

Proposal to the Agricultural Research Foundation Oregon Wheat Commission

TITLE: Development, testing, and release of wheat varieties adapted to Oregon production with enhanced disease resistance, stress tolerance, and superior end-use qualities.

INVESTIGATOR: C. James Peterson Crop & Soil Science Department Oregon State University (OSU)

COOPERATORS: Andrew Ross: Crop and Soil Science Department, OSU

Mike Flowers: Crop and Soil Science Department, OSU

Chris Mundt: Botany and Plant Pathology Department, OSU

Oscar Riera-Lizarazu: Crop and Soil Science Department, OSU

Craig Morris: Western Quality Laboratory, Pullman, Washington

FUNDING HISTORY:

2005-06 :200,000

2006-07: 190,000

2007-08: 213,961

ABSTRACT:

Wheat varieties with superior grain yield, yield stability, disease resistance, stress tolerance, and superior end-use quality are critical to the economic viability of Oregon wheat producers. A wide array of genetic resources, technologies, and selection strategies are integrated through breeding and variety development. Early generation stocks (F1 through F5) will be evaluated through a shuttle between Hyslop and Pendleton to identify promising selections with disease resistance and high yield potential. Multi-site evaluation of mid-generations (F5/F6 Preliminary trials through F9 Advanced trials) will be conducted to rapidly identify purelines with broad adaptation and high yield potential, determine response to multiple disease complexes, and development varieties that are targeted for specific management practices or constraints. Through the Oregon Winter Elite Yield Trial (OWEYT), Oregon Spring Elite Yield Trial (OSEYT), and Hard Winter Elite Yield Trial (HWEYT), candidate varieties will be evaluated throughout the state and compared to economically important and newly released varieties. These trials serve the combine needs of OSU Variety Testing, Wheat Breeding and Genetics, and the Wheat Quality Improvement programs. Results are provided to growers and industry and provide the fundamental data needed for variety selection and quality recommendations. PCR and DArT based molecular markers are being used to characterize parental stocks and mapping populations and identify genes for resistance to important PNW diseases, including stripe rust, cephalosporium stripe, strawbreaker footrot, septoria, and crown rot. Development of improved Clearfield varieties continues, but focus is now shifting to two-gene materials with enhanced herbicide tolerance. Through collaborative research and support provided the OSU Wheat Quality Improvement Program and the ARS-Western Wheat Quality Lab, we are developing soft and hard white varieties with improved end-use quality that can increase our competitive ability and create new value-added marketing

opportunities.

OBJECTIVE:

Develop, test and release improved wheat varieties

- a. Develop and release new wheat varieties with superior disease resistance and enhanced tolerance to abiotic stresses that minimize production risks and increase economic returns to growers.
- b. Evaluate performance of new and leading varieties, and variety candidates, in the major wheat-producing areas of Oregon. Provide growers with up-to-date information on variety performance, adaptation, and disease resistance.
- c. Increase demand and marketability of PNW wheat through development of soft and hard wheat varieties with superior end-use qualities. Identify germplasm, genes, and traits that contribute value-added or product-specific qualities and provide new marketing opportunities for wheat growers.
- d. Identify germplasm, genes, and traits that will contribute to superior varietal performance and enhanced yield stability under diverse production conditions. Incorporate these new genetic resources into adapted varieties through efficient use of field and laboratory evaluation methods.
- e. Identify and incorporate important genes for disease resistance, adaptation, and end-use quality using molecular marker technologies and biochemical analyses.

PROCEDURES:

Similar to previous years, this OWC proposal supports four major components of the OSU wheat improvement efforts - the Wheat Breeding Program, Variety Testing Program, Cereal Extension Program, and the Wheat Quality Improvement Program. Elite replicated yield trials needed to meet objectives of all three programs are grown in core breeding nurseries and satellite sites. This has increased our efficiencies in use of increasingly scarce resources provided to these programs by state agencies.

Field Breeding, Evaluation, and Selection Strategies:

Wheat germplasm and varieties will be evaluated under an array of environments and management practices to characterize performance and response to biotic and abiotic stresses. Early generation stocks (F1 through F5) will be evaluated through a shuttle between Hyslop and the Rugg's site (Pendleton) to identify broadly adapted, disease resistant selections with high yield potential. Multi-site evaluation of mid-generation materials (F6 preliminary lines through F9 advanced selections) will then be conducted to rapidly identify lines with both broad and specific adaptation, determine response to multiple disease complexes and pressures, and develop varieties that are targeted for specific management practices or constraints. Elite lines and candidate varieties from throughout region will be compared to economically important and newly released varieties in the Oregon Winter Elite Yield Trial (OWEYT), Oregon Spring Elite Yield Trial (OSEYT), and the Hard Winter Elite Yield Trial (HWEYT).

In addition to core breeding sites at Hyslop, Moro (Sherman County Experiment Station), and Rugg's (Pendleton), six 'satellite' test sites will evaluate genetic response to a wide array of production

conditions. Each 'satellite' nursery consists of three replications of the Oregon Winter Elite Yield Trial (40 entries), three replications of the Hard Winter Elite Yield Trial (30 to 40 entries), yield trials of advanced experimental lines with limited replication (~240 entries), and an unreplicated observation nursery of single or two-row plots (approximately 400+ entries). The observation nursery will include preliminary (F6) and advanced (F7 through F9) breeding lines and promising parental stocks for visual scoring of plant type, vigor, disease reactions, stress tolerance, and finish. This is a cost-effective means to gain information on adaptation and stress tolerance of early generation lines without the high seed requirements and expense associated with management of full-size plots.

In fall 2007, satellite test sites were planted near Moro (Chris Kaseberg), Condon (Paul Bates), Arlington (Brad Anderson), Lexington (Chris Rauch), Hermiston (Kent Madison), and North Powder (Craig Ward). These sites were chosen to represent a diverse array of production conditions; from very low rainfall to full irrigation, shallow to deep soils, and low residue to high residue management practices. Exact location of the trials may vary each year. With this large number of test sites available each year, we can more efficiently allocate time and resources to sites from which superior selections and unique genetic responses can be identified.

Additional locations of the OWEYT and OSEYT are proposed to cover historically important Statewide Variety Trial sites such as Madras, La Grande, Ontario, and Klamath Falls. These trials will be managed by local AES personnel. Observation trials, which are an important component of the satellite breeding nurseries, would not be grown at these sites.

Data from the OWEYT, OSEYT, and HWELT will be collected and analyzed and made available to growers via the OSU Wheat Project Web Site soon after harvest. Reporting will be coordinated with Mike Flowers, with data summarized and distributed via web, email, newsletters, print media, and various extension outlets. The OWEYT, OSEYT, and HWELT also provide grain samples to evaluate stability and consistency of end-use quality traits by the OSU Wheat Quality Improvement Program and ARS Western Wheat Quality Lab. The quality tests and resulting data will provide the fundamental information needed for variety recommendations and future release decisions.

Improvement of Biotic and Abiotic Stress Tolerance:

Varieties with resistance to major diseases, such as pseudocercospora, cephalosporium stripe, bunt, stripe and leaf rust, septoria, and dryland rootrots are needed to ensure stable yields and produce a superior quality wheat crop. Genetic resistance, when available, remains the most environmentally sound and cost effective means of disease control. However, this requires an on-going supply of new and more effective resistance genes and effective screening strategies to introgress these genes into adapted varieties.

In collaboration with OSU Pathologist Chris Mundt, we are evaluating advanced breeding lines and parent stocks for reaction to Cephalosporium stripe in inoculated field trials at CBARC. Dr. Mundt is evaluating a similar set of materials for pseudocercospora footrot in an inoculated nursery planted at the OSU Botany Farm. In collaborations with Dick Smiley, CBARC, varieties and advanced germplasm are

being evaluated for response to *Fusarium* dryland rootrot and nematodes. Stripe, leaf, and stem rust evaluations are conducted in collaboration with USDA-ARS Pathologists Xiaming Chen and Yue Jin, Jackie Rudd, Texas A&M and Karim Ammar, CIMMYT.

A wide array of germplasms are being used for improvement of disease resistances, including genetic stocks from CIMMYT, western and eastern European breeding programs, and programs from throughout the U.S. A high priority continues to be the introgression of new germplasm from the Nickerson breeding programs in France and the UK. A large proportion of our advanced soft white winter wheat selections, now in multi-location yield trials, are derived from these crosses.

Improvement of End-use Quality:

Improving wheat quality for the industry requires multiple levels of research and collaboration; in-house micro-analyses for rapid evaluation at early breeding stages; macro-testing to establish base product quality at intermediate stages; industry-scale evaluations to establish product-specific quality attributes, and an ongoing commitment to basic quality research. Through collaborations with Dr. Andrew Ross, the OSU Wheat Quality Lab supports end-use quality testing of early generation F4 and F5 selections and develops recommendations regarding performance of elite lines, variety candidates, and economically important varieties for Oregon. Craig Morris and the USDA-ARS Western Wheat Quality Lab provide primary support for screening of mid-generation breeding materials and assessment of OWEYT and OSEYT grain samples. We continue to collaborate with the Wheat Marketing Center, primarily through entry of variety candidates in to the Asian Products Collaborative and Overseas Variety Analyses. With Andrew Ross, we are continuing investigations of hard white wheat quality in relation to biochemical compositions of protein and starch.

Soft white winter wheat improvement will continue to be the primary focus in the breeding program, accounting for approximately 75% of the program effort. Improving soft white quality for cookies and cakes remains a high priority through development of extra-soft, low pentosan, and low PPO germplasm. The remaining 25% of our efforts will be allocated to quality improvement for 'end-use market development'. This includes hard white winter wheat development for Asian markets, development of hard and soft wheat with novel or value-added quality traits, development and testing of hard red winter wheat varieties, and soft wheat varieties with extra-soft kernel texture.

Hard white wheat development will focus on quality and applications in Asian noodle products and steam breads. As suitability for dual- or multi-purpose product applications appears critical for hard white wheat marketing, we are striving to identify and develop materials that have improved hardness, protein quality, and bread making ability in one package. Cross combinations between OSU HWW's and Plains HRW and HWW selections are being used to simultaneously improve protein quality, winterhardiness, and noodle color, while capturing the high yield, broad adaptation, low PPO, and footrot resistance of our 'quality-challenged' hard white selections, such as OR943575. The first of our 'second generation' HWW selections are now entering regional and state variety trials. Extensive quality testing will be needed to assure these selections meet market expectations, but initial results from small-scale tests have been promising.

Application of Molecular Marker Technology:

Molecular markers, when available, can be a cost-effective alternative to phenotypic screening for diseases, stress tolerance, or end-use quality. The number of useful public markers is expected to increase rapidly through national research funded by the CSREES CAP grant 'Bringing Genomics to the Wheat Field'. However, in-house research is needed to identify and characterize markers directly applicable to our germplasm base and the biotic and abiotic stresses associated with the PNW production region.

Molecular marker research and gene discovery investigations are underway in collaboration with Oscar Riera-Lizarazu and are the basis for M.S. and Ph.D. research of Martin Quincke, Dolores Vasquez, and Jari von Zitzewitz. Mapping populations have been developed and are being evaluated in multi-location field trials to generate data and trait information that will be associated with molecular markers. The 'SuperSoft' quality trait is being investigated in a Stephens x SuperSoft population of 165 individuals. Over 500 DArT and 280 SSR markers have been characterized. The population is being grown at Pendleton, Moro, and Corvallis in 2008 to generate grain for quality analyses. Stripe rust resistance is being investigated in a Stephens x Platte population of 180 individuals. DArT marker analyses are complete and SSR analyses underway. The population is being grown at two sites in Oregon, two in Washington, two in South Texas, and Toluca, Mexico to evaluate disease response. Resistance to *Cephalosporium* stripe is being investigated in a Coda x Brundage population in collaboration with Bob Zemetra, University of Idaho. DArT marker analyses are complete and being combined with marker information being generated in OSU, WSU, and U of I labs. General disease resistance and adaptation also is being investigated in a crosses of Tubbs x NSA98-0995 and Tubbs x Einstein. NSA98-0995 and Einstein are from the Nickerson programs in France and the UK. DArT marker analyses are complete on the Tubbs x NSA98-0995 population; the second population will be submitted for marker analyses this spring. The first field planting and evaluations of over 600 progeny are now underway at Corvallis.

Clearfield Variety Development:

Development of one-gene Clearfield varieties is now focused on a small number of elite lines that have potential for commercial release within the next 1-3 years. These include the release candidate ORCF-103, a reselection of ORCF-101, and a selection derived from cross of ORCF-102 with a French variety. There are few remaining early-generation populations derived from crosses with one-gene breeding material. This is largely in response to pressures from BASF to develop 2-gene Clearfield varieties with enhanced herbicide tolerance. Our two-gene breeding materials are currently in single and backcross populations in F1 through F3 generations. Multi-location yield testing of the first series of 2-gene selections will begin in the 2008-2009 season.

In collaboration with Dan Ball, we are continuing to evaluate tolerance of new CLEARFIELD* variety candidates to varying rates and application dates of Beyond herbicide. BASF requires a minimum of six sites of herbicide testing over two years prior to commercial release of a new Clearfield variety. This research also has provided important information for growers and seed industry regarding herbicide response of the new CLEARFIELD* varieties.

TIMELINES:

Wheat breeding and variety development is a long-term effort and ongoing process. Specific research activities are conducted on a seasonal basis, such as planting, crossing, disease evaluations, and harvest. Results are highly dependent on environmental conditions.

JUSTIFICATION:

Wheat is the major cereal crop for Oregon with annual production averaging over 55 million bushels from approximately 900,000 acres each year, with gross value of over \$200 million/year at the farm-gate. Investments in wheat breeding have provided tremendous economic returns to Oregon growers through deployment and production of high-yielding, disease resistance varieties such as 'Stephens', 'Gene', 'Malcolm', 'Tubbs', 'ORCF-101', 'ORCF-102', 'Goetze' and others. However, due to ever changing disease complexes, management practices, production constraints, and market needs, an ongoing commitment to variety development is needed for stable and economically viable wheat production in Oregon. Addressing management-specific and site-specific production constraints through variety development and applications of modern biotechnologies will contribute to long-term profitability of Oregon wheat producers. The OSU Agricultural Experiment Station's "Oregon Invests" program estimates that, in non-drought years, variety improvement efforts contribute an additional \$47+ million per year to growers compared with a 1970 production base. Annual economic consequences of the variety development program are expected to continue at a similar level, estimated at \$1.5 million per year. Research efforts to develop value-added, superior quality varieties will further increase demand for Oregon wheat and provide new marketing opportunities for Oregon growers.

REPORT OF SIGNIFICANT ACCOMPLISHMENTS:

The variety 'Tubbs', released in 2002, and its reselection 'Tubbs 06' are established as leading varieties in the PNW in terms of both acreage and performance. The OSU CLEARFIELD soft white winter variety 'ORCF-101' and 'ORCF-102' were released to the seed industry in 2003 and 2004 through an innovative non-exclusive licensing agreement. Twenty-three seed companies are currently licensed to produce and sell seed of these varieties in the Pacific Northwest. Combined acreage of ORCF-101 and ORCF-102 in the PNW are estimated at 330,000 acres for 2005-06, over 350,000 acres for 2006-07, and approach 400,000 acres for 2007-08. The Oregon Winter Elite Yield Trial (OWEYT) was grown at 14 locations in 2007. Data were collected and summarized from 13 sites. Data also were collected from 7 locations of the Hard Winter Elite Yield Trials (HWELT) and 5 locations of the Oregon Spring Elite Yield Trial (OSEYT). These variety trials support breeding efforts, end-use quality testing, variety release decisions, variety quality recommendations, and provide important information on variety performance to Oregon wheat growers.

New Varieties Released in 2007:

'Goetze' is a short stature soft white winter wheat variety with moderately early maturity and high yield potential. Goetze is resistant to current races of stripe rust and moderately resistant to Septoria leaf blotch, an important disease of the Willamette valley. The variety has good milling and baking quality, similar to Stephens. Goetze is a facultative type and has less cold tolerance than Stephens or Tubbs. As such, it is being targeted for the Willamette valley and areas of Oregon where the variety Gene is commonly grown.

'Norwest 553' is a hard red winter wheat developed in collaboration with the Nickerson-Advanta company in the Europe. Based on French parentage, Norwest 553 (ORN00B553) is a semidwarf variety best adapted to moderate to high rainfall areas of north east Oregon and south east Washington. The variety has acceptable milling and baking quality for the hard red winter market class with superior dough mixing strength. Norwest 553 is being licensed to PNW seed companies for production and sale of Certified seed. All commercial plantings of Norwest 553 must be from Certified seed.

NOTE: The funding request for 2008-09 has been reduced with the expectation that a portion of OSU Clearfield royalty dollars will be used to support the breeding program. Approximately 1/3 (~\$60,000) of royalty dollars returned to the Breeding program in 2008 will be used to cover basic program expenditures, including hourly labor, supplies, and travel. The remaining portion of royalty dollars are to be invested in small and large equipment purchases and basic research, including development and implementation of molecular markers.

It is not possible to provide separate budgets for each major objective of the program. These objectives cannot be considered as independent line-items. The program is designed to maximize efficiency by integrating breeding, variety testing, disease and end-use quality research, and applications of molecular markers.

RELATION TO OTHER RESEARCH:

OSU wheat variety development and genetics research is conducted in collaboration with OSU faculty in Crops, Soils, Extension, and Plant Pathology throughout the state. This project is designed to fully integrate, support, and complement OWC-funded research of Andrew Ross, Mike Flowers, Oscar Riera-Lizarazu, Dan Ball, Craig Morris, and others. Our collaborations on germplasm development, evaluation, and genetics research extend throughout the tri-state region and U.S., including projects with wheat researchers at the University of Idaho, USDA-ARS, and Washington State University.