

Wheat Research Progress Report - Final

Project #: 3019-3572
Title: Precision Breeding
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Progress Report Year: 2008

Accomplishments

A. Early Generation Assessment of F₄ Head Rows:

In 2008, 1,527 entries were selected from among 23,320 F₄ head rows planted in the field based on plant type, maturity and disease resistance (Table 1). Special emphasis was placed on selecting head rows with high-temperature, adult-plant (HTAP) resistance to stripe rust. After harvest, grain from all samples was visually inspected for plumpness, color and texture to eliminate off types. Remaining head row selections are currently being evaluated for end-use quality potential using small scale tests designed to assess protein content (NIR Technicon), protein quality (SDS Microsedimentation), flour extraction (MicroMill), and noodle color (polyphenol oxidase, PPO), depending on the product targets for each market class (Table 1). Lines with acceptable end-use quality potential will be advanced to F₅ single plot field trials in 2009.

Table 1: Number of F₄ head rows harvested in 2008 and analyzed for noodle color, flour yield and protein quality using polyphenol oxidase (PPO) assays, MicroMill evaluations and microsedimentation tests, respectively.

Market Class	Number Harvested	Number of Lines Tested			Number Selected 2008 Field Trials
		PPO	MicroMill	Micro-sedimentation	
Soft White	885	885	885	0	Pending
Hard Red	278	278	0	278	Pending
Hard White	240	240	0	240	Pending
Spring Club	124	0	124	124	Pending
<i>Total</i>	<i>1,527</i>	<i>1,403</i>	<i>1,009</i>	<i>642</i>	<i>Not Available</i>

B. Marker-Assisted Selection:

1. Stripe Rust Resistance

Yr5 and *Yr15*, two seedling resistance genes to stripe rust, have not been circumvented by any race of the pathogen found in North America to date. Our primary goal is to introgress these genes quickly and efficiently into Scarlet (HRS), WA7900 (HWS), Alpowa (SWS), and Zak (SWS) using DNA marker-assisted selection (MAS). The objective is to recover individuals with agronomic and quality attributes similar to the adapted parent with the added benefit of carrying two seedling resistance genes to stripe rust to enhance durability.

A total of 10 BC₃F₇ and BC₄F₇ derivatives of Scarlet, Zak, Alpowa and WA7900 were evaluated in replicated state field trials at Pullman, Lind, Connell, and Moses Lake in 2008 (Table 2). In addition, an elite group of 4 lines were evaluated in multi-location variety testing and regional replicated trials (Table 2). Five and 4 genotypes were selected for end-use quality assessment based on stripe rust resistance, plant height, maturity and uniformity from the 2008 replicated state and multi-location field trials, respectively. The most promising stripe rust resistant genotypes from each population with acceptable end-use quality potential will be evaluated in variety testing trials in 2009.

Table 2: Recurrent parents, generation, and number of backcross-derived lines expected to carry *Yr5* and/or *Yr15* based on DNA marker analyses that were evaluated in 2008 field trials in: A) state replicated yield trials at Pullman, Lind, Connell, and Moses Lake; and B) multi-location, variety testing, and regional replicated trials.

Recurrent Parent	Generation	Number of Genotypes Evaluated	Number of Genotypes Selected For End-Use Quality Assessment
A.			
Scarlet	BC ₄ F ₇	2	0
WA7900	BC ₄ F ₇	1	1
Alpowa	BC ₃ F ₇	4	4
Zak	BC ₄ F ₇	3	3
Total		10	8
B.			
Scarlet	BC ₄ F ₈	2	2
Zak	BC ₄ F ₈	2	2
Total		4	4

a. Scarlet and WA7900

Out of the five stripe rust resistant lines evaluated for Scarlet and WA7900 (Table 2), we identified two Scarlet derivatives and one WA7900 derivative with superior agronomic attributes that are currently undergoing end-use quality assessment. Backcross derivatives of Scarlet and WA7900 with acceptable end-use quality potential will be evaluated in replicated, multi-location field trials in 2009.

b. Alpowa

Alpowa currently has moderate levels of HTAP but poor levels of seedling resistance to current race of stripe rust, therefore, introgressing *Yr5* or *Yr15* into Alpowa should enhance the level and durability of resistance to stripe rust in this cultivar. The 4 Alpowa derivatives tested in the field in 2008 (Table 2) were submitted for end-use quality assessment. Alpowa derivatives with acceptable end-use quality potential will be evaluated in replicated, multi-location field trials in 2009.

In an effort to pyramid *Yr5* and *Yr15* into Alpowa, backcross derivatives of Alpowa containing *Yr5* were crossed with backcross derivatives of Alpowa containing *Yr15*. The F₂ population generated from these crosses was screened for the presence of both *Yr5* and *Yr15* with MAS. Thirty F₃ derivatives carrying both genes were planted in New Zealand in September 2007 for seed increase. Six additional derivatives unexpectedly exhibited winter growth habit and were given to Dr. Kimberly Garland (USDA-ARS) for fall planting in 2007. The F₄ seed

generated from the 30 lines grown in New Zealand was planted in the spring of 2008 at Spillman Farm. F₅ seed from eighteen selected derivatives is currently being evaluated for end-use quality. Lines with superior milling and baking performance will be advanced to 2009 single-plot field trials.

c. Zak

Based on superior agronomic performance in the field, all 5 backcross derivatives of Zak (Table 2) were selected for end-use quality assessment. Two of these lines had significantly less physiological leaf spot than Zak, which would be beneficial. Zak derivatives with acceptable end-use quality potential will be evaluated in replicated, multi-location field trials in 2009.

d. Louise

Louise currently has high levels of HTAP but poor levels of seedling resistance to current races of stripe rust; therefore, introgressing *Yr5* or *Yr15* into Louise should enhance the level and durability of stripe rust resistance in this cultivar. Backcross derivatives of Alpowa carrying *Yr5* or *Yr15* were used as donor parents to introgress these two genes into the genetic background of Louise. Following independent single gene introgression through traditional F₁ hybrid development, two F₁ lines carrying each gene were intercrossed. Using a rapid breeding approach, over 1,000 F₃ derivatives of Louise were developed and planted as F₄ head rows in 2008. Thirty-one head rows were selected, based on plant type, maturity and disease resistance, for end-use quality assessment using the small-scale tests as describe earlier. Lines with acceptable end-use quality potential will be advanced to 2009 single-plot field trials.

e. Whit (WA8008)

Whit, our newest soft white spring wheat variety, which was approved for release in 2008, has adequate HTAP resistance to stripe rust; however seedling tests indicate that Whit has race-specific, all-stage resistance that is not effective against current, predominant races. Introgressing *Yr5* and *Yr15* into Whit should enhance the level and durability of stripe rust resistance in this cultivar. Backcross derivatives of Alpowa carrying *Yr5* or *Yr15* were used as donor parents to introgress these two genes into Whit. Following independent single gene introgression through traditional F₁ hybrid development, two F₁ lines carrying each gene were intercrossed. Using a rapid breeding approach, over 3,500 F₃ derivatives of Whit were developed and planted as F₄ head rows in 2008. One hundred and sixty-three head rows were selected, based on plant type, maturity and disease resistance, for end-use quality assessment using the small-scale tests describe earlier. Lines with acceptable end-use quality potential will be advanced to 2009 single-plot field trials.

Additionally, Whit was crossed to ARS05305, a spring version of Stephens developed by Dr. Bob Allan. The objective was to pyramid two different sources of HTAP resistance, one from the spring wheat cultivar Whit and the other from the winter wheat cultivar Stephens, into the same genetic background. Using our rapid breeding technique in the greenhouse, 350 F₄ lines were developed and planted as head rows in the field in 2008, and 19 of these lines were selected for end-use quality testing. As above, lines with acceptable end-use quality potential will be advanced to 2009 single-plot field trials.

f. WA8010

The seedling resistance genes in WA8010, a hard white spring experimental breeding line with excellent quality, are no longer effective against current stripe rust races; therefore, introgressing *Yr5* and *Yr15* into WA8010 will provide durable resistance against this pathogen. Thirty-nine F₃ derivatives of WA8010 carrying both *Yr5* and *Yr15* were identified through MAS and were planted as head rows in New Zealand in September 2007. Resulting F₄ seed generated from the 39 lines grown in New Zealand was planted in the spring of 2008 at Spillman Farm. F₅ seed from 23 derivatives were selected for end-use quality assessment. Lines with superior quality will be advanced to 2009 single plot field trials.

g. Testcross Analysis

The presence of *Yr5* and *Yr15* in a single genotype cannot be confirmed through disease screening since no known races circumvent either resistance gene, and the presence of either gene confers resistance to the stripe rust. Twenty-eight derivatives (7 Scarlet BC₄F₇, 8 WA7900 BC₃F₇ and 13 Zak BC₄F₇) were tested in 2008 for the presence of *Yr5* and *Yr15* through testcross analysis. Four backcross derivatives of Scarlet (SRS05049, SRS05272, WA8033, and WA8034) and three backcross derivatives of WA7900 (SRW05554, SRW05611, and SRW05619) were identified as carrying both *Yr5* and *Yr15* in a homozygous state. None of the backcross derivatives of Zak carried both *Yr5* and *Yr15*.

2. High Grain Protein Content

A. Hard Red Spring Wheat

We developed a strategy, using DNA marker-assisted backcross breeding (MABB), to introgress *Gpc-B1*, the high grain protein content region on chromosome 6BS, into Scarlet and Tara 2002. The goal was to recover lines nearly identical to Scarlet and Tara 2002 with the addition of *Gpc-B1*, which was expected to increase grain protein concentration (GPC) by 1-2% as a result of earlier senescence. In 2006 and 2007 field trials, no significant differences in plant senescence or grain protein content between lines with and without *Gpc-B1* were detected. In contrast, when grown under controlled greenhouse conditions, significant increases in time of senescence based on the presence of *Gpc-B1* were detected for both genetic backgrounds. Several agronomic and end-use quality traits differed among isolines; however, these differences could not be attributed to senescence rates. Significant differences in the response of *Gpc-B1* based on genetic background, environment, and their interaction indicate that this gene is highly influenced by environmental factors. We strongly suspect that the dramatic reduction in the total number of growing degree days (GDD) accumulated in Pullman, WA, compared to the Central Valley in California where the original response was detected, as well as differences in the rate of GDD accumulation during early stages of plant development between locations, may have influenced these results. As a result, introgression of this gene into spring wheat in Washington may not be a useful means of increasing grain protein concentration.

One Tara 2002 derivative (4517 ND) was selected based on superior agronomic performance in 2008 field trials for end-use quality assessment. This line has shown consistently high grain protein content levels and superior end-use quality characteristics, although the increase in protein content is not confirmed to be associated with the presence of the gene. This line will be evaluated in replicated field trials in 2009.

B. Hard Red Winter Wheat

Farnum, a hard red winter wheat developed through this project, was approved for variety release in April 2008. Farnum is well adapted to the semi-arid wheat production regions in eastern Washington, and has superior agronomic performance, high grain protein content, and excellent milling and baking quality. Farnum was developed using MABB for *Gpc-B1* combined with our rapid breeding strategy. A sibling line of Farnum, WA8061, had the highest average protein level (13.6%) and third highest average test weight (60.4 lbs/bu) of any entry across eleven locations in the Hard Winter Wheat Variety Testing Trial in 2008. This line was planted in the 2009 trial, for further evaluation.

A project was initiated in 2007 to incorporate new stripe rust resistance genes into Farnum and WA8061 to enhance the durability of resistance. The spring wheat cultivar Lassik (UC1495) was utilized as the donor of *Yr17* and crossed with Farnum and WA8061. F₁ seeds were harvested in August 2007 and, using our rapid breeding strategy to rapid advance material through 3 generations in the greenhouse, 1706 individual F₄ rows were planted at Spillman Farm in October 2008. During the summer of 2009, lines with superior agronomic attributes will be selected and tested for the presence of *Yr17*. Selected lines with the gene will be advanced to fall yield trials in 2009.

Two WSU cultivar releases that are adapted to the semi-arid region, Farnum (hard red winter) and Hollis (hard red spring), were crossed in March 2005. Using our rapid breeding technique to advance early generation material quickly and efficiently in the greenhouse, 3,063 F₅ head rows were evaluated at Spillman Farm in 2007. A selected subset of 148 hard red and 22 hard white winter lines were planted in a single-plot yield trial at Lind, WA in August 2007. Thirty-two hard red and two hard white winter lines were selected for evaluation in replicated field trials in Lind and Pullman in 2009. Quality analyses are currently being completed at the USDA-ARS Western Wheat Quality Laboratory.

3. Hessian Fly Resistance

The Hessian fly (HF) is one of the most destructive insect pests of spring wheat in the U.S. Several HF resistance genes have been identified; however, most varieties grown in the PNW carry the *H3* gene. The risk of new biotypes overcoming the *H3* gene is concerning, therefore, we have introduced novel HF resistance genes (*H9*, *H13*, *H25*) into adapted germplasm for all four market classes of spring wheat grown in the region using conventional breeding and MABB. Recently, new markers for *H3* have been identified from our Louise by Penawawa mapping population. As a result, MAS will be implemented to combine *H3* with the aforementioned HF genes in adapted germplasm.

We developed 17 BC₁F₃ derivatives (BlancaGrande//Otis*2/P985RE1-16), 5 BC₃F₃ derivatives (Eden*4/P937A1-2) and 15 BC₁F₃ derivatives (WA7919/Louise//IDO000586) carrying Hessian fly resistance genes *H9*, *H13* and *H25*, respectively. Markers were used to verify homozygous lines for the respective gene. Homozygous lines from the Eden*4/P937A1-2 cross were evaluated in the field, and resulting F₄ grain is currently undergoing quality testing. Lines with acceptable quality will be advanced to 2009 single-plot field trials.

Homozygous lines from BlancaGrande//Otis*2/P985RE1-16 and WA7919/Louise//IDO000586 were selected to be used as donor parents from gene deployment. These lines were either crossed with elite germplasm or intercrossed with the goal of pyramiding *H9* and/or *H25* into the same genetic background (*H13* was not used due to unreliability of the markers). These lines were evaluated as F₂ field plots in 2008 and will be advanced to F₃ field plots in 2009. One F₂ population carrying *H9* and *H25* was selected for marker analysis to

identify lines homozygous for these two genes. Homozygous lines will be top crossed with Louise to incorporate *H3* into population. A rapid breeding approach will be implemented to advance these lines for field evaluations. MAS will be utilized to assure the desired combination of the genes is present in each line prior to field planting.

Results

1. Farnum was officially released in April 2008. Foundation seed was available in the fall of 2008, and Foundation and Registered seed will be available in 2009.
2. A second potential variety release developed through MAS was the hard red spring line WA8034, which was proposed for pre-release in 2008, but was denied due to concerns about its test weight. This line is a backcross derivative of Scarlet carrying stripe rust seedling resistance genes *Yr5* and *Yr15* and has been released as germplasm for use as a donor for both *Yr5* and *Yr15*. A sister line, WA8033, which was developed with the same technique as WA8034 has many of the same attributes with improved test weight, and is being considered as a variety release candidate in 2009.
3. All (100%) of our early generation (F₄) breeding material were pre-screened for end-use quality potential prior to making selections for advancement to the 2009 field trials through precision breeding efforts.
4. We successfully combined seedling resistance genes *Yr5* and *Yr15* in advanced generation backcross material derived from Scarlet, WA7900, Alpowa and Zak. A total of 12 backcross derivatives were selected for end-use quality assessment and promising lines will be evaluated in the field in 2009.
5. New sources of Hessian fly resistance have been incorporated into adapted spring wheat germplasm. *H13* was introgressed into Eden and selected lines will be evaluated in 2009 as single plots. Sixteen crosses involving *H9* and/or *H25* were advanced from F₂ to F₃ plots. One population has been selected to undergo marker analysis to pyramid *H9*, *H25*, and *H3* into adapted germplasm.

Publications:

- DeMacon, V.L., K.K. Kidwell, D.K. Santra, G.B. Shelton, S.R. Lyon, X. Chen, J.S. Kuehner, B. Baik, D.A. Engle, K. Garland-Campbell and S.S. Jones. 2008. Registration of 'Farnum' Wheat. *Crop Sci* (submitted).
- Santra, D., M. Santra, R. Allan, K.G. Campbell, and K. Kidwell. 2008. Genetic and molecular characterization of vernalization genes *Vrn-A1*, *Vrn-B1*, and *Vrn-D1* in spring wheat germplasm from the Pacific Northwest region of the U.S. *Plant Breeding* (accepted).
- Santra, D.K., X. Chen, K.G. Campbell, and K.K. Kidwell. 2008. Identification and mapping QTL for high-temperature adult-plant resistance to stripe rust in wheat (*Triticum aestivum* L.). *Theoretical and Applied Genetics* (in press).
- Walker, C., K. Garland Campbell, B. Carter and K. Kidwell. 2008. Identifying superior soft white wheat genotypes in diverse production environments using the solvent retention capacity test. *Crop Science* 48:495-506.

Abstracts, Presentations and Tours:

Carter, A., D. Santra, A. Blahnik, G. Shelton, V. DeMacon, and K. Kidwell. 2008. Assessing the impact of the *Gpc-B1* allele on early senescence and grain protein concentration in spring wheat (*Triticum aestivum* L.). Poster presentation at “Plant & Animal Genome XVI”, January 12-16, San Diego, CA, USA.

Carter A., D. See, K. Kidwell and K. Campbell. 2008. Marker Development and Marker-assisted Selection for Improved Disease Resistance and End Use Quality in Pacific Northwest Wheat. p. 32. *In* Huggins, D., Kok, H., Marsh, D., Rollins, D. (ed), “2008 Field Day Abstracts: Highlights of Research Progress: Bioenergy Cropping Systems Research”. Cooperative Extension, Washington State University, Dept. of Crop and Soil Sciences, Technical Report 08-1.

Carter, A.H., X. Chen, K.G., Campbell, K.K. Kidwell. 2008. Identification of a major QTL for high-temperature, adult-plant resistance to stripe rust in the spring wheat cultivar ‘Louise’. *Agronomy Abstracts*. American Society of Agronomy, Madison, WI.

Santra, D., M. Santra, V. DeMacon, G. Shelton, A. Carter and K. Kidwell. 2008. Application of Biotechnology to Spring Wheat Variety Improvement. p. 31. *In* Huggins, D., Kok, H., Marsh, D., Rollins, D. (ed), “2008 Field Day Abstracts: Highlights of Research Progress: Bioenergy Cropping Systems Research”. Cooperative Extension, Washington State University, Dept. of Crop and Soil Sciences, Technical Report 08-1.

Soria, M., J. Sherman, J. Anderson, P.S. Baenziger, G. Bai, B. Berzonsky, G. Brown-Guedira, K.G. Campbell, B.F. Carver, C. Shiaoman, J. Dubcovsky, A. Fritz, C.A. Griffey, S.D. Haley, J.W. Johnson, S.F. Kianian, K.K. Kidwell, D.E. Matthews, M. Mergoum, H. Ohm, J. Peterson, O. Riera-Lizarazu, J. Rudd, L. Talbert, M.E. Sorrells, E. Souza, R. Zemetra. 2008. WheatCAP: Empowering Wheat Farmers With New Breeding Technologies. Poster presentation at “Plant & Animal Genome XVI”, January 12-16, San Diego, CA, USA.

MAS workshop in conjunction with the state FFA convention held at the WSU campus. 16 May 2008. Total participants: 60 FFA students and 8 FFA advisors. Title: “CSI Plant Style: From the Laboratory to Your Lunch Tray.”