A workshop on “Searching for Alien Genes to Enhance Resistance of Wheat and Barley to Fusarium Head Blight (FHB)” was held on the campus of North Dakota State University on August 14, 2006. The goals of this workshop were to exchange information about the identification and introgression of alien FHB resistance genes and to develop a strategic and collaborative research effort to accelerate introgression and deployment of alien FHB resistance genes through the release of wheat and barley cultivars. Dr. P. Stephen Baenziger, chair of the Host Genetic Resources (HGR) Research Area Committee in the USWBSI, wrote a letter to the workshop to emphasize the exploration of possible new techniques and novel sources of FHB resistance and efficient introgression of alien FHB resistance genes into adapted backgrounds. There were over 40 participants, including geneticists, breeders, pathologists, and graduate students, from the US, Canada, and Mexico (CIMMYT). Grower and private industry representatives were also invited to attend the workshop. At least one North Dakota wheat grower planned to participate but was unable to do so for personal reasons. Seven speakers were invited to present research results on the identification of FHB resistance genes from alien species, introgression of the alien FHB resistance genes, and development of breeder-friendly germplasm and cultivars using alien FHB resistance genes (see attached Workshop Agenda).

Significant progress towards utilizing alien FHB resistance genes in germplasm enhancement and breeding has been made for both durum and bread wheat. However, similar progress in barley has been limited, partly due to the identification of relatively few alien gene sources of resistance. After all of the invited presentations, five open discussion sessions were held. Discussion topics included breeders’ needs, current progress, challenges, strategies, and potential collaborations. Discussion sessions were led by a scientist having expertise in the discussion topic area. A general consensus on the issues associated with alien introgressions was reached as a result of these discussions.

FHB resistance has been identified in a number of cultivated and wild species related to wheat and barley. Alien FHB resistance genes have been integrated into bread and durum wheat backgrounds from *Aegilops speltoides*, *Triticum monococcum*, *T. timopheevi*, *Ae. cylindrica*, *T. miguschovae* (Dr. G. Fedak’s group), *Lophopyrum ponticum* (Dr. X. Cai’s group), *L. elongatum* (Dr. H. Ohm’s group), *T. carthlicum*, *T. dicoccum* (Dr. S. Xu’s group), *Leymus racemosus* (Dr. B. Gill’s group), and *T. dicoccoides* (Dr. W. Berzonsky’s group). Some of the alien resistance genes have been mapped using molecular markers and transferred to regionally adapted bread wheat backgrounds. Based on the presentations and discussions, it is apparent that some FHB resistant germplasm releases have been made and others should be made soon. Some breeding programs (e.g. Drs. H. Ohm and W. Berzonsky) have been making efforts to incorporate alien sources of resistance into adapted genotypes as a part of their overall cultivar development strategy, which should significantly accelerate deployment of alien FHB resistance genes in new cultivars.
Participants discussed the utility of the germplasm with alien FHB resistance genes in breeding. Breeders expect to make the best use of germplasm that exhibits effective resistance to FHB, but exhibits relatively few undesirable traits. When working with a source of resistance originating from the secondary gene pool, Dr. Elias Elias (NDSU Durum Breeder) suggested that at least three backcrosses to an adapted cultivar might be necessary to minimize the impact of undesirable linkage drag. Intergenomic introgression of genes from the tertiary gene pool requires an effort to reduce the amount of alien chromatin as much as possible, while expression of the FHB resistance genes is maintained in adapted genotypes. Based on his experience, Dr. H. Ohm pointed out that linkage between FHB resistance genes and other genes may sometimes be positive. For example, wheat lines in his program with chromosome translocations from *Lophopyrum* were exhibiting FHB resistance as well as resistance to BYDV. Participants agreed that alien translocation lines involving a small alien chromosomal fragment and no obvious undesirable genes, represent the most desirable material to use in breeding for FHB resistance. Due to the amount of alien chromatin introgressed, substitution and addition lines are less desirable to use even though they exhibit resistance to FHB. Additional chromosome engineering is often needed to eliminate unwanted alien chromatin in these materials. Since intergenomic introgression is a time-consuming process, participants suggested that each research program target short-term, mid-term, and long-term goals and develop close collaborations with breeders to ensure the rapid deployment of alien FHB resistance genes in new cultivars.

The nature of complex inheritance of FHB resistance has limited progress in gene introgression and pyramiding. A major obstacle has been the dilution or complete loss of resistance during gene introgression. Using doubled-haploid procedures, USDA-ARS Scientist, Dr. S. Xu proposed a strategy to identify resistance genes and maintain them throughout a durum wheat cultivar development process, and most participants concurred that this could be a valid approach for introgressing alien FHB resistance genes into durum cultivars. Another obstacle is the efficient elimination of unwanted alien chromatin during the introgression process. Dr. B. Gill encouraged more widespread use of the *ph1b* mutant and a molecular marker for the mutant to induce recombination between homoeologous wheat and alien chromosomes. In durum wheat, Dr. X. Cai has used the chromosome 5D(5B) substitution line in a Langdon (LDN) durum wheat background to induce wheat-alien chromosome translocations. Unfortunately, the *ph1b* mutation and 5D(5B) substitution exists in the genotypes which are not very desirable for many agronomic traits. Therefore, to expedite the development of breeder-friendly germplasm, it may be useful to transfer the *ph1b mutation* and the 5D(5B) substitution into more adapted genotypes. Another suggested approach was to foster the production of advantageous translocations by developing double-monosomics for the wheat and alien chromosome of interest. In double-monosomics, spontaneous Robertsonian whole-arm chromosome translocations are frequently induced, and compensating translocation lines could be identified in the progeny. This approach is based on the transverse division of univalents at the centromere and fusion of the arms from the homoeologous wheat and alien chromosomes.

Lowering DON levels in wheat and barley was another major discussion topic. Participants suggested testing of the alien introgression lines for DON concentration levels in addition to testing for resistance to FHB as part of a strategy to develop breeder-friendly germplasm lines with both FHB resistance and low DON accumulation. Dr. G. Fedak’s group reported a number...
of alien introgression lines with low DON levels, compatible to that exhibited by Sumai 3. Many of those lines exhibited both FHB resistance and low accumulation of DON. Apparently, it is possible to transfer genes conditioning both FHB resistance and low DON accumulation to wheat and have the genes expressed in these adapted genotypes. Some of the participants expressed concern about the difficulties of testing alien species for DON accumulation. Testing large numbers of samples could be cost prohibitive, and test results can be quite variable, depending on the sensitivity of the tests and if the evaluations are conducted in greenhouse or field environments.

Some of the alien FHB resistance genes have been mapped using molecular markers and characterized using cytogenetic techniques. Participants suggested that user-friendly molecular and cytogenetic markers be developed to assist in selection of alien resistance genes in breeding. This should facilitate deployment of alien resistance genes in new cultivars and pyramiding of different sources of resistance. The allelism of alien FHB resistance genes and the resistance genes identified in wheat and barley was also discussed. To determine if newly identified alien genes represent unique sources of FHB resistance, it was suggested that allelism tests be conducted via molecular mapping. Participants suggested it is unlikely that resistance genes identified in alien species with the genomes non-homologous to those in wheat and barley would be allelic to the resistance genes identified in wheat and barley genomes. Therefore, these genes can be transferred to wheat and possibly barley and pyramided with resistance genes originating from the primary gene pools of both crops.

Identification of FHB resistance genes from wild *Hordeum* species and alien gene introgression have been relatively limited in barley partly due to the general intolerance of barley to genetic imbalances. Dr. B. Steffenson reported on the discovery of resistance to FHB in *H. vulgare* ssp. *spontaneum*, a relative of cultivated barley. His program is attempting to transfer resistance to barley from this species and map the resistance genes. He also mentioned that *H. bulbosum*, another relative of cultivated barley, could be a potential source of resistance. There are about 30 other species in the genus *Hordeum*, and he suggested it may be worthwhile to evaluate these species for FHB resistance because of the lack of resistance in cultivated barley. Dr. G. Fedak has successfully hybridized cultivated barley with *Elymus* *humidius*, a wild species exhibiting a high level of resistance to FHB, and he observed pairing between the barley and *Elymus* chromosomes in the hybrid.

The development of collaborations and the enhancement of communication were emphasized, particularly among those involved in pathology, germplasm enhancement, and breeding. A well-coordinated research effort will expedite the identification and introgression of alien resistance to FHB and the deployment of resistance genes in new cultivars. Dr. T. Ban (CIMMYT) led a discussion focused on developing a collaborative effort. Through CIMMYT and the resources available to CIMMYT, he volunteered to maintain and distribute alien introgression lines worldwide and help arrange for the evaluation of those lines for FHB resistance and agronomic performance under different environments. Some participants suggested CIMMYT could serve to facilitate additional material exchange in the development and use of alien germplasm for resistance to FHB.
This workshop provided participants with an opportunity to discuss the challenges in using alien introgression materials to enhance resistance of wheat and barley to FHB. It also provided an opportunity to develop a strategic plan for more rapidly and efficiently deploying alien FHB resistance genes in wheat and barley cultivars. Research summaries on alien introgression efforts, the exchange of information, and the discussion of issues associated with alien introgressions were helpful to develop an efficient strategy to help wheat and barley growers with the release of resistant cultivars.

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Searching for Alien Genes to Enhance Resistance of Wheat and Barley to Fusarium Head Blight

North Dakota State University, Fargo

August 14, 2006

This one-day workshop proposed by the Host Genetic Resources (HGR) Research Area Committee in the U.S. Wheat & Barley Scab Initiative (USWBSI) is funded by USDA-ARS funds provided to the USWBSI. The major goals of this workshop are to bring national and international wheat and barley geneticists, breeders, pathologists, growers, and private industries together to exchange information about the identification and introgression of alien FHB resistance genes; and to develop a strategic and collaborative research effort to accelerate introgression and deployment of alien FHB resistance genes in wheat and barley cultivars. Seven invited speakers will present their research results and ideas on the identification and introgression of alien FHB resistance genes from different species. An open discussion session will be held after the invited talks. The topics discussed will include the current status of alien introgression in different species, strategies for efficient introgression, and utility of alien introgressions in breeding, etc.

AGENDA

The meeting will take place in room 380 of the Loftsgard Hall, NDSU

Monday, August 14

8:30 AM  Welcome Remarks

8:45 AM  Interspecific Hybridization for Enhancement of FHB Resistance in Bread Wheat and Durum
George Fedak, Agriculture Canada, Ottawa

9:15 AM  Enhancement of Wheat with FHB Resistance from Tall Wheatgrass (Lophopyrum elongatum)
Herbert Ohm and Xiaorong Shen, Purdue University

9:45 AM  Development of Wheat-Alien (Leymus racemosus) Recombinant Lines Resistant to Fusarium Head Blight
Bikram Gill, Lili Qi, Mike Pumphrey, Bernd Friebe, and Peidu Chen
Kansas State University

10:15 AM  Break
10:30 AM  Evaluation of Wild Hordeum Species for FHB Resistance  
Brian Steffenson, University of Minnesota

11:00 AM  Identification and Utilization of FHB Resistance in Tetraploid Wheat Germplasm  
Steven Xu, USDA-ARS, Fargo

11:30 AM  Developing FHB Resistant Germplasm Using Alien Genes in Wheat  
Rebekah Oliver and Xiwen Cai, North Dakota State University

12:00 PM  Lunch (provided – 380 Loftsgard Hall)

1:00 PM  Stepping out of the Primary Gene Pool: A Breeder's Perspective on Using Alien Germplasm  
William Berzonsky, North Dakota State University

1:30 PM  Discussion

3:00 PM  Break

6:00 PM  Social and Dinner (provided - Holiday Inn)

**Participant List**

Dr. Tika Adhikari  
North Dakota State University

Dr. Elias Elias  
North Dakota State University

Dr. Tomohiro Ban  
CIMMYT – Mexico Genetic Resources

Dr. Justin Faris  
USDA-ARS

Lisa Benko  
North Dakota State University

Dr. George Fedak  
Agriculture and Agri-Food Canada

Dr. Bill Berzonsky  
North Dakota State University

Dr. Jerome Franckowiak  
North Dakota State University

Dr. Xiwen Cai  
North Dakota State University

Dr. Jeannie Gilbert  
Agriculture and Agri-Food Canada

Dr. Shiaoman Chao  
USDA-ARS

Dr. Bikram S. Gill  
Kansas State University

Chenggen Chu  
USDA-ARS

Justin Hegstad  
North Dakota State University
Danielle Holmes
USDA-ARS

Dr. Richard Horsley
North Dakota State University

Dr. Prem Jauhar
USDA-ARS

Dr. Shahryar Kianian
North Dakota State University

Dr. Masahiro Kishii
CIMMYT – Mexico Genetic Resources

Rachel I. McArthur
North Dakota State University

Dr. Mohamed Mergoum
North Dakota State University

Dr. Stephen Neate
North Dakota State University

Dr. Herb Ohm
Purdue University

Rebekah Oliver
North Dakota State University

Dr. LiLi Qi
Kansas State University

Dr. Xiaorong Shen
Purdue University

Dr. Pawan Kumar Singh
North Dakota State University

Dr. Brian Steffenson
University of Minnesota

Adisu Teshome
North Dakota State University

Dr. Dennis Tobias
North Dakota State University

Dana Weiskopt
USDA-ARS

Dr. Steven Xu
USDA-ARS

Dr. Yang Yen
South Dakota State University

Yongliang Sun
North Dakota State University

Xianwen Zhu
North Dakota State University