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

Submitted to: Agricultural Research Foundation
Oregon Wheat Commission

Submitted by:

C. James Peterson — Date
Professor, Wheat Breeding and Genetics
Dept. of Crop and Soil Science

Approved:

Dr. Russ Karow — Date
Head, Department of Crop Science
(541) 737-2821

Dr. Sonny Ramaswamy, Dean — Date
College of Agricultural Sciences
(541) 737-4251

Dorothy Beaton — Date
Agricultural Research Foundation

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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 Wheat Quality Lab, ARS, Pullman, WA
	Deven See	Western Reg. Genotyping Lab, ARS, Pullman, WA

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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 in collaborative research to characterize parental stocks and mapping populations and identify genes important for adaptation to the PNW, including resistance to 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 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 Pendleton (Betts Ranch), 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 2009, satellite test sites were planted near Moro (Chris Kaseberg), Condon (Jeff Nelson), Arlington (Jim Rucker), Lexington (Chris Rauch), Hermiston (Kent Madison), and La Grande (Roben Arnoldus). An additional Valley test site was added this year near Forest Grove (Tom Duyck) for the OWEYT and advanced SWW trials. Two no-till trials also were established, one at CBARC the other near Dufur. 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 managed, on a fee basis, by local AES personnel to cover historically important Statewide Variety Trial sites such as Madras, La Grande, Ontario, and Klamath Falls.

Data from the OWEYT, OSEYT, and HWELT will be collected, analyzed and made available to growers 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 HWEYT 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 Stress Tolerance:
Varieties with resistance to major diseases, such as pseudocercosporella, 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, parental stocks, and mapping populations for reaction to Cephalosporium stripe in inoculated field trials at CBARC. Dr. Mundt is evaluating a similar set of materials for Fusarium crown rot in eastern Oregon, and for psuedocercoporella 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 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 priority continues to be crossing and introgression of germplasm from Nickerson breeding programs in Western Europe. This fall, over 300 new lines were received from Nickerson and through reciprocal germplasm exchanges.

Improvement of Abiotic Stress Tolerance and Adaptation to Management Practices:
Adaptation and tolerance to environmental stress, including heat and drought, is generally achieved indirectly through multi-location field testing. Test sites are chosen to obtain a wide array of stress conditions each year, with annual precipitation ranging from ~10" to full irrigation and yields ranging from 35 to 150 bu/a. Winter cold tolerance of OSU varieties and selections is being further evaluated in growth chamber studies in collaboration with Dan Skinner, USDA-ARS Pullman, WA.

On-farm trials also are chosen to represent the predominant management practices used in the area, ranging each year from conventional tillage to chem-fallow and no-till systems. Dryland trials are generally in wheat-fallow-wheat rotations, while irrigated trials are generally in rotation with potato. We are placing increasing emphasis on testing and selection under no-till and high-residue management systems. In 2008, a double-cone research drill was purchased and modified in collaboration with CBARC for application to no-till situations. Two no-till trials were established last fall, one at CBARC and the other on-farm near Dufur. For 2011, we are proposing to establish three no-till sites, one in the Adams area; one at CBARC, and one in Sherman or Wasco counties. Results will be compared to those from conventional trials at our Pendleton and Moro sites.

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 wheat development is focused on white grain for multi-purpose product applications, including Asian noodle products, pan bread, and stream bread. Our breeding strategy has based on cross combinations of OSU HWW's, Plains HRW and HWW selections, and CIMMYT HWS germplasm. Significant advances have been made in adaptation, yield potential and end-use quality of our HWW selections, as evidenced by performance in the HWELT. However, with these improvements, we have found genetic resistance to stripe rust has been compromised. Efforts to identify and introduce broad-based resistance into our HWW selections are underway using both field screening and molecular markers. Populations based on Norwest 553 (HRW), which has a unique combination of excellent stripe rust resistance and protein quality, are high priority in our HWW development efforts.

Breeding of hard red winter varieties has not been a priority in our program. The exception is the HRW 'Norwest 553', released by OSU in 2008 jointly with Nickerson UK and targeted for production in moderate to high-rainfall areas. We have long used red wheat germplasm as parents in both our soft and hard wheat breeding efforts, then discarded red-seeded progeny. As interest and demand for HRW varieties is continuing, we intend to maintain red-seeded segregates from the most promising populations and advance these in parallel with our hard white selections.

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 increasing rapidly, in part through public 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. A significant commitment of both time and resources are needed if we are to effectively implement marker assisted selection in our evaluation and selection strategies.

Molecular marker research and gene discovery investigations are underway in collaboration with Oscar Riera-Lizarazu, OSU, and Deven See, USDA-ARS. Over the past four years, five linkage mapping populations have been evaluated in multi-location field trials and serve as the basis of M.S. and Ph.D. research of Martin Quincke, Dolores Vasquez, Jari von Zitzewitz, and Chris Gaynor. Progeny have been genotyped using DArT and SSR molecular markers, phenotyped for adaptation, yield components, disease, and quality, and then associations between valuable traits and markers identified. To-date, we have identified valuable new markers for resistance to stripe rust and Cephalosporium stripe, and for the super-soft quality trait. Analyses and publications drafts are in-progress. The next steps include 'fine-mapping' the critical areas where genes have been located and develop robust markers for implementation in the breeding program.

The focus for molecular marker research is now shifting to two major elite populations; Tubbs x Einstein (UK) and Tubbs x NSA98-0995 (Fr). In these populations were are investigating adaptation (maturity, grain filling, photoperiod sensitivity), plant architecture (height, leaf

dimensions, leaf angle), yield components (tillering, spike and spikelet fertility, kernel weight) and disease resistance (stripe rust, septoria, Cephalosporium stripe, crown rot). The goal is to identify genes, markers and genetic regions that are critical for adaptation in the PNW, which will facilitate rapid introgression of novel genes from unadapted germplasm. Preliminary analyses of 2009 field trials have identified unique markers associated with spike fertility and seed weight, with genetic contributions coming from each parent. The populations, over 250 individuals for each, are being evaluated in replicated field trials at Corvallis and Pendleton again for 2010.

Deven See, USDA-ARS, is characterizing our advanced lines and parental stocks for presence of key markers and associated traits. These include VPM-1 for resistance to strawbreaker footrot; Lr46-Yr29, Lr34-Yr18, Lr39-Lr41 and others for rust resistance; Pina-D1 for grain hardness; and Vrn 1, 2 and 3 for vernalization requirements. The information will be valuable both for selection purposes and to match parents for making cross combinations.

Clearfield Variety Development:
Our priorities in the Clearfield program have shifted to breeding varieties with two genes for herbicide resistance. For 2010, seven two-gene selections were advanced to multi-location testing and pre-Breeder seed increase. These are in Weatherford background (similar to ORCF-102), with many similarities in plant type and performance. A problem, however, is that these carry 'new mutant events', not characterized or approved by BASF. It is unclear if we will be allowed to commercialize these without additional field and biochemical tests. If not, crosses with the 2nd-gene donor provided by BASF (in Australian spring HW background) are in early generations, meaning several years from commercialization.

A small number of one-gene Clearfield breeding stocks remain active, primarily for use as parents. The most notable is ORI2060306, a reselection of ORCF-101. It has similar performance and more uniform plant type than the original variety, and could be easily adopted as a replacement for ORCF-101.

In collaboration with Dan Ball, we are continuing to evaluate tolerance of new CLEARFIELD* variety candidates to Beyond herbicide. This research also has provided important information for growers and seed industry on herbicide management practices. For 2009, with focus now on 2-gene stocks, two locations of yield trials are established for application of herbicide at 2-dates with 2x rate. BASF requires a minimum of six sites of herbicide testing over two years prior to commercial release of a new Clearfield variety. Verification of genetic composition by molecular markers also will be important for our 2-gene variety candidates.

TIMELINES:

Wheat breeding and variety development is a long-term effort and ongoing process. Average timeline from initial cross to variety releases is 10 to 12 years. 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 $250 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', 'ORCF-103', 'Goetze', 'Norwest 553' 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. 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:

A total of nine varieties have been released since 2002, including Tubbs and Tubbs 06; ORCF-101, 102, 103; Norwest 553, Goetze, and Skiles. These varieties accounted for 457,200 acres, or 60.4% of all winter wheat produced in Oregon in 2009 (either alone or in blends). This exceeds acreage of Stephens, long the #1 variety in Oregon, at 170,000 acres, or 19.3% of all winter wheat. Varieties released by OSU since 2002 accounted for 31% of all Washington Certified winter wheat seed sold in fall 2008. Using conservative estimates, these nine new wheat varieties have increased yields across the state by 5 bushels per acre (8 to 12%) compared to Stephens. At the current price of wheat (~$5.50 per bushel) this equates to an economic impact for Oregon wheat growers of $12 million dollars in 2009 alone. Availability of these new varieties has contributed to a nearly 10-fold increase in wheat acreage in the Willamette valley. In Washington, these new OSU wheat varieties increase wheat yields by an average 6.5 bushels per acre compared to Madsen. At the current wheat, the economic impact of these improved Oregon wheat varieties for Washington growers is conservatively estimated to be $21.5 million dollars in 2009.

The CLEARFIELD varieties ORCF-101, ORCF-102, and ORCF-103 were the leading royalty income sources for OSU in 2007 and 2008. Twenty eight seed companies in the PNW are currently licensed to produce and sell seed of the OSU CLEARFIELD varieties. In fall, 2008, approximately 450,000 acres of ORCF-101 and 102 were seeded in the PNW from sale of 540,000 bushels of Certified seed. For fall 2009, combined seed sales of ORCF-101, 102, and 103 are anticipated to be over 700,000 bu.

The Oregon Winter Elite Yield Trial (OWEYT) was grown at 14 locations in 2009. Data were collected and summarized from 11 sites. Data also were collected from 7 locations of the Hard Winter Elite Yield Trials (HWELT) and 4 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.

BUDGET:

Salaries		
	0.25 of three FRA (Larson, Simons, Heesacker)	29,460
	OPE share for FRA	17,840
	0.50 FTE Instructor (Verhoeven)	31,914
	OPE Instructor	21,504
	Student	80,000
	OPE Student (8-10%)	6,800
Services/ Supplies		60,000
AES Cooperators (Madras, La Grande, Ontario, Klamath Falls)		12,000
Travel (domestic in-state)		27,000
Travel (domestic out-of-state)		3,000
Total		289,518

NOTE: *Relative to 2009, the budget request is revised to include 0.25 FTE for each of three FRA (Mark Larson, Eddie Simons, Adam Heesacker). This is the proportion which was lost to state budget cuts. Increased operating costs are anticipated due to new land charges on OSU Experiment Station. A one-time increase in land-rent for 2010 is being incurred for our base nursery at Pendleton. An alternative field is being rented while long-time fields rented from Larry Williams are being renovated.*

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, Deven See, 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.