessions are being screened by Dr. Yu Jin (South Dakota State University), durum wheat accessions are being evaluated by Dr. Elias Elias (North Dakota State University), and barley accessions by Dr. Brian Steffenson (University of Minnesota) Initial geographical areas targeted have included Asia (China, Japan, South Korea), Eastern Europe, Italy and South America. Screening protocols vary with program but in general measure incidence, spread, kernel quality and DON levels in germplasm maintained in the National Small Grains Collection.

Researchers at CIMMYT are working on incorporating genetic resistance for scab into commercially grown varieties. Specifically, they are working to identify and combine low incidence, and reduced spread, with genes for kernel retention and low DON accumulation. Sources of resistance include genetic sources from Brazil, Japan, Argentina, China and Romania coupled with promising sources identified in CIMMYT's wide crossing program. CIMMYT varieties combine good levels of scab resistance with resistances to other biotic stresses including resistance to Septoria leaf blotch and stripe rust and good agronomic type. Through the collaborative agreement, CIMMYT will enable U.S. breeders to access these improved sources of resistance currently being developed in Mexico.

CIMMYT scientists will also facilitate the acquisition of germplasm possessing either different types or sources of resistance from programs in China, South America and Europe. Lines to be acquired will be identified by either CIMMYT or U.S. Scab Initiative scientists. Secondary distribution rights will be acquired by CIMMYT who will then facilitate the introduction of this promising germplasm into U.S. breeding programs involved with the National Scab Initiative.

RESULTS AND DISCUSSION

Results from spring and winter wheat as well as from durum wheat and barley will be presented in other papers in this forum. For spring and winter wheat and for barley, results of these evaluations have been posted on the National Scab Initiative web site at . Where these sources are genetically different, their utilization will help to broaden the genetic base for resistance. As transgressive segregation is a relatively common phenomenon when different sources of resistance are crossed, their combination may also enhance the levels of resistance in breeding programs.

U.S. Wheat and Barley Scab Initiative scientists visited CIMMYT's wheat and barley breeding programs in September 2000. After visiting the nurseries at Toluca, a number of lines from both the bread wheat and wide-crossing programs were identified for introduction into the US. These lines (Table 1) have been shipped to the U.S. Wheat lines will be quarantined in Missouri and then distributed to interested scientists in the spring. Durum and barley lines were introduced into the U.S. through an import permit issued to Dr. Elias.

Table 1. Scab resistant wheat and barley germplasm from CIMMYT breeding programs introduced into the United States in November 2000 as part of the CIMMYT/National Scab Initiative partnership facilitating global germplasm exchange.

CROP	CROSS/PEDIGREE
BREAD WHEAT	
	CATBIRD
	NG8675/CATBIRD
	MILAN/SHA7
	CHUM 18//JUP/BJY
	NS73/PCI//B143.241.2/3/NING 8647
	MIAN YANG 81-5//PC B084.985/JIANZIMAI
	PC B084/JIANZIMAI//8744
	SHANGAI
	GOV/AZ//MUS/3/DODO/4/BOW
	RECURRENT SELECTION 1
	NG 8675/NING 8645
	SODAT/SUM 3//NING 820/3/NING 8626
	NG8201/KAUZ
	JIAN85.11//SUZHOU 7906/NING 8249
SYNTHETIC HEXAPLOID DERIVATIVES	
	TURACO/5/CHIR3/4/SIREN//ALTAR 84/ AE. SQUARROSA (205)/3/3*BUC
	BCN//DOY 1/AE. SQUARROSA (447)
	MAYOOR//TK SN1081/AE. SQUARROSA (222)
	OPATA/5/CPI/GEDIZ/3/GOO//JO69/CRA/4/AE. SQUARROSA (223)
	MAYOOR/5/CS/THINOPYRUM CURVIFOLIUM //GLEN/3/ ALD/PVN/4/ CS/LE. RACEMOSUS//2*CS/3/CN079
	CS/TH.CUR//GLEN/3/ALD/PVN/4/CSS/LE.RACEMOSUS//2*CS/3/CN079
	BCN*2//CROC 1/AE. SQUARROSA (886)
	MAYOOR
	CROC 1/AE. SQUARROSA (205) /5/BR12*3/4/IAS55*4/CI141223 /3/IAS55*4/EG. AUS//IAS55…
	BUC//RUFF/AE. SQUARROSA/3/MIAZ
	SABUF/5/BCN/4/RABI//GS/CRA/3/AE. SQUARROSA (190)
	CHIRYA.1
	LCK59.61/AE.SQUARROSA (313)
	CS/LE.RA//CS/3/PVN
DURUM WHEAT	
	CHAIKA_1/TILO
	LABUD/NEHAMA//SRN/VIC-U
	SCOOP_1/LOTUS_1
	SRN_1/6/FGO/DOM//NACH/5/ALTAR 84/4/GARZA/AFN//CRA/3/ GGOVZ39417/GEDIZ/FGO//GIA/3/CNDO/8/DUKEM_1
	ZEGZAG/ALTAR 84//DIPPER_2
BARLEY	
	TOCTE//GOB/HUMAI10/3/ATAH92/ALELI
	PENCO/CHEVRON-BAR
	ZHEDAR#1/SHYRI//OLMO
	ATAH92/GOB
	CANELA/ZHEDAR#2
	MNS1
	SVAANHAALS-BAR/MSEL//AZAF/GOB24DH
	ZHEDAR#11/4/SHYRI//GLORIA-BAR/COPAL/3/SHYRI/GRIT/5/ARUPO/K8755//MORA

While in China for the International Symposium on Improving Scab Resistance in Wheat, Dr. Lucy Gilchrist and Dr. Anne McKendry identified several lines that potentially possess either different sources or different types of scab resistance. Sources include those developed through somaclonal variation observed from wheat embryo culture of the susceptible commercial cultivar Ningmai 3 (Ning 895004, Ning 894037 and Shangkang1) and resistance lines derived from wide crosses with Roegneria kamoji, R. ciliaris, and Leymus racemosus (e.g. Zhonge 3 – derived from R. Kamoji and Yangmai 158). CIMMYT will facilitate the introduction of these lines into the U.S. in December, 2000. Along with these sources, elite lines that combine one or more sources of resistance will also be introduced from breeding programs in China and Romania (Table 2). Again, these lines will be quarantined in Missouri and subsequently distributed to scientists participating in the National Scab Initiative under terms of secondary distribution acquired by CIMMYT. A second round of collections of advanced lines is now underway. Access to these and other lines should significantly contribute to the efforts to broaden the genetic base for scab resistance in the U.S. and through testing of U.S. lines in the International Scab Nursery, facilitate the exchange of scab germplasm globally.

Table 2. Scab resistant germplasm from China and Romania introduced into the United States in November 2000 as part of the CIMMYT/National Scab Initiative partnership facilitating global germplasm exchange.

Origin	Cultivar/Descriptor
Introductions from China	
	Ning 89401
	Ning 894037
	Ning 96242
	Ningmai 9
	Mutant AT 1
	Mutant AT 2
	Yangmai 158
	Yangmai 9
	Emai 6
	Shengkang 1
	Zhonghua 1
	Sumai 2
	85004/Mexico 354
Advanced Lines from Nanjing Agricultural University	
	SB 107
	SB 108
	SB 109
	SB 110
	SB 111
	SB 114
	SB 115
	SB 116
Advanced Lines from Romania	
	Fundulea 01 R
	Fundulea 183 P5
	Fundulea 483
	Fundulea 143-T3-103
	Turda 95
	Turda 195
	Turda 2317-90

EVALUATION OF YUGOSLAVIAN WINTER WHEAT GERMPLASM FOR RESISTANCE TO FUSARIUM HEAD BLIGHT

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INTRODUCTION

Fusarium graminearum Schwabe (teleomorph *Gibberella zeae* (Schwein.), also known as scab is an increasingly important problem in the north-central region of the United States because of the emphasis on conservation tillage, (Wilcoxson et al., 1988; Bai and Shaner, 1994), rotations with corn (Windels and Kommedahl, 1984), the lack of effective cultural and/or fungicide control (McMullen et al., 1997) and the lack of effective sources of genetic resistance. In addition to reduced kernel density and color at harvest, associated deoxynivalinol (DON) accumulation in the grain prevents it from being marketed. Host resistance has long been considered the most economical and effective means of control (Schroeder and Christensen, 1963; Martin and Johnston, 1982), but breeding has been hindered by a lack of effective resistance genes and by the complexity of the resistance in identified sources (Mesterházy, 1997). No source of complete resistance is known, and current sources provide only partial resistance, often in genetic backgrounds with inferior agronomic type. The identification of different sources of resistance and their incorporation into adapted wheat varieties is critical to the continued improvement of Fusarium head blight resistance in winter wheat. Research funded by the National Wheat and Barley Scab Initiative has led to the systematic evaluation of resistance to scab in winter wheat accessions from targeted geographical regions of the world where resistance has been identified or where environmental conditions are conducive to scab development. Accessions from China, Korea, Japan, Italy and Brazil have been screened and a number of promising sources of resistance have been identified (McKendry et al. 1999). Eastern Europe was targeted as a region where scab has been a problem and approximately 2,000 winter wheat accessions from Yugoslavia and the Balkans were identified in the USDA National Small Grains collection for evaluation.

OBJECTIVES

The purpose of this research was to evaluate, under greenhouse and field conditions, approximately 1,000 Yugoslavian accessions for resistance to *Fusarium graminearum.*

MATERIALS AND METHODS

In the fall of 1999, 1006 accessions representing winter wheat landraces, breeding lines, cultivars and cultivated genotypes from Yugoslavia were acquired from the USDA-ARS Small Grains Collection at Aberdeen, Idaho.

Disease Resistance Screening - Greenhouse

Vernalized seedlings (4 per accession) were planted in the greenhouse. At first anthesis, plants were inoculated with 10µL of a macroconidial suspension of *Fusarium graminearum* concentrated to 50,000 macroconidia/mL. Inoculum was placed in a single central floret using an Oxford 8100™ repeat dispensing syringe. For all inoculations, a single isolate was used which had been previously determined to be the most aggressive Missouri isolate on our most resistant cultivar, Ernie. Previous research had also determined that this Missouri isolate was more aggressive in causing disease than similar isolates acquired from Indiana, Michigan, Ohio and Virginia. Plants were incubated in a mist chamber (100% relative humidity) for 72 h post-inoculation to promote disease development and then returned to the greenhouse bench. Ratings for disease spread in the spike were made at 21 d after inoculation. At maturity, heads were harvested, kernels were counted and evaluated for the degree of shriveling and the presence of tombstone kernels. Seeds were counted and each was given a value on a 5 point scale as follows: 1 (sound): 2 (slightly shriveled): 3 (moderately shriveled): 4 (very shriveled): 5 (tombstone). Lines meeting the following criteria for resistance are currently being progeny tested to verify resistance. Concurrently, Dr. Paul Murphy at North Carolina State University conducted a similar greenhouse screening of a subsample of approximately 500 accessions from this group. The aim of this joint screening was to expedite verification of resistance in this collection. Plants were identified for further evaluation that had low spread in the head (mean spread $\leq$ 2 spikelets), and good kernel quality relative to an uninoculated head. Resistant check cultivars included Sumai 3, Ning 7840, Ernie, Roane Wangshuibai and Futai 8944. Susceptible checks were Patterson, and Coker 9663.

Disease Resistance Screening - Field

Accessions were planted as head rows in the field at the Agronomy Research Center near Columbia, MO. Plants were sprayed at 75% heading with a macroconidial suspension concentrated to 50,000 macroconidia/mL. Head rows were maintained under overhead mist irrigation through heading and evaluated for scab incidence 7-10 d post inoculation and severity18 - 21 d after inoculation. A field scab index was determined as incidence * severity.

RESULTS AND DISCUSSION

Table 1 provides information on the accession, improvement status, and resistance data for accessions identified as having some level of potentially useful resistance in both the Missouri and North Carolina evaluation programs. Data are presented for accessions that had either reduced spread in the spike following greenhouse inoculations, a low scab index in the field (determined as the product of incidence and severity) or both. Of note are accessions that had both low spread in the head and a field scab index $\leq$ 30% (PI 221346, PI 345022, PI 350033, PI 350089, PI362463, and PI 362676). Kernel quality scores, collected in the greenhouse, ranged from 1 – 3.5 in this set of accessions. It is important to note that often, those with a kernel quality score of 2 –3 (indicating some shriveling of the seed) were only marginally worse under inoculated head than in the uninoculated head. Much of the Yugoslavian material was late in the greenhouse and grain fill was often affected. Kernel

quality data from the Missouri screening will be presented at the scab forum in December 2000 for comparative purposes.

Resistance identified in a further 200 accessions screened only at Missouri is being verified and data will be presented on these lines at the 2000 Scab Forum. The majority of accessions with low scab reaction were landraces. Of 237 accessions being re-evaluated at Missouri, 209 are landraces, 12 are breeding lines, 9 are cultivated and 7 are cultivars. Progeny evaluations of each of these accessions are ongoing. Field evaluations of accessions being re-screened will be completed during the summer 2001 season.

Field and greenhouse evaluations of the remaining 1000 accessions from the Balkans will be completed during the 2000/2001 season.

Table 1. Fusarium head blight resistance data for Yugoslavian winter wheat germplasm with low scab reactions simultaneously screened at the University of Missouri and North Carolina State University in 2000.

		Greenhouse Type II		Kernel quality (NC State)		Field Data	
Accession	Improvement Status	Missouri	NC State	Inoculated	Un-inoculated	Scab index	BYDV
		----------%----------		----------1 to 5 ----------		----------%---------	
PI 221341	Cultivated	25	16	1	-	27	20
PI 221346	Cultivated	18	16	1.7	-	28	20
PI 316425	Breeding	26	25	3	-	10	25
PI 345022	Landrace	17	7	1.3	-	30	30
PI 345106	Landrace	14	13	3	-	34	30
PI 345108	Landrace	16	25	2.2	-	21	10
PI 345163	Landrace	21	15	1	-	27	40
PI 350021	Landrace	25	19	1	-	29	60
PI 350027	Landrace	10	25	3	-	38	10
PI 350033	Landrace	7	15	1	-	27	50
PI 350036	Landrace	17	8	2	-	38	10
PI 350058	Landrace	19	9	1.3	-	42	20
PI 350089	Landrace	10	7	2	-	27	20
PI 362434	Landrace	22	15	3.2	3	27	-
PI 362450	Landrace	28	8	2.5	2.5	15	10
PI 362459	Landrace	34	13	3.3	1.5	14	50
PI 362463	Landrace	14	7	3	3	3	50
PI 362477	Landrace	22	6	2.8	2.5	10	40
PI 362512	Landrace	12	24	2.5	1	35	45
PI 362541	Landrace	9	32	2.5	2	16	50
PI 362552	Landrace	14	4	2.5	2.5	66	50
PI 362565	Landrace	19	17	2.5	2	34	30
PI 362676	Landrace	12	10	2.9	2	27	50
PI 374476	Landrace	27	17	3.1	1.5	29	25
PI 374481	Landrace	17	19	3.1	3	38	30
PI 378265	Landrace	25	22	2.7	-	18	-
PI 378277	Landrace	12	3	2.4	2	32	-
PI 378319	Landrace	10	7	3.2	3	45	-
PI 378320	Landrace	7	13	3	3	57	-
PI 378323	Landrace	7	9	2.5	-	76	-
PI 378331	Landrace	7	5	3.5	2	38	-
Checks	Ernie	20	18	2	-	14	-
	Roane	20	23	3.2	-	15	
	Futai 8944		11	1.7	-	-	-
	Sumai 3	15	-	-	-	-	-
	Wangshuibai	11	-	-	-	24	-
	Coker 9663	-	89	4.2	-	-	-
	Patterson	83	-	-	-	52	

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ALIEN GENETIC DIVERSITY FOR WHEAT IMPROVEMENT: FOCUS ON SCAB RESISTANCE

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INTRODUCTION

Because of their diversity and global distribution, accessions of the primary gene pool diploid wheat relative, *Aegilops tauschii,* (2n=2x=14, DD) syn. *Ae. squarrosa, Triticum tauschii,* constitute a unique source of novel genetic variability for bread wheat, providing among other things resistance to several factors that reduce the crop's productivity in developing countries. Due to stress screening constraints, *Ae. tauschii's* winter habit, and its tendency for grain shattering, we have hybridized available accessions indiscriminately with elite *T. turgidum* cultivars, producing 800 synthetic hexaploids (SH; 2n=6x=42, AABBDD) to date, with several involving a unique *Ae. tauschii* accession. We report here on the current status of scab resistance in these SH wheats, in their advanced, free threshing derivatives upon hybridization with elite but scab susceptible bread wheats (BW), and on the development of a doubled haploid mapping population involving a BW/SH stable advanced line with resistance to multiple scab types (Types I-IV) and to several other biotic constraints. Finally, the potential of some tertiary pool species for scab resistance is briefly addressed.

MATERIALS AND METHODS

- 800 SH wheats derived from crosses of 51 *T. turgidum* cultivars and 438 of the 490 *Ae. tauschii* accessions in the wide crosses working collection at CIMMYT.

- Advanced bread wheat/SH derivatives.

- 64 doubled haploids of a mapping population involving the resistant BW/SH line (Mayoor//TKSN 1081/*Ae. tauschii* (222) and the susceptible BW cultivar 'Flycatcher'.

- Intergeneric amphiploids, backcross I self-fertile intergeneric derivatives, and alien disomic addition lines in wheat.

- 174 A genome hexaploids derived from durum x A genome diploid combinations (2n=6x=42, AAAABB)

Location: CIMMYT station, Toluca, Mexico (19° 17'N, 99° 39'W, 2640 m above sea level).

Plot size: Unreplicated hill plots except for BW/SH advanced derivatives in two 2.0 m rows spaced at 15 cm between rows in 90 cm beds.

Disease inoculation: Fusarium head scab isolates were obtained from Toluca, Patzcuaro, and El Tigre, Mexico. A spore concentration of 50,000/ml of water and the cotton inoculation method were used (a tiny, inoculum-permeated tuft of cotton is placed in the floret by opening the glumes of a spikelet in the middle of the spike with a pair of tweezers. The spike is then covered with a glassine bag to prevent damage). Ten, randomly selected spikes of each entry were inoculated.

Disease evaluation: Fusarium head scab (Type II: Spread) disease scoring was done 30 to 35 days after inoculation. The inoculated spikes were harvested, percentage of spikelets infected with scab evaluated, and scab scores of the inoculated spikes averaged. Results and Discussion

RESULTS

Primary gene pool

Resistance in synthetic hexaploid wheats: The SH wheats (*T. turgidum* x *Ae. tauschii*) most resistant (less than 15% infection) to *Fusarium graminearum* (Type II) are presented in Table 1. Resistant BW check Sumai 3 scored around 15% or slightly less, while the moderately susceptible BW check 'Flycatcher' always had over 20% infection and the durum wheat 'Altar 84' over 40%. After three cycles of testing the advanced BW/SH scab resistant entries were selected for Type II resistance. These derivatives also possessed resistance to leaf rust, stripe rust and *Septoria tritici*. Each scab resistant entry selected had a disease score of less than 15% across each test year. Sumai-3 averaged 12% over the three test years (Delgado et al. 2000).

The most promising entries from the BW/SH combinations were further tested for the other three scab categories (I, III, IV). Four were found to possess combined resistance to all four types of scab (Table 2). These are currently being used in bread wheat breeding at CIMMYT and in the collaborative activity with the US Scab Initiative.

The combination Mayoor//TK SN 1081/*Ae. tauschii* (222) and several of its sister lines exhibit superior scab resistance across its four categories and also possess resistance to *S. tritici*, *N. indica,* and *H. sativum* (Mujeeb-Kazi et al. 2000). One line was crossed with 'Flycatcher' (susceptible to all the above stresses), and the F_1 seed used to produce 150 doubled haploids (DH) for molecular mapping/phenotyping. A partial batch of 51 DHs were tested for Type II and a 24:27 resistant:susceptible segregation was observed, indicating a 1:1 frequency. The F_1 of the above cross was completely resistant for Type II infection.

Tertiary gene pool

Tertiary pool species hold promise for providing additional genetic diversity for scab resistance (Table 3). Of high priority at this stage are crosses of wheat x *Th. bessarabicum* and their backcross derivatives, where the *ph* locus is involved to promote the introgression of alien genes.

Durum wheat improvement. Several diploid (2n=2x=14, AA) accessions combined with elite durum cultivars yielded AAAABB hexaploids, after their AAB F_1 hybrids were colchicine doubled. In the initial screening only 3 of the 174 hexaploids exhibited Type II promise with mean infection scores between 13.5 to 15.0%. These will be evaluated further. A novel batch of B genome hexaploids have been produced that may have potential for scab resistance. These are AABBBB and result from durum x *Ae. speltoides* combinations.

Another strategy in place is attempting to incorporate the resistant D genome diversity into the A genome via homoeologous exchange facilitated by the *ph1c* genetic durum stock 'Capelli'. Cytological evidence from F_1 hybrids validate A and D genome chromosome pairing since 7 bivalents are commonly observed. The univalents are identified as B genome chromosomes due to their C-banded giemsa stained sites.

CONCLUSIONS

- *Ae. tauschii* is a valuable source of genetic diversity for resistance to Fusarium head scab in bread wheat. The resistance is distributed over several accessions.

- Synthetic hexaploid wheats derived from *T. turgidum x Ae. tauschii* crosses express moderate levels of diversity for scab resistance equivalent to resistance levels in the best bread wheat cultivars.

- This resistance has been transferred to elite-but-susceptible bread wheat cultivars.

- Some advanced BW/SH derivatives possess resistance to scab Types I-IV, coupled with resistance to other important biotic stresses.

- The most promising line— the multiple disease resistant Mayoor//TK SN1081/ *Ae. tauschii* (222)—has been crossed with Flycatcher (susceptible) and a DH population developed from the F_1 progeny for molecular mapping for several stresses and for phenotyping.

- Tertiary pool diversity for scab identified in some *Thinopyrum* and *Leymus* species is being introgressed into bread wheat using cytogenetic transfer protocols associated with *ph* manipulation and molecular diagnostics.

- Durum improvement is being addressed via AAAABB, AABBBB hexaploids and by D genome to A genome homoeologous transfers.

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Mujeeb-Kazi, A., L.I. Gilchrist and R. Delgado. 2000. New synthetic hexaploids and a set of bread wheat/ synthetic hexaploid derivatives as sources for scab resistance. Annual Wheat Newsletter. 46:81.

Table 1. Promising D genome synthetic hexaploids screened for head scab (Type II) at Toluca, Mexico.

Germplasm pedigree	1999	2000
YUK/*Ae. tauschii* (217)†	11.4	11.8*
68.111/RGB-U//WARD/3/FGO/4/RABI/5/*Ae. tauschii* (629)	11.9	10
68.111/RGB-U//WARD/3/FGO/4/RABI/5/*Ae. tauschii* (878)	12.4	13.1
68.111/RGB-U//WARD/3/FGO/4/RABI/5/*Ae. tauschii* (882)	11.1	13.6
SORA/*Ae. tauschii* (884)	12.9	13.5
68.111/RGB-U//WARD/3/FGO/4/RABI/5/*Ae. tauschii* (890)	11.4	14.1
CETA/*Ae. tauschii* (895)	10.8	13.2
GAN/*Ae. tauschii* (180)	10.7	10.9
LCK59.61/*Ae. tauschii* (313)	11.5	12.2
SCOOP 1/*Ae. tauschii* (358)	12	13.9
YUK/*Ae. tauschii* (217)	11.4	11.8
TRN/*Ae. tauschii* (700)	13.4	13.7
DOY1/*Ae. tauschii* (333)	11.1	13.9
DVERD_2/*Ae. tauschii* (1027)	14.6	11.7
MAYOOR//TK SN1081/*Ae. tauschii* (222)	11.7	5.7
FLYCATCHER (Mean across years)		33.8
SUMAI-3 (Mean across years)		12
ALTAR 84		40.8
* Percentage score means from 10 spikes tested. † *Ae. tauschii* accession in wide crosses working collection.		

Table 2. Some promising BW/SH derivatives tested in Toluca for the various Scab resistance categories (Type I to IV) and grain finish over 2 years in Toluca.

Lines	Type I* 1998-1999	Type II* 1998-1999	DON (ppm)	Test weight losses (%)	Grain (0-5)†
TURACO/5/CHIR3/4/SIREN//ALTAR 84/*Ae. tauschii* (205)/3/3*BUC CASS94Y00034S-24PR-2B-0M-0FGR-0FGR-0FGR	8	9.9	0.6	5.3	2
BCN//DOY1/*Ae. tauschii* (447) 0FRG	9.6	10.1	1	2.6	1
MAYOOR//TK SN1081/*Ae. tauschii* (222) CASS94Y00009S-18PR-3M-0M-0FRG-0FRG-0FRG	7.3	9.9	1.2	6.1	1
MAYOOR//TK SN1081/*Ae. tauschii* (222) CASS94Y00009S-50PR-2B-0M-0FRG-0FRG-0FRG	4.1	11.7	1.2	6.5	1
SUMAI # 3 (resistant check)	3	12.9	0.3	38.6	3
FRONTANA (moderately resistant check)	11.6	22.4	2	7.7	2

* = Percent damage

† = Grain 0 = Excellent (no differences in appearance with fungicide protected grain).

Table 3. Scab screening (Type II) of promising intergeneric amphiploids and backcross I fertile combinations at Toluca, Mexico.

Germplasm pedigree	2000
Amphiploids	
CS/*Th. elongatum* (2n=8x=56)	6.2*
CS/*Th. scirpeum* (2n=10x=70)	7.5
CS/*Th. bessarabicum* (2n=8x=56)	6.5
Th. elongatum /GOSHAWK (2n=8x=56)	15.2
Backcross I Self Fertiles	
CS/*Th. curvifolium* //PAVON (2n=8x=56)	14.8
CS/*Th. scirpeum* //CIANO 79 (2n=8x=56)	5.2
CS/*Th. scirpeum* //PAVON (2n=8x=56)	10.6
* Percentage score means from 10 spikes tested.	

FUSARIUM HEAD BLIGHT REACTION OF DURUM WHEAT LINES CONDITIONED BY CHROMOSOME SUBSTITUTIONS FROM *TRITICUM TURGIDUM* L. VAR. *DICOCCOIDES*

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ABSTRACT

Fusarium head blight (FHB) is a serious disease problem on durum wheat (*Triticum turgidum* L. var. *durum*). As far as has been reported to date, the resistance to FHB available in hexaploid wheat sources has not successfully been transferred to durum — a tetraploid wheat. Wild emmer (*Triticum turgidum* L.var. *dicoccoides*) is a wild tetraploid wheat that possesses many interesting traits including some unique disease resistances. In the 1980's, USDA geneticist L.R. Joppa produced a set of disomic substitution lines derived from 'Langdon' durum, each with a different pair of chromosomes from *T. t. dicoccoides* substituted for the corresponding durum chromosomes. We tested these lines for FHB response by inoculation with *Fusarium graminearum* under controlled conditions in several repeated experiments. One of the lines, LDN(DIC-3A), was significantly less susceptible and another, LDN(DIC-2A), was significantly more susceptible in all trials when compared to the 'Langdon' durum parent, which itself showed an intermediate FHB reaction. Several other substitution lines were significantly more or less susceptible than 'Langdon' in some experiments. Since each line differs by an entire chromosome pair, the results suggest that FHB resistance genes are on several different chromosomes in durum. Chromosome 3A is not among those which have been identified in recent papers as a site of resistance genes in hexaploid wheat. (This poster was presented at the 1999 American Phytopathological Soc. Annual Meeting in Montreal, Canada. This abstract in slightly different form was published in Phytopathology 89:S74)

INHERITANCE OF RESISTANCE TO FUSARIUM HEAD BLIGHT IN SPRING WHEAT F-1 HYBRIDS

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ABSTRACT

Fusarium Head Blight (FHB), caused by *Fusarium graminearum*, has occasioned serious economic loss in spring cereals in the north-central United States. As a result, resistance to FHB has become a high priority for spring wheat breeding. In replicated greenhouse experiments, we tested the FHB reactions of reciprocal F-1 hybrid wheats from seven crosses between four FHB-resistant parents and four susceptible adapted lines. Resistant parent lines were removed by one, two, or three breeding cycles from the Chinese line “Sumai3”, the original resistance source. For all crosses the FHB reaction of the F-1’s were intermediate between the resistant and susceptible parents (Table 1). The reciprocal F-1’s did not differ from each other. In development of hybrid wheat requiring FHB resistance, both parents will likely have to carry resistance if Sumai3 derived resistance sources are to be used. (This poster was presented at the International Symposium on Wheat Improvement for Scab Resistance, Suzhou and Nanjing, China, May 5-11, 2000. The paper is in those Proceedings p.94-97.)

Table 1. Fusarium Head Blight reaction of resistant and susceptible parents and reciprocal F-1 hybrid spring wheat lines inoculated with *Fusarium graminearum*.

Genotype	FHB incidence	FHB severity (%)	Visual FDK (%)
RESISTANT PARENT	0.45	11.1	0.8
F-1 (female=RESISTANT)	0.53	28.3	3.6
F-1 (female=SUSCEPTIBLE)	0.53	30.5	2.9
SUSCEPTIBLE PARENT	0.74	63.2	11.1
FLSD(.05)	0.12	10.4	1.9

INHERITANCE OF SCAB RESISTANCE IN SAPPORO HARU KOMUGI JUGO

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ABSTRACT

A spring wheat cultivar, Sapporo Haru Komugi Jugo (PI 81791) originated from Japan, has shown consistent resistant response to scab or Fusarium head blight (FHB) in various tests under greenhouse and field environments. Inheritance of FHB resistance was investigated in a cross using Wheaton as the susceptible parent. Backcross F_2 (BCF_2) families were evaluated in the greenhouse for their response to point-inoculation. BCF_2 plants with low disease severity were harvested and F_3 plants were re-evaluated for FHB reaction to confirm the resistance in F_2 plants. Frequency distribution of the number of heterogeneous resistant and homogenous susceptible BCF_2 families suggested that three dominant genes may be involved in FHB resistance in Sapporo Haru Komugi Jugo.

FUSARIUM HEAD BLIGHT RESISTANT SOURCES OF SPRING WHEAT IDENTIFIED FROM THE USDA COLLECTION

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INTRODUCTION

The use of resistant cultivars in wheat will be one of the major components in managing Fusarium head blight (FHB). Breeding for resistance is, however, hindered by a lack of adequate resistant sources. Identifying additional sources of resistance and incorporating new resistances are critical for diversifying the current resistance gene pool and for enhancing the level of resistance. Since 1998, we have begun to characterize variations for FHB resistance in the USDA National Small Grain Collection, focusing on spring wheat accessions from regions where FHB has historically been problematic. This report summarizes the methodology, resistant selections made from previous years, and observations of rust reactions of these selections.

MATERIALS AND METHODS

In the past three years, we have been working towards the development of a germplasm evaluation and enhancement scheme from which reliable data can be derived while maintaining the efficiency of screening operation and the accessibility of the selected germplasm. The scheme is illustrated (Fig. 1) and described as following.

1. Entries were planted into single 4-foot row plots in a field nursery. The nursery was inoculated with Fusarium-colonized corn grains at a weekly interval for four consecutive weeks beginning at the early jointing stage of plant development. Ground was maintained moist through irrigation to promote perithecial development. Entries at anthesis were tagged and inoculated with a conidial suspension (50,000-75,000 conidia/ml) using a sprayer. A second spray-inoculation was applied seven days later. The nursery was mist-irrigated following a schedule of 3-min misting with 30-min recess between 8:00pm and 9:00am during the course of inoculation. We used this intense inoculation protocol to generate high disease pressure throughout the evaluation period to select for high levels of resistance and to prevent disease escape due to late tillering or differences in heading dates. ND 2710, BacUp, Wheaton and Sonalika (with different levels of resistance/ susceptibility and maturity) were used as checks and check-to-entry ratio was 1:37.

Disease severity (% of infected spikelets) and incidence (% of infected spikes) were recorded 14 to 20 days after the first spray inoculation on 20 spikes/plot, depending upon the disease development. Entries (or plants within an entry) with a low disease index (severity*incidence) were selected for further testing. In addition to selections based on FHB index, entries with good seed setting were selected. Selections from PSN were increased in an off-season nursery in New Zealand.

2. Field selections were evaluated in the greenhouse in the fall and again in the spring by spray and point inoculation. These evaluations were designed 1) to verify the resistance of field selections, and 2) to characterize the resistance types. Approximately 30-50 plants were evaluated in each of the two greenhouse seasons. Plants were grown in pots and inoculated at anthesis. Inoculated plants were incubated in a mist-chamber for 48 hours. Although selections were made to derive the entries of the Elite Germplasm Nursery (EGN) for next year, the selection pressure was minimal at this stage in order to avoid eliminating genotypes with good field resistance.

3. Greenhouse evaluations of PSN selections were used to derive entries for the EGN of next year. Entries were planted in 4-foot rows and replicated three times in a randomized complete block design. In 2000, 160 lines selected from 1998 and 1999 PSNs were tested in EGN with a check-to-entry ratio of 1:26. Nursery management (tagging of flowering stage, inoculation and irrigation) and check varieties were the same as that of PSN. Fusarium head blight incidence and severity were recorded. All entries were harvested for scoring seed infection, yield (weight per row), and volume-weight. Selected entries with low or moderate FHB reactions were tested for DON using bulked seed (among reps). Selections from EGN will be evaluated again in the next year's EGN. Entries of EGN were also evaluated for stem rust and leaf rust in field rust nurseries.

4. Five to six most elite selections from EGN were entered into the Uniform Regional Scab Nursery for spring wheat. This allowed evaluations of the elite selections over multiple locations, and provided the accessibility to individual programs for crossing.

RESULTS AND DISCUSSION

Evaluation data (FHB index converted into a 0-9 scale) from the 1998, 1999, and 2000 PSNs were reported in the GRIN database (USDA-ARS, National Genetic Resources Program, Germplasm Resources Information Network, www.ars-grin.gov/cgi-bin/npgs/html/desc.pl?65066). Lines with low FHB reactions (disease index <40% and tombstone <40%) were considered as elite selections (Table 1). Lines with intermediate FHB reactions (disease index <55% and tombstone <55%) are given in Table 2. Lines with low disease index but high tombstone percentage (>55%), or vise versa, were also listed in the intermediate group. In the elite selection group (Table 1) the correlation coefficients were highly significant between disease index and %tombstone (r = 0.83) and between disease index and DON content (r = 0.74). The correlation coefficient between %tombstone and DON content was also significant (r = 0.68). Disease index and %tombstone was not correlated in the intermediate group (Table 2). Some of the selections possess resistance to leaf rust and/or stem rust under natural rust infections (Table 1 & 2).

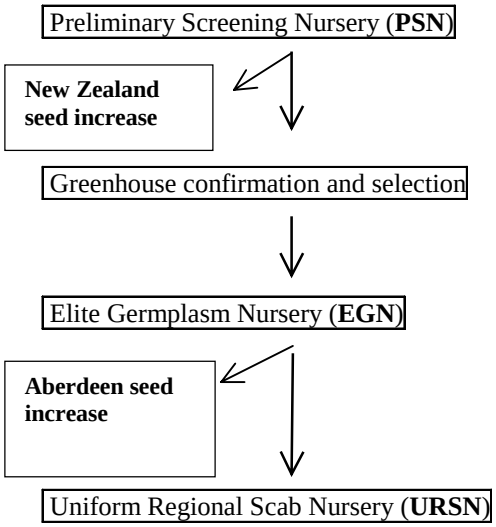

Figure 1. A scheme used for identifying Fusarium head blight resistance in spring wheat.

Table 1. Spring wheat germplasm selections with low FHB reaction from the 2000 Elite Germplasm Nursery.

Accession	ID	Origin	Improv. Status	FHB index (%)	Tombstone (%)	DON (ppm)	Leaf[d] rust	Stem[d] rust
PI 382167	16-52-9	Brazil	breed. mat.[e]	10.9	23.3	5.5	tR	60MS
PI 382161[a]	Tokai 66	Brazil	cultivar	11.2	16	1.9	90S	80S
PI 349478[b]	193C	Switzerland	landrace	11.5	10	4.4	-[g]	-
PI 382154	Nyu Bai	Japan	landrace	11.9	15	1.5	90S	80S
CItr 5103	274	Argentina	landrace	13.1	19	16.5	90S	90S
PI 350768[b]	69Z108.42	Austria	landrace	14.3	21.7	6.1	tMS	0
PI 382140[b]	Abura	Brazil	cultivar	15.1	38.3	3.3	10MS	0
PI 214392	Colotana 266/51	Brazil	cult. mat.[f]	15.7	30	16.3	-	-
PI 382153	Nobeoka B.	Japan	landrace	18.1	13.8	4.8	90S	60S
PI 462151	S. C. W. No. 3	China	cult. mat.	20	18.8	4.2	60S	80S
PI 81791[a]	Sapporo H. K. J.	Japan	cultivar	20.5	21.7	18	30MS	30S
PI 294975	Artemowska	Bulgaria	cult. mat.	24.5	20	11.4	-	-
PI 163429		Argentina	cult. mat.	24.9	30	12	90S	60S
PI 345731	Tezanos P. P.	Argentina	cultivar	30.4	20	12	80S	tMS
PI 264927	220	Greece	landrace	31.9	16.7	5.6	80S	50MS
PI 185380[b]	Prodigio I.	Italy	cult. mat.	32.2	27.5	11.2	90S	0
PI 192660	Prodigio I.	Italy	cult. mat.	34.5	22.5	16.4	90S	10MR
PI 285933	Chudoskaja	Poland	cult. mat.	34.7	26.7	21.8	80S	80S
PI 362437	III/14-B	Yugoslavia	landrace	35.5	33.3	8.9	90S	60S
PI 351743	Cluj 49-926	Romania	cultivar	39.1	26	9.1	90S	50MS
CItr 11215	Belgrade 4	Yugoslavia	cult. mat.	39.6	35	9.2	80S	70MS
CItr 17427	16-52-2	Brazil	breed. mat.	39.7	33.3	19.4	10MR	70S
PI 104131[b]	Excelsior	Argentina	cultivar	40.6	21.7	7.6	90S	70MS
PI 519798	PF 79782	Brazil	breed. mat.	40.7	27.5	14.6	40MS	0
PI 256958	Academia 48	Romania	cultivar	42.4	20	11.7	70S	60S
	ND 2710--ck	USA	breed. mat.	14.2±2.	22.8±8.8	5.4		
PI 596533	BacUp--ck	USA	cultivar	25.5±7.	30.8±5.5	7.7		
PI 469271	Wheaton--ck	USA	cultivar	86.9±1.	93.3±5.4	24.3		
PI 478282	Sonalika--ck	India	cultivar	87.1±2.	76.4±9.5	37		

[a] Lines were tested in the 2000 Uniform Region Scab Nursery for spring wheat.

[b] Lines will be tested in the 2001 Uniform Region Scab Nursery for spring wheat.

[c] DON of bulked seed (among reps) was tested by Dr. Paul Schwarz at North Dakota State University.

[d] Observations on leaf and stem rust reactions were based on natural infection in field rust nurseries.

[e] Breeding material.

[f] Cultivated material.

[g] Not tested.

Table 2. Spring wheat germplasm selections with intermediate FHB reaction from the 2000 Elite Germplasm Nursery.

Accession	ID	Origin	Improv. status	FHB index (%)	Tombstone (%)	Leaf rust	Stem rust
PI 519434	PF 82192	Brazil	breed. mat.	15.3	53.3	30s	10MS
PI 519790	274-1-118	Uruguay	breed. mat.	19.3	40.0	60S	5S
PI 434987	Estanzuela Y.	Uruguay	cultivar	19.6	58.0	30S	70S
PI 182583	Chuko	Japan	landrace	19.9	78.8	80S	80S
PI 182561	SinChunaga	Japan	cult. mat.	20.8	86.7	90S	60S
PI 351256	Japon 2	Japan	cult. mat.	21.2	41.7	30S	80S
PI 182568	Norin 34	Japan	cultivar	21.3	46.7	100S	50S
CItr 12002	Renacimiento	Uruguay	cultivar	24.9	41.7	90S	90S
PI 411132	Gogatsu-K.	Japan	cultivar	27.6	77.5	0	40MS
PI 382144	Encruzilhada	Brazil	cultivar	29.6	45.0	40S	90S
PI 182586	Norin 43	Japan	cultivar	30.0	50.0	30S	80S
PI 182565	Haya K.	Japan	cult. mat.	31.8	53.3	5MR	80S
CItr 12021	Centenario	Uruguay	cultivar	32.2	41.7	90S	30S
PI 351816	Froment D. J.	Switzerland	cult. mat.	33.1	70.0	90S	60S
PI 337151	Magnif 100	Argentina	cultivar	34.8	46.7	90S	90S
PI 351898	B 130	Switzerland	breed. mat.	37.9	70.0	40MS	80S
PI 83729	Magyarovar 81	Hungary	cultivar	38.3	46.0	70S	70MS
PI 263422	Forlani	Yugoslavia	cultivar	39.6	56.7	70S	70MR
PI 182591	Norin 61	Japan	cultivar	40.1	66.7	-	-
PI 272348	Lontoi	Hungary	cultivar	40.2	26.7	90S	80S
CItr 13136	Rio N.	Brazil	cultivar	42.8	50.0	70S	70S
PI 264998	628	Greece	landrace	43.7	30.0	30S	10R
PI 57364	CItr 7175	China	landrace	45.0	55.0	-	-
PI 185383	3084	Argentina	cult. mat.	45.4	50.0	90S	70S
PI 584926	Pantaneiro	Brazil	cultivar	47.0	45.0	90S	0
PI 168727	Bahiense	Argentina	cultivar	47.5	25.0	90S	50S/0
PI 210869	4207-50	Brazil	breed. mat.	48.5	56.7	10R	10MR
PI 192219	Hatvani	Hungary	cultivar	48.8	36.7	90S	20MS
PI 520498	Jacui	Brazil	cultivar	49.0	43.3	5MR	30S
PI 185843	Surpresa	Brazil	cultivar	49.2	42.5	80S	20S
PI 351187	T. V. S.	Switzerland	breed. mat.	49.5	26.7	80S	80S
PI 203083	Wabian	Paraguay	cult. mat.	51.1	32.5	10MR	20MR
PI 163428		Argentina	cult. mat.	51.8	46.7	-	-
PI 352000	Z.89.37	Switzerland	breed. mat.	52.2	26.7	90S	30MS
PI 344467	Oncativo I.	Argentina	cultivar	53.1	38.8	10MS	10R
PI 192634	Trintecinco	Brazil	cultivar	53.7	41.7	90S	10MR
PI 233207	Odesskaja 13	Ukraine	cultivar	54.3	32.5	60S	40MS
PI 349534	533B	Switzerland	landrace	54.3	26.7	90S	60S
PI 214394	Colotana 1085/50	Brazil	breed. mat.	54.7	30.0	-	-
PI 264940	111a	Greece	landrace	55.3	41.7	5R	5R
PI 351476	Vaulion	Switzerland	cultivar	55.8	25.0	90S	50MS
PI 344465	Laureano A. L.	Argentina	cultivar	56.0	36.7	5MS	40S
CItr 2492	Manchurian	China	landrace	57.0	25.0	-	-
PI 184221	BR 5480	Yugoslavia	landrace	57.5	45.0	70S	50MS
PI 192229	Gran C. U.	Romania	landrace	57.7	31.7	80S	30MS
PI 584934	Whestphalen	Brazil	cultivar	57.8	41.3	tR	tR
PI 352118	62 FF 70	Switzerland	breed. mat.	58.1	50.0	5MR	70MS
PI 351993	Z.88.54	Switzerland	breed. mat.	58.4	30.0	70S	30MR
PI 168716	Klein Condor	Argentina	cultivar	58.9	35.0	70S	60MS
PI 352062	Vivela Mar	Argentina	cult. mat.	58.9	50.0	70MR	70S

Table 2. (continued)

Accession	ID	Origin	Improv. status	FHB index (%)	Tombstone (%)	Leaf rust	Stem rust
PI 362043	Arnaut De T.	Romania	cultivar	59.6	23.3	90S	30MS
PI 344454	Buck Austral	Argentina	cultivar	60.0	28.8	10MR	50S
PI 192498	IV C…	Argentina	cultiv. mat.	61.8	47.5	60S	80MS
PI 185216	3111	Argentina	cultiv. mat.	61.9	50.0	10MR	60MS
PI 113949	Stepnjachka	Ukraine	cultivar	63.0	38.3	30S	30MR
PI 168653	Klein C	Argentina	cultivar	63.2	46.7	20S	70MS
PI 113948	Kooperatorka	Ukraine	cultivar	64.3	26.3	50MS	40MS
CItr 14371	8475-59	Brazil	breed. mat.	65.6	36.7	80MS	10MR
PI 559677	Ljutseune 76	Yugoslavia	cultiv. mat.	69.3	50.0	90S	80S
PI 349448	1882B	Switzerland	landrace	71.3	43.3	80S	60MS
PI 57363	163	China	landrace	72.2	41.7	90S	70S
PI 184512	H 51	Argentina	breed. mat.	76.7	33.3	20MR	40MR
PI 192647	Granadero	Argentina	cultivar	77.0	48.3	60S	40MS
PI 349447	1882A	Switzerland	landrace	77.3	20.0	-	-
PI 351649	263.25-2	Switzerland	breed. mat.	78.3	46.7	90S	40S

GEOGRAPHICAL DISTRIBUTION AND PEDIGREE ANALYSIS OF FUSARIUM HEAD BLIGHT RESISTANT SELECTIONS FROM THE USDA SPRING WHEAT GERMPLASM COLLECTION

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INTRODUCTION AND OBJECTIVES

Spring wheat selections with low and intermediate Fusarium head blight (FHB) reactions reported by Zhang et al. (this Proceeding) represented a diverse pool of germplasm. The objective of this research was to analyze the geographical distribution and pedigree of the resistant selections. Information obtained from such analysis may help in identifying potential new gene pools for FHB resistance.

MATERIALS AND METHODS

A total of 1405 accessions of spring wheat with diverse origin (Table 1) were evaluated in the Preliminary Screening Nurseries (PSN) in 1998 and 1999. Nursery management, inoculation techniques, and selection criteria are described by Zhang et al. (this Proceeding). Selections of PSN were evaluated in the Elite Germplasm Nursery (EGN) in 2000. This report analyzed the geographical distribution and pedigree of the resistant selections from EGN based on available information in GRIN (USDA-ARS, National Genetic Resources Program, Germplasm Resources Information Network).

RESULTS AND DISCUSSION

Geographical distribution of the FHB resistant selections. Table 1 lists the geographical distribution of the spring wheat germplasm evaluated and the frequency of selections. Selections from South America contributed to 43.6% of the total selections, followed by Europe (39.4%). While resistance from Asian germplasm has been recognized and used in breeding worldwide, only 16.5% of the total selections were from Asia. The results suggest that South America and Europe may possess FHB resistant gene pools, which may have been under-exploited.

Resistance lines were identified from most of the countries tested (Table 1). In Asia, resistance better or equal to Sumai 3 was not identified in test collections from China, while some selections from Japan were better than or equal to reported Japanese resistant lines. In Europe, resistance from Austria, Bulgaria, Greece, Hungary, Poland, Romania, Switzerland, Ukraine, Yugoslavia in addition to Italy was identified. Among the European countries, Romania ranked the first in terms of ratio of number of selected lines to the number of tested, Switzerland ranked the first in the number of resistant lines. The highest number of elite selections (2 lines/country) was from Italy, Romania, and Yugoslavia. In South America,

Argentina ranked the first for the ratio of selected lines to the number of lines tested, whereas the highest number of elite selections (6 lines) was from Brazil. The fact that resistant lines were identified from various countries may indicate that diversity of FHB resistant sources exists, and systematic search and characterization based on the country of origin may prove beneficial.

Pedigree analysis of the resistant selections. Of the 94 resistant selections, eighteen were landraces (Table 2). Pedigree information was obtained on 42 cultivars or breeding materials. Pedigree analysis in those 42 lines revealed that Frontana (Fronteira/Mentana) appeared as the primary or secondary parent of nine selections, Shinchunaga in four selections, and Mentana in two selections (Table 3). Resistant selections from this study, including Tokai 66, Surpresa, and Centenario, were parents of several other selections. Selections of landraces and cultivars released prior to 1940 are given in Table 2. Although pedigree of a landrace is not clear, the landraces may provide the most diversity for potentially new genes for FHB resistance. Similarly, old cultivars may be more valuable for providing potentially new resistance genes.

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Table 1. Number of spring wheat lines tested and selected from each country for low and intermediate Fusarium head blight reaction.

Country	Accessions tested	Selections			Composed of total selections (%)
		Elite	Interm.	% selected	
Asia	**149**	**4**	**12**	**10.3**	**16.5**
China	73	1	4	6.8	
Japan	76	3	8	14.5	
Europe	**887**	**11**	**26**	**4.2**	**39.4**
Austria	174	1	0	0.0	
Bosnia and Herzego	22	0	0	0.0	
Bulgaria	12	1	0	8.3	
Czech Republic	28	0	0	0.0	
Greece	43	1	2	7.0	
Hungary	32	0	3	9.3	
Italy	123	2	2	3.3	
Poland	45	1	0	2.2	
Romania	29	2	2	13.8	
Switzerland	291	1	11	4.1	
Ukraine	26	0	3	11.5	
Yugoslavia	62	2	3	8.1	
South America	**369**	**10**	**31**	**11.1**	**43.6**
Argentina	130	4	14	21.5	
Brazil	179	6	12	12.3	
Paraguay	9	0	1	11.1	
Uruguay	21	0	4	19.5	
Others	30	0	0	0.0	
Total	**1405**	**25**	**69**	**6.7**	**100.0**

Table 2. Fusarium head blight resistant selections of landraces and cultivars released or received by National Small Grains Collection (NSGC) before 1940.

Accession	ID	Group	Status	NSGC received year
CItr 5103	274	Elite	Landrace	1916
PI 264927	220	Elite	Landrace	1960
PI 349478	193C	Elite	Landrace	1970
PI 350768	69Z108.42	Elite	Landrace	1970
PI 362437	III/14-B	Elite	Landrace	1971
PI 382153	Nobeoka Bozu	Elite	Landrace	1973
PI 382154	Nyu Bai	Elite	Landrace	1973
CItr 11215	Belgrade 4	Elite	Cultivated	1929
PI 81791	Sapporo Haru K.	Elite	Cultivar	1929
PI 104131	Excelsior	Elite	Cultivar	1934
CItr 2492	Manchurian	Intermediate	Landrace	1904
PI 57363	163	Intermediate	Landrace	1923
PI 57364	CItr 7175	Intermediate	Landrace	1923
PI 182583	Chuko	Intermediate	Landrace	1949
PI 184221	BR 5480	Intermediate	Landrace	1949
PI 192229	Gran Commune Ungerese	Intermediate	Landrace	1950
PI 264940	111a	Intermediate	Landrace	1960
PI 264998	628	Intermediate	Landrace	1960
PI 349447	1882A	Intermediate	Landrace	1970
PI 349448	1882B	Intermediate	Landrace	1970
PI 349534	533B	Intermediate	Landrace	1970
CItr 12002	Renacimiento	Intermediate	Cultivar	1936
CItr 12021	Centenario	Intermediate	Cultivar	1938
PI 113948	Kooperatorka	Intermediate	Cultivar	1936
PI 113949	Stepnjachka	Intermediate	Cultivar	1936
PI 132856	Mentana	Intermediate	Cultivar	1939
PI 83729	Magyarovar 81	Intermediate	Cultivar	1930

Table 3. Fusarium head blight resistant selections with known resistant parent in their pedigrees.

Accession	ID	Origin	Known resistant parent
PI 584934	Whestphalen	Brazil	Frontana, Tokai 66
PI 214392	Colotana 266/51	Brazil	Frontana
PI 345731	Tezanos Pintos Precoz	Argentina	Frontana
CItr 14371	8475-59	Brazil	Frontana
PI 214394	Colotana 1085/50	Brazil	Frontana
PI 352118	62 FF 70	Switzerland	Frontana
PI 434987	Estanzuela Young	Uruguay	Frontana
PI 519790	274-1-118	Uruguay	Frontana
PI 520498	Jacui	Brazil	Frontana
CItr 12470	Frontana	Brazil	Mentana
PI 344465	Laureano Alvarez Laah	Argentina	Mentana
PI 182591	Norin 61	Japan	Shinchunaga
PI 182568	Norin 34	Japan	Shinchunaga
PI 182586	Norin 43	Japan	Shinchunaga
PI 411132	Gogatsu-Komugi	Japan	Shinchunaga
CItr 13136	Rio Negro	Brazil	Surpresa, Centenario