Partners in Progress
WHEAT

Wheat Research at OSU 2014

Supported by the

Oklahoma Wheat Commission

and the

Oklahoma Wheat Research Foundation

Oklahoma State University
Division of Agricultural Sciences and Natural Resources
Oklahoma Agricultural Experiment Station
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Partnerships Enhance Wheat Research

Partners in Progress – Our long-standing partnership with the Oklahoma Wheat Commission (OWC) and the Oklahoma Wheat Research Foundation (OWRF) is a valuable asset for Oklahoma State University's wheat research and Extension programs. The partnership not only provides partial funding for our research programs, but also provides valuable input from producers that helps keep our research programs focused and relevant. It is truly one of the best examples of the Division of Agricultural Sciences and Natural Resources (DASNR) working in a cooperative relationship with commodity groups to achieve common goals. Partial funding for our research and Extension programs comes from wheat producers through the check-off program. We have been and continue to be accountable for the use of these funds.

The *Partners in Progress Wheat Research Report* is one of a series of annual reports from DASNR highlighting research results and impacts of funded projects. This information is utilized throughout the year in educational wheat programs and is distributed to Oklahoma wheat producers to keep them up-to-date on the latest research findings. The research contained in this report has been directed as closely as possible to meet the needs of Oklahoma wheat producers.

At the beginning of the first section is a summary of accomplishments for fiscal year 2013-2014. The narrative that follows explains in more detail the progress made during the year.

The long-term continuous support of our wheat research programs from the OWC and the OWRF has allowed our faculty to make significant progress toward the common goal of keeping Oklahoma wheat farmers competitive in regional, national and international markets. This support makes us truly *Partners in Progress*.

Keith Owens
Interim Associate Director
Oklahoma Agricultural Experiment Station
Division of Agricultural Sciences and Natural Resources
Oklahoma State University

Oklahoma State University
Division of Agricultural Sciences and Natural Resources
Mission Statement

The Mission of the Oklahoma State University Division of Agricultural Sciences and Natural Resources is to discover, develop, disseminate and preserve knowledge needed to enhance the productivity, profitability and sustainability of agriculture; conserve and improve natural resources; improve the health and well-being of all segments of our society; and to instill in its students the intellectual curiosity, discernment, knowledge and skills needed for their individual development and contribution to society.

Crafting Success

Partners in Progress WHEAT

"Construct your determination with sustained effort, controlled attention and concentrated energy. Opportunities never come to those who wait … they are captured by those who dare to attack."
– Paul J. Meyer

One can look at the strides being made at Oklahoma State University (OSU) with the OSU Wheat Improvement Team (WIT) and see the concentrated energy being pushed forward to help Oklahoma wheat producers capture the best when it comes to wheat production. It is important to remind Oklahoma wheat producers that the support made possible through the OWC and the OWRF continues to make our wheat variety improvement program at OSU second to none.

During this past year, Oklahoma wheat producers have faced some of the most challenging times with regard to production agriculture. If you look at the breakdown of this report, you will see the analysis of wheat varieties with more favorable yields than expected, which is no small feat considering the drought conditions and late freeze damage caused to this crop.

The release of new varieties with different available attributes continues to make us more competitive in the marketplace, not only with yield benefits, but also with quality. The importance of creating varieties for maximum yield potential to make the producer more profitable is the main goal. However, it also is important to note the technologies funded to help release varieties focusing on better end-use value for the milling and baking industries. End-use quality attributes are highly regarded by selections released through the OSU breeding program. This is extremely important when focusing on consumer needs.

With the breeding program at OSU, we examine and study the end-use quality characteristics beneficial to our foreign and domestic customers. Therefore, we are working to capture more market share for the farmer using varieties created with our breeding program.

Quality starts with seed placed into the soil. To have a good product for the end game, we must remember good quality also has to start from the beginning. We encourage soil testing that is available through your local county Extension office. We also encourage producers to look at the importance of nitrogen applications for increased protein levels. Exporters and domestic grain companies are looking for higher protein wheat that has better attributes for baking. By focusing on some of these factors in an operation, it can help ensure good decisions are being made to deliver high quality wheat.

The OWC and OWRF, along with OSU's WIT and DASNR, continue to work on items beneficial to both the producer and buyer. We carry on by making great strides with the wheat research and Extension program at OSU, and we want to thank the producers for the support to keep these programs at the forefront of technology discovery and transfer. The OSU WIT prepares for planting by spending numerous hours on research with sustained effort, controlled attention and concentrated energy creating the tools to help make our wheat producers more competitive, and therefore, we are glad to be *Partners in Progress*.

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Genetic Improvement and Varietal Release of Hard Winter Wheat

Wheat Improvement Team

2013-2014 progress made possible through OWRF/OWC support

- Increased its web-based and social media presence, with team sites and social media receiving more than 50,000 visits per year. (Edwards)
- Provided 11 in-season wheat disease updates to producers, consultants, Extension educators and researchers via an electronic format. (Hunger)
- Added a first-hollow-stem estimator to the Oklahoma Mesonet Ag Weather page. This web-based tool allows producers to not only estimate current first hollow stem throughout Oklahoma, but also project the advancement of first hollow stem two weeks beyond. (Edwards)
- Evaluated nearly 1,700 wheat experimental lines for reaction to multiple diseases, of which 50 percent were developed by WIT. (Hunger)
- Evaluated about 850 WIT experimental lines for reaction to the wheat soilborne mosaic/ wheat spindle streak mosaic (WSBM/WSSM) complex. For a subset of 466 lines, the enzyme-linked immunosorbent assay (ELISA) was used to test for virus presence to better define the reaction of lines to both viruses. (Hunger)
- Determined additional reactions of 466 WIT experimental lines to leaf rust, 411 lines to tan spot, 141 lines to powdery mildew and 705 lines to barley yellow dwarf (BYD). (Hunger)
- Implemented highly sensitive, molecular tests to (i) detect three viruses simultaneously—*Wheat streak mosaic virus* (WSMV), *High plains virus* (HPV) and *Triticum mosaic virus* (TriMV); and (ii) distinguish among several viruses classified as BYDVs and *Cereal yellow dwarf viruses* (CYDVs). These tests were validated with samples collected during 2013-2014 and are now available for use in the future to determine reaction of WIT lines to these viruses. (Hunger)
- Confirmed procedures to evaluate wheat cultivars and experimental lines for reaction to common root rot and spot blotch, which are the root and foliar diseases caused by the fungus *Bipolaris sorokiniana*. (Hunger)
- Initiated testing of advanced experimental lines for reaction to tan spot and septoria leaf blotch in a no-till field nursery. (Hunger)
- Developed precise molecular markers for the novel *Lr34* gene present in Duster. (Yan)
- Discovered a major quantitative trait locus (QTL) or gene responsible for consistently high level of resistance against Hessian fly in the cultivar Duster. (Yan)
- Identified new gene regions controlling reproductive development in winter wheat cultivars adapted to the southern Great Plains. (Yan)
- Determined genotypes of more than 100 WIT experimental lines and cultivars using three gene markers for a triplicate set of loci governing reproductive development and six gene markers for resistance to leaf rust, stripe rust and powdery mildew. (Yan)
- Analyzed subsamples from the wheat variety performance tests for milling and baking quality in addition to grain protein content. Preliminary analysis confirmed desirable milling and baking superiority was sometimes, but not always, bundled into the same cultivar. (Edwards)

- Determined total, soluble and insoluble fiber contents in grain samples of 46 advanced experimental lines and locally adapted hard red winter (HRW) cultivars. OK10126 will be further tested for stability of trait expression and as a source of elevated fiber content. (Rayas-Duarte)
- Placed 10 additional winter wheat candidates under preliminary or extended seed increase by Oklahoma Foundation Seed Stocks (Carver):

OK09125	TAM 303/Overley
OK1059060	Fuller/OK01307
OK10126	OK Bullet/OK98680 reseln
OK10728W	OK Rising/OK98G508W-2-49
OK11754WF	CIMMYT seln/Overley//Jagger-derivative
OK11231	Deliver/Farmec (beardless)
OK11D25056	Gallagher/OK05511
OK12621	Duster/P961341A3-2-2
OK13625	Billings/Fannin sib
OK08707W-19C13	OK98G508W/Lakin//Trego

- Tested for presence of Karnal bunt in 42 wheat grain samples from 14 counties, and based on the negative results, obtained a phytosanitary certificate allowing Oklahoma wheat to move without restriction into the export market. (Hunger)
- OSU-bred cultivars Duster and Endurance remained the top two planted wheat cultivars in Oklahoma for a fourth consecutive year. (WIT)

WIT is one of the longest running research teams in any capacity at OSU. Its formation was self-motivated by the researchers themselves, rather than by any organizational directive. Nine faculty from three DASNR academic units form a complete team that combines fundamental and applied components of wheat research to propel a common cause—to advance Oklahoma's wheat industry with development of improved cultivars and dissemination of the know-how that best captures their genetic potential. Now in its 16th year of uninterrupted service, pride is taken in elevating OSU's mission of "create, innovate and educate" to new heights.

WIT scientists who received funding from the OWRF in 2013-2014 and reported their findings were **Jeff Edwards**, information exchange; **Bob Hunger**, wheat pathology research and development of disease-resistant germplasm; **Liuling Yan**, gene discovery and genomic technology; **Gopal Kakani**, drought and heat tolerance mechanisms; **Patricia Rayas-Duarte**, cereal chemistry; and **Brett Carver**, wheat breeding and cultivar development.

The 2013-2014 crop season may have left the wheat crop high and dry in unprecedented fashion, but the work of OSU WIT must go on. While data was pulled from the field, the best results came from a laboratory or a greenhouse where progress can still be made under any weather pattern or condition. This underscores a telling difference in how WIT conducts research today versus 16 years ago. It points to where WIT is headed with more advanced and targeted breeding tools to help predict field performance without necessarily being in the field.

In this report, you will learn about the advances made in fighting wheat diseases (even in the absence of disease in the field), in developing the necessary tools to better select for drought and heat stress tolerance, and in understanding how key traits important for Oklahoma are regulated and expressed at the DNA level. In addition to advances in research, almost all WIT members engage with the agricultual community directly to enable wheat growers to make timely, effective managment decisions.

Information Exchange

Jeff Edwards
Plant and Soil Sciences

WIT has significantly increased its web-based and social media efforts over the past few years. The blog www.osuwheat.com, for example, was created in the fall of 2013 to deliver technical information and updates in a concise, timely manner. In just a couple of years, the site has generated 38,000 page views with 5,000 of these views coming from overseas clientele. Other efforts include an Extension site, a YouTube channel, a Facebook page and several WIT member Twitter accounts. In total, these sites receive more than 50,000 visits per year.

A first-hollow-stem estimator was developed for the Oklahoma Mesonet and can be found in the Agriculture section of the site (www.mesonet.org). The program provides a current estimate of first hollow stem throughout the state (Figure 1) as well as one- and two-week first-hollow-stem projections based on historical weather patterns. The model for the estimator was developed from an OWRF-funded project and was refined using first-hollow-stem data collected from the OWRF-supported wheat variety performance tests. When combined with current first-hollow-stem measurements from the wheat variety performance tests, the estimator will allow Oklahoma wheat farmers to make well-informed and timely decisions regarding removal of cattle from wheat pastures.

In addition to elite WIT nurseries at Kingfisher and Cherokee, several advanced experimental lines were tested as part of the OSU wheat variety performance tests in 2014. The experimental line OK09125 was tested at several sites across Oklahoma and compared to advanced lines from other states. Unfortunately, the 2013-2014 wheat production year did not allow the team to learn a great deal more about the yield potential of OK09125 in the absence of an extreme drought, so testing will continue in 2014-2015.

Wheat variety trial results were posted on the small grains Extension website (www.wheat.okstate.edu) within a few days of harvest, which allowed producers to access data quickly, regardless of their location. Farmers were notified of new data postings via email and Twitter feed and the site was accessed more than 3,000 times during the summer of 2014, with more than 9,000 individual page views. The print version of the small grains variety performance tests was published in early July and distributed to more than 8,000 "High Plains Journal" subscribers in Oklahoma.

Subsamples from the wheat variety performance tests were measured for grain protein and results were

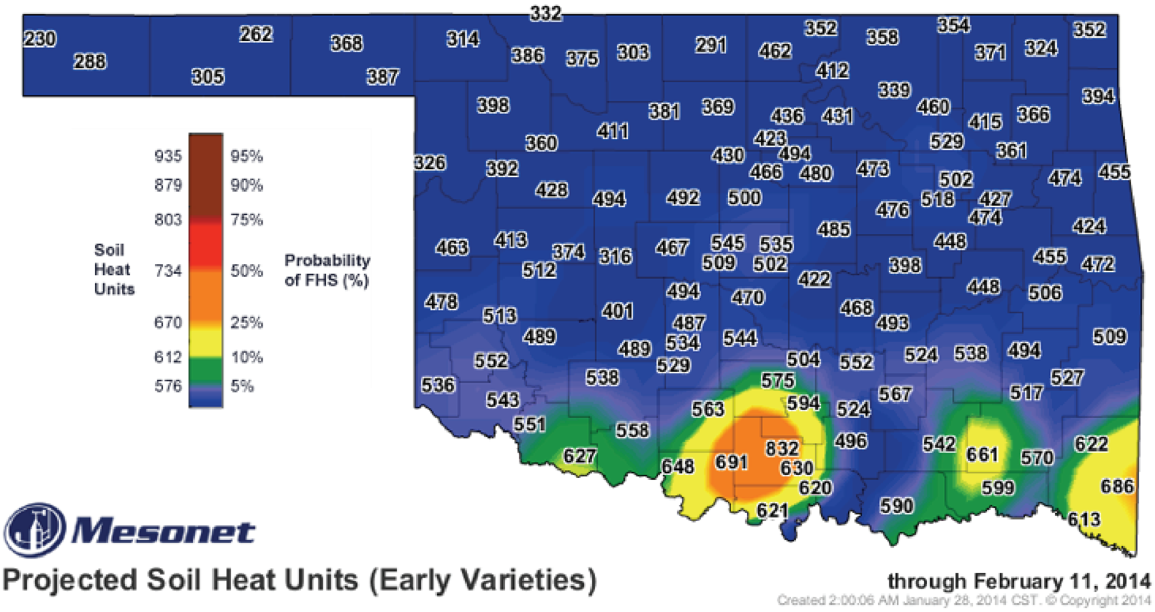

Figure 1. Screenshot of the Oklahoma Mesonet first hollow stem estimator as found on 11 February 2014, indicating generally very low probability of Oklahoma wheat fields at the first hollow stem stage. Higher probabilities existed, however, in some southern areas of the state.

distributed in fall 2014. WIT has measured and distributed wheat grain protein results in this manner for several years, but has not broadly tested milling and baking quality of grain samples from the wheat variety performance tests. In 2014, subsamples from two sites were saved for milling and baking quality analysis. Data are still being analyzed at the time of writing this report but will be published in 2015.

Wheat Pathology Research and Development of Disease-Resistant Germplasm

Bob Hunger
Entomology and Plant Pathology

Evaluation of WIT experimental lines for reaction to diseases including the WSBM/WSSM complex, leaf rust, powdery mildew, tan spot and BYD is critical to developing improved wheat cultivars. Table 1 summarizes the number of breeder lines tested for reaction to these diseases during the last six years. These evaluations, which occur in both field and greenhouse/growth chamber (GH/GC) settings, are used to facilitate selection of lines for development of improved wheat cultivars. OWRF funds support this testing and allowed expanded testing to include tan spot and septoria starting in 2010. Testing for reaction to tan spot has been intense and led to the identification of resistant lines. However, testing for reaction to septoria has been less successful because infection of known control cultivars has not been sufficiently consistent to provide reliable results. Hence, optimization of a procedure to produce reliable incidence of septoria in a GH/GC setting is an ongoing endeavor.

Table 1. Number of WIT experimental lines tested for disease reaction in the last six years, either in the field or in greenhouse (GH) or growth chamber (GC) assays.

		Disease[a]					
Year	Assay	WSBM/WSSM	LR	PM	TS	SEP	BYD
2009	Field	1,500					
	GH/GC		400	400	400		
2010	Field	1,500					
	GH/GC		400	400	400	400	
2011	Field	1,400					
	GH/GC		324	67	262	262	
2012	Field	1,030		65			573
	GH/GC		427	618	170	105	
2013	Field	2,410		197	95	95	150
	GH/GC		347	150	277	277	
2014	Field	1,700			21	21	705
	GH/GC		466	141	411		
Total	Field &/or GH/GC	9,540	2,364	2,038	3,080	3,080	1,428

[a] LR=leaf rust; PM=powdery mildew; TS=tan spot; SEP=septoria.

OWRF funding also has allowed WIT to initiate a no-till field nursery (Figure 2) that will be used to test advanced lines for reaction to tan spot. This field nursery is being developed cooperatively with WIT members Edwards and Carver, and was started in the 2013-2014 season. A large field located west of Stillwater was grown with Duster (susceptible to tan spot) and was managed (heavily fertilized) to produce abundant straw. A selected area in the field was inoculated in early spring 2014 with oat kernels infected with the tan spot fungus (Figure 3). These infected oat kernels provide inoculum (spores) that infect the wheat leaves and stems. Residue left on the soil surface will provide inoculum to cause tan spot the next year. In fall 2014, Edwards planted three replications of 16 advanced wheat lines plus five cultivar controls into this nursery. In addition to sparse, infected residue present in the nursery in December 2014 (Figure 2 inset), infected oat kernel inoculum is again being added to the nursery. This trial will be observed during spring 2015 for tan spot. Although it may take a couple years to build up tan spot in this nursery, the hope is that it can be used to evaluate the reaction of advanced experimental lines to tan spot. A similar field nursery currently is being initiated for septoria.

As mentioned in the 2013 PIP report, OWRF funding also has supported expansion of testing capabilities to spot blotch and common root rot, which are foliar and root diseases caused by the fungus *Bipolaris sorokiniana*. During the past year, Nathalia Graf Grachet (graduate student in Entomolgy and Plant Pathology) has confirmed testing protocols to evaluate spot blotch reaction (Table 2), and is continuing her efforts

Figure 2. No-till field nursery in which advanced experimental lines are being evaluated for reaction to tan spot in 2014-2015 (top). Some inoculum is already present in the nursery, (inset showing spore-containing bodies of the fungus that causes tan spot) but inoculum also will be placed in each plot during winter 2014.

to standardize a protocol for testing reaction to common root rot. Candidate lines in the cultivar development pipeline are being evaluated for reaction to spot blotch for the first time.

In 2013, the OWRF provided funding to validate an RNA-based test developed by Francisco Ochoa-Corona that allows for simultaneous detection of WSMV, HPV and TriMV. In 2013-2014, this test was successfully conducted by WIT partner Jennifer Olson, verifying results were consistent with serological testing (Figure 4; Table 3). The RNA-based method is more sensitive than serological tests, so lower virus concentrations are detectable. In several instances, additional viruses were detected with the molecular tests that were not detected with serological

Table 2. Reaction (percent infected leaf area) of selected hard red winter wheat cultivars developed in Oklahoma to spot blotch caused by *Bipolaris sorokiniana*. Values are the average of seven replications from two experiments. Both visual and digitized assessments were used with high correlation between the two (R^2=0.80). Atilla/PBW343 and Sonalika are the resistant and susceptible checks, respectively. Boldfaced cultivars appear to offer moderate resistance to spot blotch.

	Percent of infected leaf area	
HRW Cultivar	Visual	Digital
Atilla/PBW343 (R)	10.9	9.3
Billings	17.2	12.4
Cedar	27.4	18.6
Deliver	17.5	14.3
Doublestop CL+	29.0	18.8
Duster	54.9	35.4
Endurance	18.4	12.5
Everest	16.1	12.4
Gallagher	36.4	25.5
Garrison	12.5	9.0
Iba	46.2	26.4
Jagger	31.5	22.7
Ruby Lee	16.4	12.0
Sonalika (S)	59.1	41.2

tests. This is valuable for early season virus detection, especially when mixed infections are possible. Fields with mixed virus infections often suffer greater losses than fields with single virus infections (synergistic effect). In 2015, the Plant Disease and Insect Diagnostic Laboratory (PDIDL), under Jennifer Olson's supervision, plans to switch from serological testing to RNA-based testing for both WIT and producer samples. Very few producer samples were submitted from fields during the past few years due to environmental problems with the crop (drought and late winter freeze).

Figure 3. Inoculum to be placed in a field nursery to promote tan spot disease of wheat. (A) In large plastic bags, sterile oat kernels are inoculated with *Pyrenophora tritici-repentis* (causal fungus of tan spot). (B) The fungus grows over and colonizes the oat kernels. (C) After four weeks to five weeks, oats are removed from the bag, dried, and then added to the field nursery.

The RNA-based test has been highly successful, whereas the serological tests are not cost-effective with the low sample number. Additionally, this will allow PDIDL to offer routine testing for TriMV, which is not presently possible since there is no commercial serological test for this virus.

Finally, funds provided by the OWC supported the testing of the 2014 Oklahoma wheat crop for the presence of Karnal bunt. Results from this testing were used to certify Oklahoma wheat was produced in areas not known to be infested with Karnal bunt, which allowed Oklahoma wheat to move freely into the export market.

Gene Discovery and Genomic Technology

Liuling Yan
Plant and Soil Sciences

Hessian fly is one of the most destructive pests of wheat worldwide. The recently released winter wheat cultivar Duster possesses consistent and

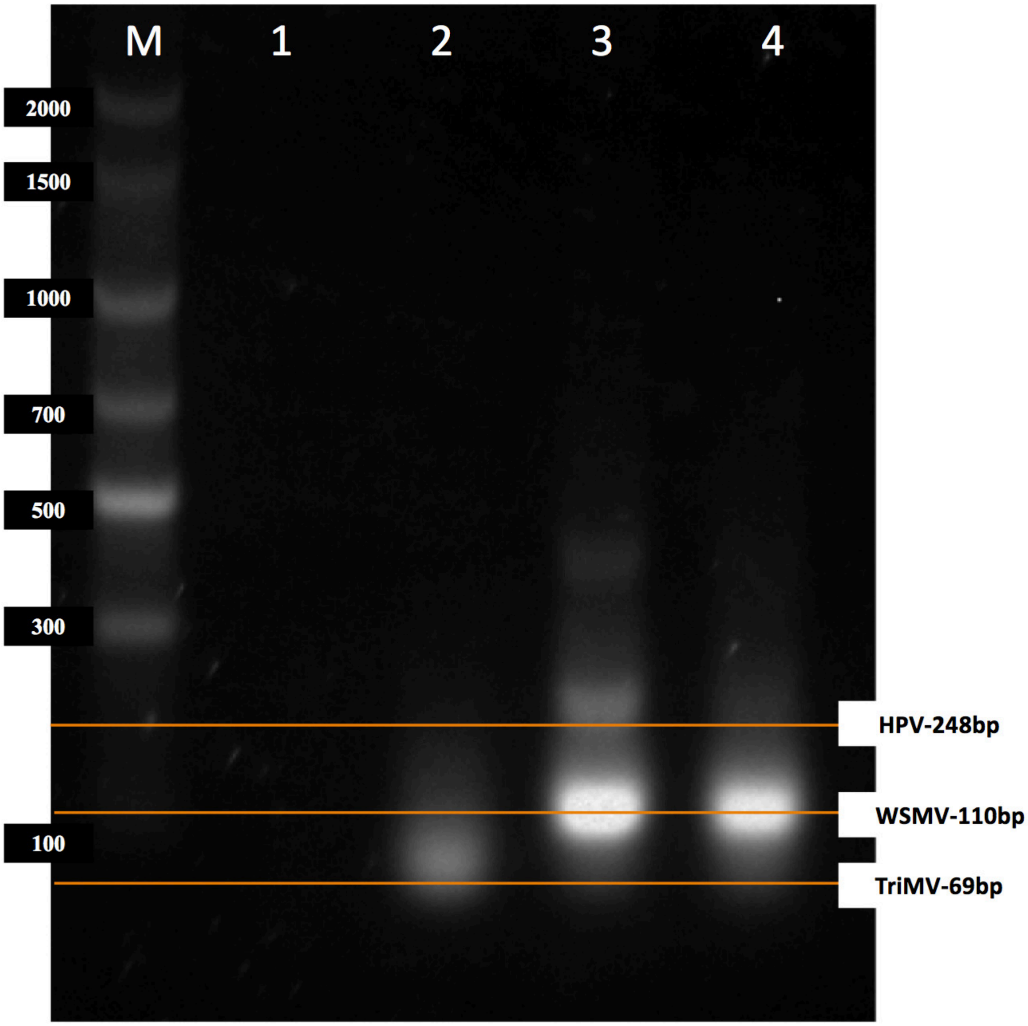

Figure 4. Agarose gel shows multiplex reverse-transcriptase polymerase chain reaction amplification products for WSMV, HPV and TriMV. M denotes a standard size marker. Lane 1 contains a nontemplate control (nuclease-free water). Lane 2 is a laboratory control infected with TriMV only. Lane 3 is a field sample that is positive for both HPV and WSMV. Lane 4 is positive for WSMV.

unique resistance to the Great Plains (GP) biotype. Hessian fly intensities have not been reported at economically significant levels in any field plot containing this cultivar.

Doubled haploid (DH) progeny from the cross Duster × Billings (Hessian fly-susceptible) were genotyped using 2,358 Genotyping By Sequencing (GBS) markers. A major QTL controlling Hessian fly reaction in this population, called *QHf.osu-1A^{d}*, was mapped to the short arm of chromosome 1A. The candidate gene in Duster has been delimited within a 2.7 centimorgan (cM) region flanked by two GBS markers GBS7851 and GBS10205 (Figure 5A). Where this becomes even more fascinating is comparing this Hessian fly resistance gene to one recently discovered in 2174. In a previous study, a different QTL controlling Hessian fly reaction, called *QHf.osu-1A^{2}*, also was mapped to the short arm of chromosome 1A using progeny from the cross, Jagger × 2174. Mapping in that population was accomplished with a different kind of marker system called

Table 3. Comparison of serological (ELISA) and RNA-based (RT-PCR) testing methods for presence (+) or absence (-) of WSMV, HPV, TriMV and BYDV/CYDV). The RNA-based method is more sensitive. Thus, a greater number of virus detections were made. There is no commercially available ELISA for TriMV, so no samples were tested with this method (NT).

	WSMV		HPV		TriMV		B/CYDVs	
Sample number	ELISA	RT-PCR	ELISA	RT-PCR	ELISA	RT-PCR	ELISA	RT-PCR
201400172	+	+	-	-	NT	+	-	-
201400174	+	+	-	+	NT	-	-	-
201400175	+	+	-	-	NT	-	-	-
201400176	+	+	-	-	NT	-	-	-
201400194	+	+	-	+	NT	-	-	-
201400199	+	+	+	+	NT	-	-	-
201400219	-	-	+	+	NT	-	-	-
201400232	-	-	+	+	NT	-	-	-
201400283	-	-	-	-	NT	-	+	+
201400284	-	-	-	-	NT	-	+	+
201400286	-	+	-	-	NT	-	+	+
201400287	-	-	-	-	NT	-	-	-
201400288	-	+	+	+	NT	-	-	-
201400291	+	+	-	-	NT	-	+	+
201400292	+	+	-	-	NT	-	+	+
201400350	+	+	-	-	NT	-	-	-
Healthy	-	-	-	-	NT	-	-	-

Single Nucleotide Polymorphism (SNP) markers (Figure 5B). Comparative mapping of the common markers for the gene for *QHf.osu-1A^{d}* in Duster and the gene for *QHf.osu-1A^{2}* in cultivar 2174 showed the two Hessian fly resistance genes are located in different regions of the same chromosome arm 1AS, but only 11.2 cM apart in genetic distance (Figure 5). Precise mapping of the two distinct resistance genes provides an excellent opportunity to pyramid them into a single germplasm line, or to distinguish among them when they might appear together in the same breeding population. WIT currently favors the gene from Duster, due to its greater strength of expression under controlled conditions.

The heavily GBS-genotyped Duster × Billings DH population also was phenotyped for developmental traits. Although the two parental lines have the same allele for each of three key developmental genes, *vrn-A1*, *PPD-D1* and *vrn-D3* (identified in previous OWRF-supported projects), Duster and Billings still show large differences in development. For example, when vernalized for six weeks, Billings flowered 20 to 25 days earlier than Duster. The QTLs/genes affecting winter wheat development in the DH population were located on chromosomes 7B, 6A and 2D. The GBS markers for these three QTLs are being converted to selectable markers that will be used by WIT. The various allelic combinations of the previously identified three genes, plus three newly identified QTLs for different sensitivities to photoperiod and low temperature, will be researched further to design the proper breeding tools to manipulate winter wheat reproductive development as needed.

In the 2013 PIP report, WITs research with a powerful and versatile disease resistance gene, *Lr34* was reported extensively. Research continues in this area for the ultimate purpose of improving broad-spectrum disease resistance in Oklahoma wheat cultivars. The strategy still includes capitalizing on the novel *Lr34* haplotype present in Duster. The current thinking is that wheat has only one *Lr34* copy. However, it was found *Lr34* in Duster has been duplicated. One copy contains the expected sequence of the susceptible allele, whereas the other contains the sequence of a newly discovered resistance allele. The resistance allele *Lr34-Dr* in Duster is a mutation from

Comparison of two QTLs on wheat chromosome 1AS for resistance to Hessian fly

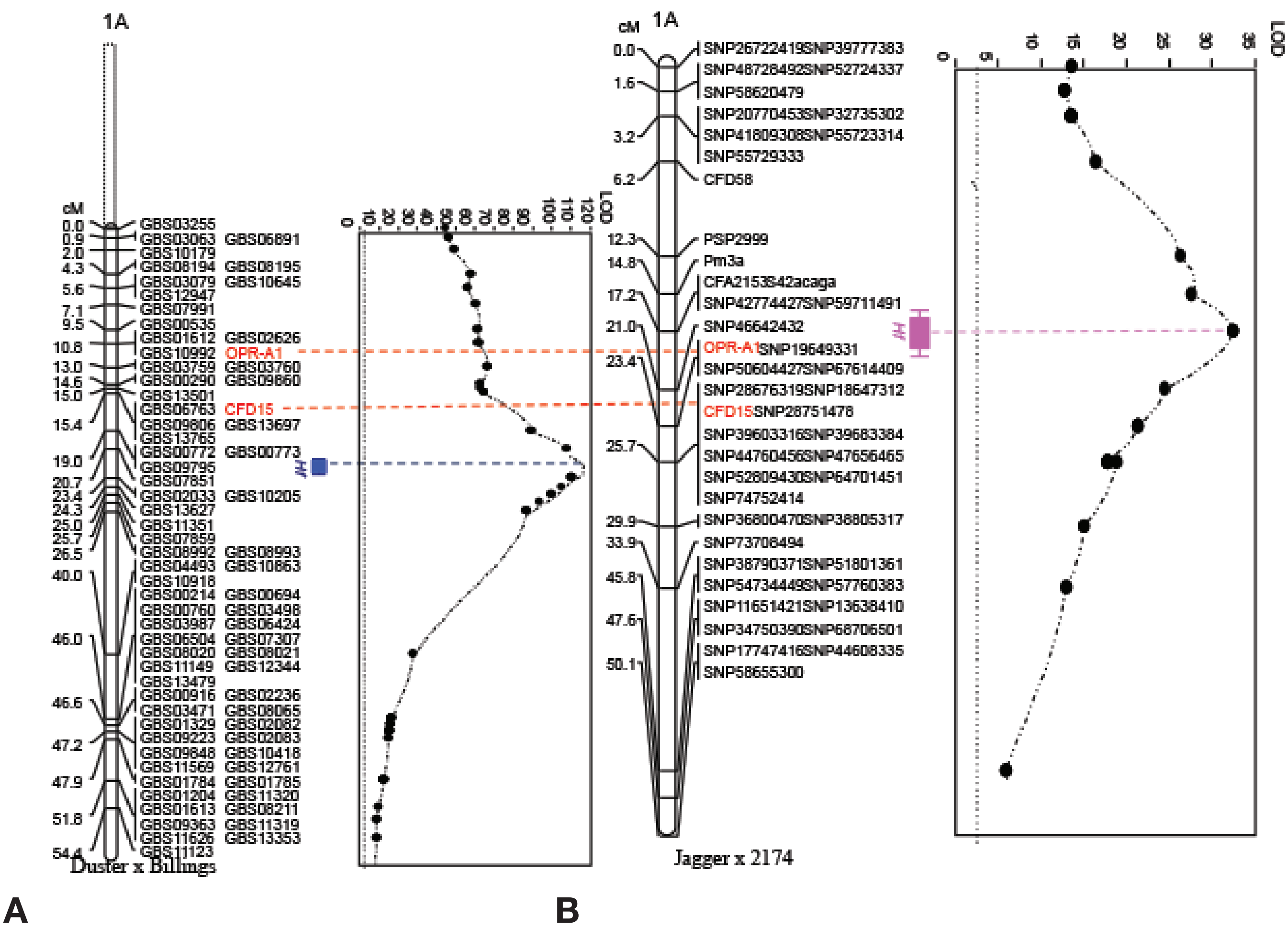

Figure 5. Comparison of two QTLs for resistance to Hessian fly. A) Map position of the *QHf.osu-1A^d^* locus in the Duster × Billings DH population. The gene at the *QHf.osu-1A^d^* locus is centered in a 2.6 cM region flanked by markers GBS07851 and GBS10205 highlighted on the left. B) Map position of the *QHf.osu-1A^74^* locus in the Jagger × 2174 population. The gene at the *QHf.osu-1A^74^* locus is centered in a small region indicated on the right and covering *TaOPR-A1* and *Pm3*. Common markers TaOPR-A1 and Xcfd15 connected by dotted lines on the two maps are aligned to indicate their relative positions on chromosome 1AS. *QHf.osu-1A^d^* is on the proximal side of the common markers, whereas *QHf.osu-1A^74^* is on the distal side of the common markers.

the original form of the susceptible *Lr34-Ds* gene. Both copies of *Lr34* were mapped in the Duster × Billings DH population. The co-existence of two *Lr34* copies in Duster provides the unique possibility that two effective *Lr34* genes for resistance can be stacked into a single line through conventional crossing of Duster with a cultivar such as 2174, which was previously identified to have the functional *Lr34r* allele. Again, the ability to accomplish this feat requires having the specific targeted markers for tracking these genes separately or together.

Drought and Heat Tolerance Mechanisms

Gopal Kakani
Plant and Soil Sciences

Rapid and more efficient selection protocols are desperately needed at the plant and canopy levels to develop wheat cultivars better adapted to the combined effects of drought and heat stress. Preliminary GC experiments were conducted using four cultivars with putative differences in drought tolerance based on field performance. These were OK08707W and TAM112 (drought tolerant), 2174 (drought susceptible) and Duster (check cultivar). Excess photosynthetic assimilates are stored as stem reserves in the form of starch and fructans (polymer of fructose) and are remobilized to the spike during grain filling. These four cultivars showed relatively high nonstructural carbohydrates in the stem (Figure 6) under well-watered conditions when compared with water-stress conditions at optimum growing temperatures of 19C and 22C. This indicated more stem reserves were remobilized into the grain under water-stress conditions at 19C and 22C. However, an increase in temperature above 22C reduced the levels of nonstructural carbohydrates in the stem, suggesting nonstructural carbohydrates are being remobilized for grain filling and plant maintenance. Among the simple sugars, glucose and maltose concentrations increased with an increase in temperature under water-stress conditions. This indicates some of the sugars are being used for plant maintenance respiration under extreme stress conditions.

Among the cultivars, Duster had lower stem reserves at the end of the growing season. This translated into less yield decrease in Duster under both water-stress and high-temperature conditions as shown in an earlier PIP report. Identifying physiological and genetic control for this enhanced remobilization in Duster can help in breeding cultivars with higher grain filling rates under water-stress and high-temperature conditions.

Zooming out to the canopy level, an initial study with a subset of 44 experimental lines from a DH population having the cross Duster × Billings, showed leaf area index (LAI, Figure 7) and canopy temperature (expressed relative to ambient temperature, Figure 8) were associated with grain yield under actual field conditions. The LAI values are much lower than normal due to the drought and high temperatures experienced during flowering and the post-anthesis period in 2013. As LAI is essential for higher light capture, and thus, higher photosynthetic rates, lines with high LAI had higher grain yield even under severe water-stress conditions during the grain-filling period. It is hypothesized greater

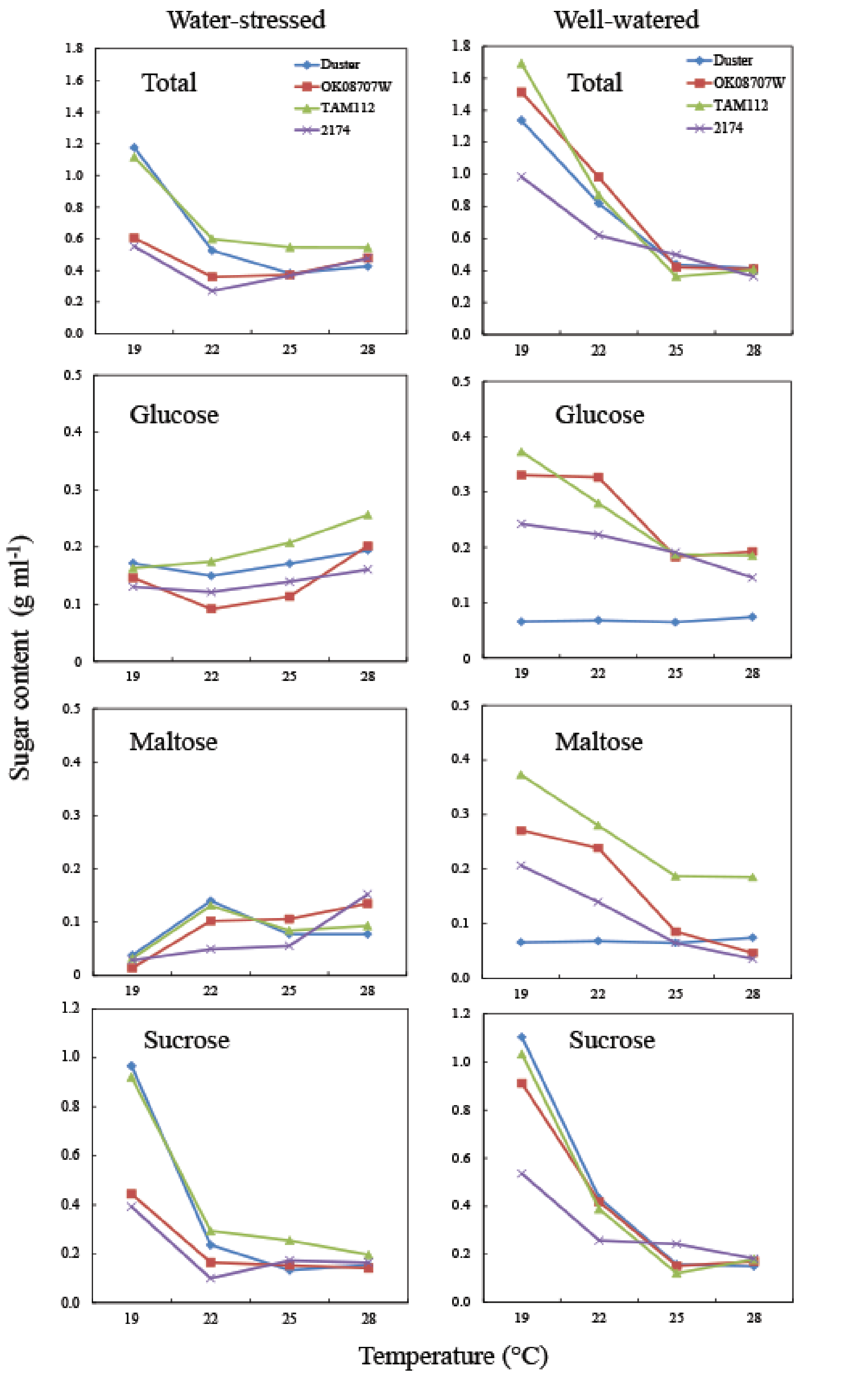

Figure 6. Nonstructural carbohydrate content in stems of four wheat lines (Duster, OK08707W, TAM112 and 2174) grown after anthesis under water-stress and well-watered conditions at four growing temperatures.

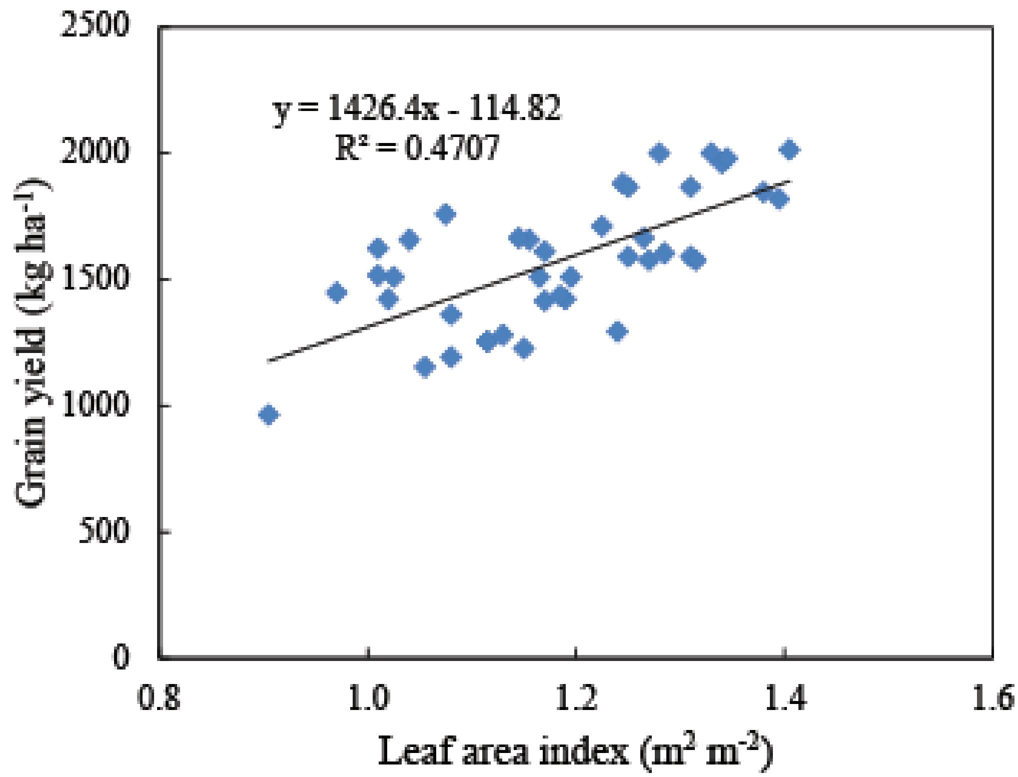

Figure 7. Relationship between leaf area index and grain yield of 44 DH progeny from the cross Duster × Billings measured in spring 2013 at Stillwater.

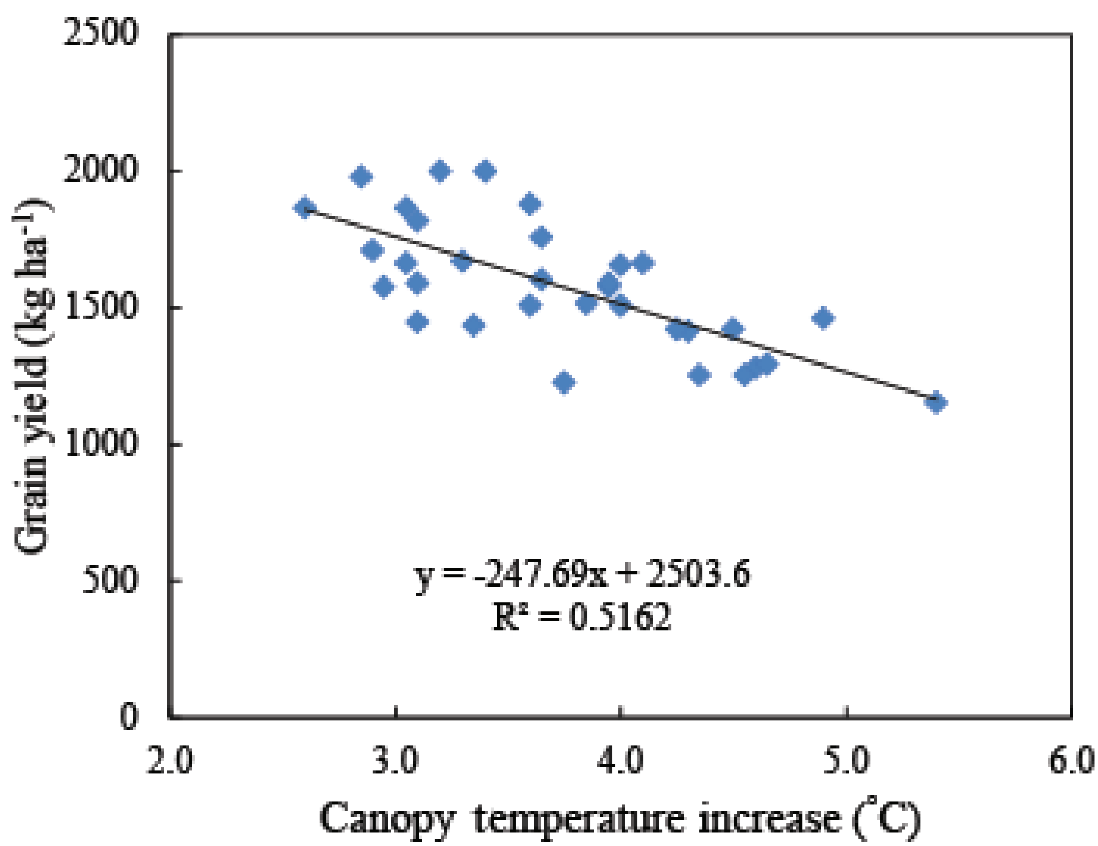

Figure 8. Relationship between canopy temperature increase (relative to ambient temperature) and grain yield of 44 DH progeny from the cross Duster × Billings, measured in spring 2013 at Stillwater.

LAI leads to potentially greater stem reserves and remobilization during grain filling, resulting in higher grain yield.

Similarly, lines that can maintain canopy temperature, or minimize the increase over ambient temperature, may lead to higher grain yield. A lower canopy temperature maintains the plants at near optimum growing temperature and makes stem reserves available for grain filling in contrast to being used for maintenance respiration. Hence, selecting cultivars with higher LAI and lower canopy temperature increase under water-stress and high-temperature conditions may ensure higher grain-filling rates. Future research will test these hypotheses with greater environmental replication in larger populations.

Cereal Chemistry

Patricia Rayas-Duarte
Biochemistry and Molecular Biology

The tide of bad press and misinformation about wheat and wheat-based products must be challenged in the short term with facts, and in the long term with new cultivars carrying a perceived healthier value. Among the most important components in wheat are found in the bran outer layers, which contain antioxidant activity. In other words, these compounds stop and sequester oxygen-containing compounds that damage human cells. Insoluble fiber, or roughage, is quite healthy, as it helps to maintain healthy gut microorganisms very important in the immunological system and the production and absorption of nutrients consumed in the diet. There are 10 times more microorganism cells in the gastrointestinal tract than human cells. Maintaining the beneficial microorganisms in the gut is as important as consuming a good diet containing whole wheat or extracted compounds from bran. Thus, it is important to identify variation in soluble, insoluble and total dietary fiber content present in the wheat gene pool. Insoluble fiber represents one of at least four more components in the bran with antioxidant activity that commands immediate attention to improve our current understanding of fiber levels currently available in our germplasm.

From a panel of advanced experimental lines and locally adapted HRW cultivars (46 genotypes), WIT determined total, soluble and insoluble fiber contents in grain samples produced in a single environment. This preliminary data revealed a wider range of insoluble and total fiber, whereas the content of soluble fiber showed the least variation. Whole-meal samples showed remarkably high content of insoluble fiber, with values between 14 percent and 14.5 percent. Highest values were observed in entries OK13124 [(Jagger*4/ *Ae. geniculata*)*2/ NuHills], OK13216 (Endurance/ Fuller//Billings), OK1080029 (U3556-3-1-1/Deliver), and OK10126 (OK Bullet/OK98680 reselection). Compared with commercial-grade whole wheat flours from the most common food composition data bases, these four lines have about 5 percent more insoluble fiber. The insoluble fiber is commonly reported around 9 percent in commercial whole wheat flours. This significantly high content of insoluble fiber is of particular interest, as well as other lines that contain higher than 12 percent insoluble fiber. This research will be replicated in additional environments using a smaller subset of lines to determine repeatability of fiber content and to identify lines with greater genetic potential.

Wheat Breeding and Cultivar Development

Brett Carver
Plant and Soil Sciences

What did 2014 yield?

In stark contrast to the 2013 crop harvest, spring crop conditions in 2014 were so dry that disease reactions in the field, with exception of the WSBM/ WSSM readings taken by Hunger, were practically nonexistent. Heat and drought once again dominated or drove most selection decisions in 2014. Much like the past two years, however, one consistency was highly evident—greater yielding ability was expressed as the ability to grain-fill and mature rapidly.

In unusual fashion, the highest yielding entry in the 2014 Oklahoma Elite Trial (OET), which contains the most advanced experimental lines and candidate cultivars, was not experimental. It was Iba, which is not necessarily a bastion of drought and heat tolerance, but one could make a case for its resilience across a wide range of environmental yield potentials.

Summarized in Table 4 are yield ranks and across-location yields for the top 10 entries in the 2014 OET. The locations are arranged from highest yielding ability to lowest. Erratic results like these underscore the importance of considering multiyear yield data when making selection decisions. There were no environmental filters to separate the acceptable from the unacceptable. Those filters help determine fitness. In the absence of timely rainfall events, 2014 yields were indeed quite low by scale and by breeding value.

What footprints?

Lost temporarily in the ongoing drought in the southern plains were some of the genetic footprints that defined the OSU wheat improvement program in recent years. Where disease reactions typically dominate trait selection at all levels of inbreeding, from early generations such as $F_{4:5}$ headrows to later generations such as $F_{4:10}$ advanced lines, only those assays performed by Hunger impacted the 2014 selection decisions.

In regard to future release decisions, WIT may be most vulerable to leaf rust, because leaf rust reactions have not been highly relevant to experimental line advancement since 2009. A five-year absence can wreak havoc on a wheat breeding program that depends on natural occurrence of leaf rust for selection pressure. One trend in WIT's favor is the continued use of seedling assays for leaf rust reaction by Hunger on all experimental lines nominated for statewide yield trials. While this assay by itself is not sufficient to identify leaf rust resistance built from multigene complexes, its utility may be enhanced when combined with molecular marker assays for specific gene components in those complexes. Thus, it is the combined work of Hunger and Yan who are providing protection from leaf rust at the moment. Another favorable factor is the omnipresence of Duster and Billings, or progeny thereof, in the OSU wheat breeding program. WIT will not rest the future of the program strictly on these two cultivars. However, each one offers a different form of leaf rust

Table 4. Average yield and location-yield ranks (1 to 30) for the 10 highest yielding entries tested in the 2014 OET. The highest yielding site was Goodwell-irrigated at an average of 77 bu/A^{-1}, and the lowest was Tipton at 17 bu/A^{-1}. Other checks tested but not shown due to lower mean yields were (in decreasing yield order) Doublestop CL+, Garrison, Duster, Cedar, Ruby Lee and Chisholm (long-term check). Boldfaced numbers indicate that entry placed in the top 10 percent of all entries at that location.

Entry	Yield	GDI[1]	GA	GD	LA	ST	GR	KF	CK	TP
	bu/A^{-1}	yield rank								
Iba	45	5	16	5	7	5	10	**3**	4	**2**
OK1059060	44	15	14	8	**3**	15	8	8	**2**	9
OK0986130-7C13	44	14	**3**	4	24	7	23	9	**1**	26
OK05511-2C13	44	19	**2**	3	15	**3**	19	**1**	19	13
OK109143CF (CL+)	42	**1**	15	**1**	19	21	18	16	27	22
Gallagher	42	**2**	18	9	10	20	16	23	18	28
OK10126	42	10	10	7	28	25	**2**	12	20	12
OK09125	41	29	9	12	14	**2**	**3**	4	8	**1**
OK10805W	41	12	20	17	26	6	21	5	9	21
Gallagher reselection	41	4	23	16	**2**	14	29	20	23	30

[1] GDI (Goodwell irrigated), GA (Gene Autry), GD (Goodwell partially irrigated), LA (Lahoma), ST (Stillwater dual-purpose), GR (Granite), KF (Kingfisher), CK (Cherokee dual-purpose) and TP (Tipton low-fertility).

resistance that remains highly effective even today.

Likewise, BYD always can be counted on somewhere in OSU wheat breeding nurseries across the state. This was not the case in 2014, with the exception of some scant, short-lived appearances too unreliable as opportunities for selection. WIT continues to steer its germplasm strongly and deliberately in the direction of improved tolerance to this very common and economically significant disease.

Again, a primary reason for that progress lies in the germplasm, with Duster and Endurance providing namesake examples as sources of tolerance, though they probably offer different mechanisms of protection. The BYD protection provided by Duster is tied to the presence of a leaf rust resistance gene called *Lr34*, as discussed in Yan's report. This gene, or others tightly linked to it, can be counted on for a good base level of BYD protection. It also is present in the OSU wheat cultivars Iba, Deliver and 2174. With the assistance of Guihua Bai, USDA-ARS research geneticist in Manhattan, Kansas, WIT has expanded its sights for another source of BYD tolerance, courtesy of the wheat breeding program at Purdue University. Combining the source of resistance in Duster with that from Purdue provides highly effective BYD protection under the most severe disease conditions. The limitation has been tracking and selecting for the two-gene combination, a job that requires molecular marker tools. That work was carried out in 2014 by Bai thanks to a subaward from OWRF to jumpstart marker-assisted breeding of the stacked BYD trait. To help carry that work forward is Carol Powers, postdoctoral fellow in Yan's laboratory, who is financially supported by the OWC through the check-off.

Also through Bai's OWRF-supported research, his laboratory has selected, from OSU breeding populations, certain adapted lines that carry a key gene for Fusarium head blight (FHB) resistance that originated in Chinese germlasm. These fixed or nonsegregating lines represent three highly useful genetic backgrounds, two of which are known as Garrison and Ruby Lee. Bai's research previously identified Garrison as a less prevalent source of partial resistance to FHB, and thus, a preferred recipient of the Chinese source of resistance. Selection for FHB resistance has not been possible or practical in the field, even in years with greater rainfall, or in Hunger's disease assays. As soon as conditions allow in 2015, attention will return to the historically prevailing diseases, such as numerous leaf spotting diseases, powdery mildew and stripe rust, as discussed in detail in the 2013 PIP report.

The numbers.

Field evaluation, molecular and GH assays, and end-use quality testing were conducted in 2013-2014 to allow selection and advancement of 4,863 breeding lines in preliminary (F_6), intermediate (F_7) and advanced inbreeding generations (F_8 and beyond) in 2014-2015. This number represents a 64 percent increase over 2014, thanks to cooperative efforts with USDA-ARS scientist and WIT member Xiangyang Xu, and to germplasm derived from past WIT member Art Klatt. About 11 percent are confirmed to be hard white (HW), with the balance being HRW or in rare cases soft red winter (<1 percent). CLEARFIELD materials constitute 12 percent of the total number of breeding lines in the F_6 generation and beyond moving into the 2015 season. DH lines account for 11 percent of the total, excluding several hundred more lines yet to be delivered by Heartland Plant Innovations, Inc. in Manhattan, Kansas, and at least that number from private collaborators. WIT's most advanced DH progeny (in terms of yield testing) feature Gallagher, Garrison, Duster, Billings, or a recent cultivar candidate, OK09634, as a parent.

Finally, 44 advanced lines were moved into various stages of breeder seed increase in 2015. This nursery is located at the Oklahoma Panhandle Research and Extension Center in Goodwell. Of those 44, 10 candidates are in the possession of Oklahoma Foundation Seed Stocks (OFSS), as reported later in Table 5. Two of those are HW, one is a soft white, and one is a beardless line with all of the attributes expected of a conventional bearded cultivar. All other candidates are HRW.

The OSU hybridization component of the breeding program continued with great success in 2014, producing 937 unique crosses strictly for the purpose of cultivar development. The annual goal is about 900 to 1,050 crosses, excluding the additional crosses conducted by collaborators at USDA-ARS. About 18 percent of these crosses will potentially lead to populations that contain genes fixed for white kernel color or otherwise segregatingfor kernel color. Less than 30 percent of these hybridizations were resticted to elite in-house parentage, underscoring the emphasis placed on germplasm introgression from external sources. As is the usual case, introgression was principally focused on disease and insect resistance, with special emphasis placed on introgression of germplasm from eastern Europe, and US germplasm with WSM resistance.

About 35 percent to 40 percent of the total breeding effort is dedicated toward improving disease resistance while at least maintaining current yield levels. The team would prefer to decrease that percentage somewhat, in favor of putting more direct selection pressure on increasing yield potential. A DH population produced from the cross Duster × Billings is currently being used as a training population to develop marker-based, genomewide selection tools that specifically target grain yield potential. This is the same population used by and reported above by WIT member Yan.

Candidate cultivar lineup.

As a result of unfavorable weather in 2014, release decisions have begun to stack up, and so have the number of candidates currently under breeder seed or foundation seed multiplication by OFSS. The first decision will likely come with the HRW candidate, OK09125 (Table 5). OK09125 has consistently placed at the top of the yield charts in four of the last five years. Unfortunately, it tends to produce average to below-average test weight. In addition to showing exceptional tenacity with grazing, OK09125 excelled in the 2013 USDA-ARS Southern Regional Performance Nursery, where it ranked in the top four entries among 40 candidates submitted by public and private breeding programs throughout the Great Plains. OK09125 has a strong reputation of good drought tolerance, but is not as resilient under severe stripe rust or powdery mildew infection. Its performance was blemished by poor yield placement in breeder nurseries and the OSU wheat variety performance tests at Goodwell in 2014. OK09125 offers strong tolerance to low pH soils and to leaf spotting diseases, including tan spot and physiological leaf spot.

Right on the heels of OK09125 is another HRW candidate, OK10126, which has parentage from OK Bullet and an OSU experimental line that was derived from a Ukrainian selection and Mesa. Unlike OK09125, however, OK10126 would be targeted toward grain-only management systems because earlier planting tends to expose its weakness to late winter freezes. Otherwise, OK10126 is an outstanding grain producer in the presence of several problem diseases, such as stripe rust and tan spot. It shows outstanding straw strength under intensively managed conditions, perhaps unrelated to the presence of an infrequent semidwarfing gene called *Rht8*. Another unusual characteristic that will need further verification is a tendency to produce high soluble fiber content in the grain. Pending any release decision, ample foundation seed should be available for OK09125 or OK10126 in summer 2015.

Among three HW candidates under the watch of OFSS, OK10728W could be the strongest candidate with statewide adaptation, tan spot resistance and resistance to shattering and lodging. It also fits the **Graze*n*Grain** mold, though BYD susceptibility and early dormancy release are weaknesses when managed for grazing. If released, this experimental line would be specifically targeted toward north central Oklahoma, where it is best adapted for grain production. Its apparent resistance to preharvest sprouting (genetic basis unknown), even under highly conducive field conditions, will help garner acceptance where skepticism about white wheat sprouting is prevalent. Other favorable attributes of OK10728W are above-average test weight and kernel size,

Table 5. OSU candidate cultivars placed under seed increase in fall 2014 with OFSS. Bold-faced experimental names indicate white wheat.

Candidate	Pedigree	Increase status	Primary adaptation
OK09125	TAM 303/Overley	Large (year 2)	Downstate
OK1059060	Fuller/OK01307	Small	Southwest
OK10126	OK Bullet/OK98680	Large (year 2)	Statewide, grain-only
OK10728W	OK Rising/OK98G508W-2-49	Large (year 2)	North central
OK11754WF	Overley-complex cross	Large (year 2)	Northeast
OK11231	Deliver/Farmec	Small	Statewide (beardless)
OK11D25056	Gallagher/OK05511	Small	Panhandle
OK12621	Duster/P961341A3-2-2	Small	Statewide
OK13625	Billings/Fannin sib	Small	North central
OK08707W-19C13	OK98G508W/Lakin//Trego	Small	Panhandle, North

early maturity, and tolerance to low pH soils.

OK11754WF is a high-yielding soft white candidate with very large kernel size. Due to the nature of its inherently different functionality, OK11754WF will be considered independent of OK10728W in release decisions. Pilot testing of food product suitability is ongoing with Oklahoma Genetics, Inc. This early maturing line has shown very high yielding ability in northern Oklahoma and points northeast of Oklahoma. It shows very early dormancy release like one of its parents Overley. Because OK11754WF is high-tillering, its relative performance increases with significantly later planting. Other strengths are tan spot resistance, lodging resistance and it shows one of the highest levels of tolerance to low pH soils among OSU advanced lines. Other experimental lines listed in Table 5 are entering their first year of seed increase by OFSS and can be observed in the 2014 wheat variety performance tests conducted by WIT member Edwards.

Wheat Variety Trials

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At the time of writing this report, 2014 Oklahoma wheat production was estimated to be 51 million bushels, which is roughly half of 2013 production (Table 6). Oklahoma has not seen wheat production this low since the 43-million-bushel crop of 1957, and with any luck, production will not be this low again for at least another 60 years.

Table 6. Oklahoma wheat production for 2013 and 2014 as estimated by OK National Agricultural Statistics Service, July 2014.

	2013	2014
Harvested Acres	3.4 million	3.0 million
Yield (bu/A)	31	17
Total bushels	105 million	51 million

The 2013-2014 wheat production season had a good start in central Oklahoma. Topsoil moisture was short in September, but October rains resulted in favorable conditions for wheat emergence and establishment. In addition, many areas had a fair amount of stored soil moisture from the summer of 2013. This stored soil moisture allowed sites such as Chickasha and Lahoma to produce 43 bu/A and 47 bu/A average wheat yield on less than 8 inches of rainfall during the growing season. Stored soil moisture also contributed to adequate forage production at grazed sites such as Marshall dual-purpose (DP), but production of a forage crop did not leave behind enough moisture to fuel much of a grain crop.

The multiyear drought never released its stranglehold on western Oklahoma during the 2013-2014 wheat production season. Small rains here or there allowed most producers to obtain an acceptable stand of wheat, but moisture was never sufficient to spur tillering or leaf area development. Early winter snowfall made for a few bright spots for forage production in southwestern Oklahoma, but this moisture was quickly utilized by growing wheat plants, and dry conditions soon returned. As a result, many fields in southwestern and western Oklahoma were abandoned and not taken to harvest.

The winter of 2013-2014 was not just dry, it was cold too. Young, drought-stressed wheat plants had difficulty dealing with the cold, windy conditions, and winterkill was common in late-sown wheat. Winterkill also was common in grazed wheat that was stressed by heavy grazing pressure and inadequate soil moisture. Considerable winterkill also was present in no-till wheat without adequate seed-to-soil contact in northwestern Oklahoma.

The inadequate seed-to-soil contact was generally the result of heavy residue from the previous year's wheat crop.

While the wheat crop did not appear to be on its way to bumper production, most producers hoped for a turnaround similar to 2013 and topdressed in late winter. Unlike the spring of 2013, however, the rains never came and much of this topdress nitrogen (N) applied did not make it into the soil until the crop was at boot stage or later.

The cold winter delayed the onset of first hollow stem by about five days as compared to 2013, and 25 days as compared to 2012. Despite a slow start to the spring, wheat in southern Oklahoma was near heading when a hard freeze occurred the morning of April 15, 2014. As expected, drought-stressed wheat in advanced stages in southwestern Oklahoma suffered severe freeze damage. However, injury from the 2014 spring freeze did not always follow the rule-of-thumb guidelines used by agronomists. Many areas that received small amounts of rain just prior to the freeze seemed to escape widespread injury, regardless of growth stage. In southcentral Oklahoma, injury seemed to be most severe on later maturing varieties that were approximately Feekes GS 7 to booting, while earlier-maturing varieties that were just starting to head escaped freeze injury. Wheat that was barely past two nodes in northern Oklahoma suffered severe injury, while more advanced wheat in central Oklahoma endured similar temperatures with minimal injury.

There were relatively few insect or disease issues to deal with during the 2013-2014 wheat production season. Winter grain mite and/or brown wheat mite infestations proved to be too much for some drought-stressed wheat fields in northcentral and northwestern Oklahoma. Some fields already devastated by the drought were left unsprayed, while others still showing some sign of yield potential were treated.

Other than a rare sighting of a single leaf rust pustule, there was no foliar disease in Oklahoma in 2014. The lack of foliar disease is evidenced by the lack of response to foliar fungicides at either Chickasha or Lahoma. These two sites provided a rare opportunity in 2014 to observe yield impacts of foliar fungicides in the absence of disease, as most years reported at least light or negligible foliar disease at these sites. While foliar disease was not an issue in 2014, WSM was an issue for many producers. This disease has historically been most prevalent in northwestern Oklahoma and the Panhandle. WSM was confirmed in several fields downstate this year. However, it is likely some fields affected by WSMwere not identified as such because it is sometimes difficult to distinguish WSM symptoms from those of severe drought stress. The wheat variety testing program was not immune from this disease, and the Kildare location was lost to WSM.

Warmer temperatures in May hastened crop maturity and the Oklahoma wheat harvest began near Frederick May 22, 2014. By the first week of June, harvest was in full swing, only to be delayed by rain shortly thereafter. Harvest resumed across most of the state by June 13 and was mostly completed by June 30, with the exception of some waterlogged areas in northern Oklahoma. The Cherokee Mesonet site, for example, reported 5.1 inches of rainfall from Oct. 1, 2013, to

May 31, 2014, but the same site received 10 inches of rain from June 1 to June 30, 2014.

Methods

Seed was packaged and planted in the same condition as it was delivered from the respective seed companies. Most seed was treated with an insecticide plus fungicide seed treatment, but the formulation and rate of seed treatment used was not confirmed or reported in this document.

Conventional plots were eight rows wide with 6-inch row spacing and were sown with a Hege small plot cone seeder. No-till plots were seven rows wide with 7.5-inch row spacing and were sown with a Great Plains no-till drill modified for coneseeded, small-plot research. Plots were 25 feet long at planting and were trimmed to 20 feet at harvest with the plot combine. Wheel tracks were included in the plot area for yield calculation, for a total plot width of 59 inches. Experimental design for all sites other than Lahoma was a randomized complete block with four replications. Lahoma was a split-block arrangement of a randomized complete block with four replications, where whole plots were fungicide treated or nontreated and subplots were wheat variety.

Conventional till plots received 50 lbs/A of 18-46-0 in-furrow at planting. No-till plots received 5 gals/A of 10-34-0 at planting. The Marshall DP, Walters and forage trials were sown at 120 lbs/A. All other locations were sown at 60 lbs/A. Grazing pressure, N fertilization, and insect and weed control decisions were made on a location-by-location basis and reflect standard management practices for the area.

Plots were harvested with a Hege 140 or Wintersteiger Delta small plot combine. When sample size allowed for grain moisture measurement on individual plots, grain yields were corrected to 12 percent moisture. Grain moisture at all sites was generally below 11 percent, and maximum and minimum grain moisture for all plots at a location typically ranged no more than 1 percent. Alva, Cherokee and Kildare plots were harvested, but data are not reported as the coefficient of variation exceeded 25.

Additional Information on the Web

A copy of this publication, as well as additional variety and wheat management information, can be found at: www.wheat.okstate.edu.

Website
www.wheat.okstate.edu

Blog
www.osuwheat.com

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Funding Provided by:
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Irrigation Scheduling Provided by:
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Varieties: Armour, Winterhawk, WB4458, WB-Cedar, WB-Grainfield, WB-Redhawk

Oklahoma Genetics, Inc.
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Varieties: Billings, Centerfield, Doublestop CL+, Duster, Iba, Gallgher, Garrison, OK Bullet, OK Rising, Pete, Ruby Lee

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Watley Seed
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Varieties: TAM 112

We sincerely thank our variety trial cooperators for donation of land, time and resources. Several locations were lost this year due to drought. Variety trial cooperators not otherwise listed in this document include:

Wes Mallory, Alva
Bryan Vail, Apache
NRCS, Buffalo
Kenneth Failes, Cherokee
J.B. Stewart, Keyes
Don Schieber, Kildare
Kirby Farms, Lamont

2014 Oklahoma Wheat Variety Trial Yield Summary

Variety	Afton	Balko	Chickasha	Chickasha IWM[1]	Goodwell Irrigated	Hooker	Homestead	Kingfisher
	----------	----------	----------	----------grain yield (bu/A)	----------	----------	----------	----------
Armour	-	-	50	46	61	-	-	-
Billings	64	11	36	39	67	41	23	28
Brawl CL+	-	13	47	44	76	37	28	30
Byrd	-	13	48	44	62	39	29	45
Centerfield	-	-	40	42	60	-	-	-
CJ	50	-	35	37	32	-	-	-
Deliver	-	-	47	52	63	-	-	32
Doans	49	13	38	39	50	30	22	35
Doublestop CL+	59	16	39	44	59	35	27	36
Duster	64	14	50	49	69	41	24	48
Endurance	46	15	43	44	59	38	24	37
Everest	54	10	49	47	60	39	25	37
Gallagher	49	12	45	39	60	27	27	37
Garrison	49	12	46	43	62	36	20	34
Greer	55	13	45	45	60	29	23	43
Iba	58	16	49	45	74	44	28	43
Jackpot	57	14	46	47	55	38	24	38
LCH11-109	-	-	39	45	74	-	-	-
LCH11-1117	-	-	40	42	67	-	-	-
LCH11-1130	-	-	46	44	74	-	-	-
LCS Mint	59	17	44	45	58	42	32	35
LCS Wizard	55	13	50	47	64	30	24	26
Mace	-	10	-	-	59	28	-	-
OK Bullet	-	-	36	43	65	-	-	-
OK Rising	-	-	39	42	59	-	-	-
Pete	-	-	35	40	65	-	-	-
Ruby Lee	53	13	44	48	57	37	29	35
SY Llano	56	-	36	34	43	-	-	-
SY Southwind	-	-	39	41	-	-	-	-
T153	-	-	42	42	67	-	-	-
T154	-	-	46	45	64	-	27	-
T158	62	14	40	38	74	40	30	38
TAM 112	-	13	47	43	72	35	-	-
TAM 113	-	15	43	49	65	44	-	-
WB-Cedar	54	-	48	48	67	-	28	32
WB-Grainfield	57	15	42	44	63	42	26	37
WB-Redhawk	-	-	43	34	46	-	-	-
WB4458	58	16	41	40	64	45	31	29
Winterhawk	-	14	45	48	71	37	-	32
OK10126	60	-	40	39	71	-	-	-
OK08707W-19C	13	-	11	-	-	64	-	-
OK09125	-	18	47	45	48	41	31	39
OK09520	-	-	43	48	71	-	26	30
OK10728W	-	-	-	-	60	-	28	-
OK10805W	-	14	38	41	58	-	23	-
OK11754WF	58	-	-	-	-	-	27	-
Mean	56	14	43	43	62	37	26	36
LSD $_{(0.05)}$	8	3	7	11	11	6	7	9

[1] IWM = Intensive Wheat Management

2014 Oklahoma Wheat Variety Trial Yield Summary (continued)

Variety	Lahoma	Lahoma Fungicide	Marshall Dual-Purpose	Marshall Grain Only	McLoud	Thomas	Walters
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Armour	44	39	-	-	-	-	-
Billings	43	42	11	20	31	12	-
Brawl CL+	42	40	21	25	34	10	29
Byrd	50	51	22	25	33	10	28
Centerfield	44	44	-	-	-	-	-
CJ	32	31	-	-	-	-	-
Deliver	52	45	-	-	32	12	-
Doans	42	40	16	23	32	17	27
Doublestop CL+	41	41	20	22	30	13	29
Duster	48	45	22	28	30	9	35
Endurance	43	39	18	22	32	11	29
Everest	42	44	17	21	32	13	33
Gallagher	55	49	15	18	34	16	33
Garrison	46	41	18	21	36	13	26
Greer	50	48	17	25	31	11	28
Iba	44	39	22	24	33	11	31
Jackpot	45	44	19	21	29	18	30
LCH11-109	49	48	-	-	-	-	-
LCH11-1117	49	46	-	-	-	-	-
LCH11-1130	49	44	-	-	-	-	-
LCS Mint	42	40	17	22	36	12	25
LCS Wizard	48	46	16	23	36	15	28
Mace	-	-	-	-	-	-	-
OK Bullet	48	48	-	-	-	-	-
OK Rising	49	48	-	-	-	-	-
Pete	40	39	-	-	-	-	-
Ruby Lee	49	49	18	23	37	14	37
SY Llano	52	49	-	-	-	-	-
SY Southwind	43	43	-	-	-	-	-
T153	55	50	-	-	-	-	-
T154 4	6	47	19	24	-	-	-
T158	48	48	18	23	30	14	30
TAM 112	47	45	-	-	-	-	25
TAM 113	42	36	-	-	-	-	25
WB-Cedar	52	44	15	21	36	14	-
WB-Grainfield	42	41	19	26	34	12	28
WB-Redhawk	49	41	-	-	-	-	-
WB4458	54	53	15	21	32	16	27
Winterhawk	53	46	-	-	35	11	32
OK10126	48	50	-	-	30	-	-
OK08707W-19C13	-	-	-	-	-	-	-
OK09125	52	47	23	24	-	18	29
OK09520	48	43	17	21	-	14	-
OK10728W	50	51	17	26	-	-	-
OK10805W	41	37	-	-	-	-	30
OK11754WF	47	46	-	-	-	-	-
Mean	47	44	18	23	33	13	29
LSD $_{(0.05)}$	8	7	4	4	4	4	7

OKLAHOMA STATE UNIVERSITY

RESEARCH