Partners in Progress
WHEAT

Wheat Research at OSU 2015

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
Oklahoma Cooperative Extension Servic

P-1045

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Partnerships Enhance Wheat Research

Partners in Progress – Our long-standing partnership with the Oklahoma Wheat Commission and the Oklahoma Wheat Research Foundation 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 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 2014-2015. 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
Associate Vice President
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.

Commitment to Excellence

Partners in Progress WHEAT

Desire is the key to motivation, but it's determination and commitment to an unrelenting pursuit of your goal—a commitment to excellence that will enable you to attain the success you seek.
– Mario Andretti

The past five to six years have been an unrelenting period for wheat production with regards to the long term drought and different environmental factors Oklahoma producers have had to face during each season. It is because of this determination and commitment from Oklahoma wheat producers during these challenging times that we have been able to continue our efforts in funding the public wheat research being conducted at Oklahoma State University. None of this would be possible without the producer support to the Oklahoma Wheat Commission.

When looking at this report, you will see the analysis of wheat varieties. In the data, one can see the great consistencies with OSU varieties across our region, which is impressive considering the drought conditions of 2015, followed by the large amount of moisture received at harvest time. Further in this report the issues with stripe rust that plagued us in 2015 are discussed with continued focus on how the Wheat Improvement Team continues to breed for resistance. The 2015 data also shows the importance foliar fungicides played in the intensive wheat management studies at Chickasha, along with the fungicide studies at Lahoma. As we move forward we also continue to fund research in order to fight stripe rust, Barley Yellow Dwarf, Fusarium Head Blight, and several other wheat disease issues.

This year we also are proud of the new variety release of Bentley, with its exceptional milling and baking characteristics. On top of that, this variety has good adaptation for dual purpose ***Grazen**Grain*™ systems. You can find more discussed on this important variety in the OSU lineup New to the Neighborhood on page 25.

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 move ahead by making great strides with the wheat research and Extension program at OSU, and want to thank the producers for the support to keep these programs at the front of technology discovery and transfer. The OSU WIT prepares for planting by spending numerous hours on research with sustained effort. The WIT is motivated by desire, with a determination and commitment to excellence, in pursuit to make our wheat producers successful, and therefore, we are glad to be 'partners in progress.'

Mike Schulte, Executive Director
Oklahoma Wheat Commission
3800 North Classen Blvd., Suite C-40
Oklahoma City, OK 73118
Phone: (405) 608-4350
Fax: (405) 848-0372
Email: mschulte@okwheat.org

Partners in Progress WHEAT

Genetic Improvement and Varietal Release of Hard Winter Wheat

Wheat Improvement Team

2014-2015 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 last year (Edwards)**
- **Provided 15 in-season wheat disease updates to wheat growers, 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).**
- **Analyzed subsamples from the wheat variety performance tests for milling and baking quality in addition to grain protein content. Analysis from the 2014 crop season confirmed desirable milling and baking superiority was sometimes, but not always, bundled into the same cultivar (Edwards).**
- **Evaluated nearly 1,500 wheat experimental lines for reaction to multiple diseases, of which 62 percent were developed by the WIT (Hunger).**
- **Evaluated 770 WIT experimental lines for reaction to the wheat soilborne mosaic virus/ wheat spindle streak mosaic virus complex. For a subset of 466 lines, the enzyme-linked immunosorbent assay was used to test for virus presence and better define the reaction to both viruses (Hunger).**
- **Subjected about half of the 770 WIT experimental lines to additional greenhouse/growth chamber, or field assays for leaf rust, tan spot, powdery mildew, barley yellow dwarf and/or *Septoria tritici* blotch (Hunger).**
- **Initiated testing of WIT advanced lines for reaction to *Septoria tritici* blotch in a no-till field nursery (Hunger).**
- **Tested more than 20 fungicides for wheat foliar disease management, which showed that some fungicides control wheat leaf rust for up to five weeks (Hunger).**
- **Demonstrated in field trials that foliar fungicides do not increase relative chlorophyll content, yield, or test weight in the absence of foliar disease (Hunger).**
- **Demonstrated in growth chamber studies that fungicides prevent flecking, or cell death, on leaf rust resistant wheat cultivars. This prevention of flecking may explain why Duster typically shows a yield response to a fungicide applied in the presence of a foliar disease such as wheat leaf rust (Hunger).**
- **Tested for presence of Karnal bunt in 30 wheat grain samples from 12 counties, and based on the negative results, will allow Oklahoma wheat to move without restriction into the export market (Hunger).**
- **Constructed a detailed genetic map for both copies of the novel *Lr34* gene present in Duster and its derivatives (Yan).**
- **Discovered gene *TaXA21-A1*, a wheat orthologue of a rice OsXA21-like gene, and confirmed its involvement in reactions to multiple stripe rust races, powdery mildew and Hessian fly biotype GP (Yan).**

- **Identified a novel haplotype of gene *TaALMT1*, which confers tolerance to acidic soils (Yan).**
- **Determined genotypes of more than 100 WIT experimental lines using three gene markers for a triplicate set of loci governing reproductive development and six or more gene markers for resistance to leaf rust, stripe rust, powdery mildew, wheat streak mosaic and wheat curl mite (Yan).**
- **Placed these and other wheat candidates under preliminary or extended seed increase by Oklahoma Foundation Seed Stocks (Carver):**

OK09915C-1	N91D2308-13/OK03908C//OK03928C (CLEARFIELD)
OK10728W	OK Rising/OK98G508W-2-49 (hard white)
OK11D25056	Gallagher/OK05511
OK10126	OK Bullet/OK98680
OK1059060-3	Fuller/OK01307
OK12621	Duster/P961341A3-2-2
OK13625	Billings/Fannin sib
OK11231	Deliver/Farmec (beardless)
OK11P228	Deliver/Farmec (beardless)
OK12912C	N91D2308-13/OK03926C//OK03928C (CLEARFIELD)
OK12DP22002-042	Billings/OK08328

- **OSU-bred cultivars Duster and Endurance remained the top two planted wheat cultivars in Oklahoma for a fifth consecutive year (WIT).**

WIT is one of the longest-running research teams in any capacity at OSU. 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 17th year of uninterrupted service, WIT takes pride in elevating OSU's mission to new heights.

WIT scientists who received funding from the OWRF in 2014-2015 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; and **Brett Carver**, wheat breeding and cultivar development.

While the return of moisture late in the wheat growing season of 2014-2015 was a much welcomed departure from severe drought-ending crops in the two previous years, the WIT was challenged once again with diseases both familiar and less familiar such as stripe rust and head scab, respectively. Despite these climate-induced ups and downs, the WIT continues to make steady progress in advancing yield potential among experimental lines considered for possible release. Current estimates point to a per annum rate of about 1.5 percent genetic gain in grain yield, with no apparent yield plateau in sight. With more advanced and targeted breeding tools on the horizon to help predict yield potential relevant to Oklahoma field conditions, the current rate of genetic gain may be due for an uptick.

This report features advances made in fighting wheat diseases–most notably stripe rust and a much-needed boost in selecting for Septoria tritici blotch resistance–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 agricultural community directly to enable wheat growers to make timely, effective management 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 osuwheat.com, for example, was created in fall 2012 to deliver technical information and updates in a concise, timely manner. In just a couple of years, the site has generated 55,000 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 at mesonet.org. The estimator 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

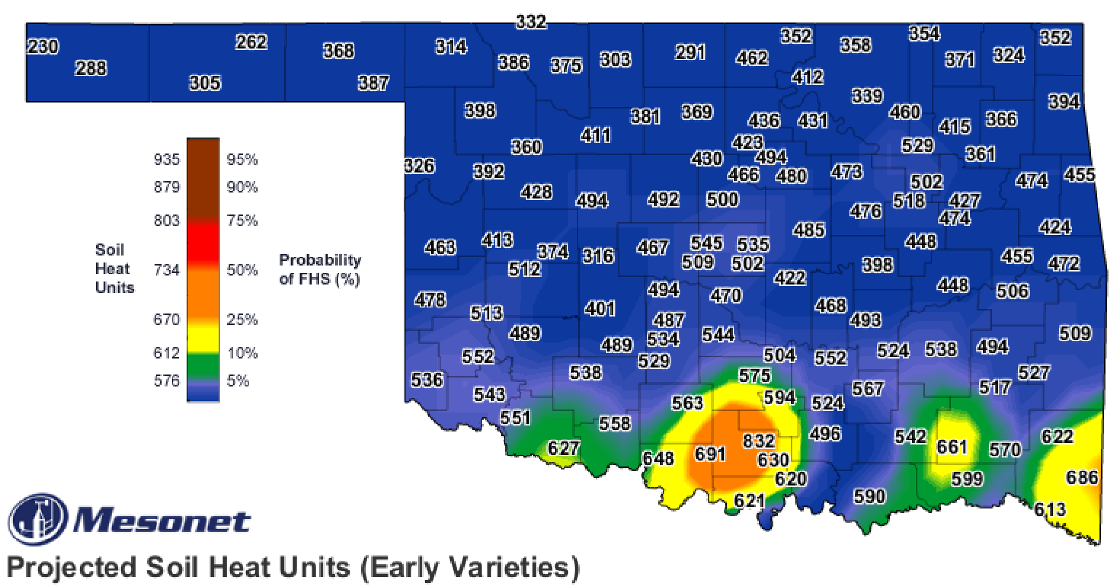

Figure 1. Screenshot of the Oklahoma Mesonet first-hollow-stem estimator as found on Feb. 11, 2014, indicating generally very low probability of Oklahoma wheat fields at the first hollow stem stage.

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.

Several advanced experimental lines were tested as part of the OSU wheat variety performance tests at Cherokee and Kingfisher. Data collected at these and other sites were instrumental in determining the fate of the experimental line OK09125, which was released as Bentley in summer 2015. In addition to gaining valuable information regarding experimental lines, the team was able to increase its knowledge of stripe rust susceptibility among current cultivars. Spring 2015 was a hard reminder for some producers regarding the importance of disease resistance or fungicide use as a substitution for foliar disease resistance.

Wheat variety trial results were posted on the small grains Extension website 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 and the site was accessed more than 3,000 times during summer 2015 with over 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 distributed in fall 2015. WIT has measured and distributed wheat grain protein results in this manner for several years, but it has not broadly tested milling and baking quality of grain samples from the wheat variety performance tests until the 2014 crop season. Results from those tests were published in the Oklahoma Cooperative Extension Service Current Report CR-2165, where only a few varieties such as Winterhawk and Billings performed consistently well for milling and flour-quality combined. In 2015, subsamples from two sites were saved again for milling and flour-quality analysis. This report will be published in 2016.

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 experimental lines tested for reaction to these diseases over the last seven years, and Table 2 summarizes the number of lines evaluated from 1983 to 2015. These evaluations, which occur in both field and greenhouse/growth chamber settings, facilitate selection of lines for development of improved wheat cultivars. OWRF funds support this

Table 1. Number of WIT experimental lines tested for disease reaction in the last seven years, either in the field or in GH or GC assays.

Year	Assay	Disease[a] 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		150
	GH/GC		347	150	277	277	
2014	Field	1,700			21		705
	GH/GC		466	141	411		
2015	Field	1,500				75	160
	GH/GC		385	115	385		
Total	Field and/or GH/GC	11,040	2,749	2,153	2,421	1,119	1,588

[a] WSBM/WSSM=complex of wheat soilborne mosaic and wheat spindle streak mosiac; LR=leaf rust; PM=powdery mildew; TS=tan spot; SEP=septoria; BYD=barley yellow dwarf.

Table 2. Summary of OSU experimental lines evaluated for reaction to specific diseases from 1983 through 2015, excluding ratings in breeder/extension trials.

Disease	Year evaluations started	Evaluation location	Total number of lines evaluated
WSBM/WSSM[a] complex	1983	GH/GC[b]	500
		Field	31,517
Leaf rust	1983	GH/GC	20,975
		Field	3,500
Powdery mildew	2000	GH/GC	2,515
	2011	Field	670
Tan spot	2003	GH/GC	1,885
	2014	Field	45
Septoria tritici blotch	2004	GH/GC	1,200
	2014	Field	70
Barley yellow dwarf		GH/GC	0
	2011	Field	360
Spot blotch/common root rot		GH/GC	25
	2014	Field	0
Total	1983-2015	GH/GC	27,100
		Field	36,162
Grand total	1983-2015	GH/GC and field	63,262

[a] WSBM/WSSM=complex of wheat soilborne mosaic and wheat spindle streak mosiac.

[b] GC/GH=growth chamber and/or greenhouse.

testing and allowed WIT to expand testing to include tan spot and *Septoria tritici* blotch, starting in 2010.

Testing for reaction to tan spot has been intense and productive and has led to the identification of resistant lines. However, testing for reaction to *Septoria tritici* blotch in a GH/GC setting has been less successful because infection of known controls has not been sufficiently consistent to provide reliable results. Hence, over the last couple of years, efforts were made to establish field nurseries to test for reaction to this and other leaf spotting diseases. Initial efforts in 2013 and 2014 were not successful but revealed having the capability of supplying moisture was critical. In the 2013-2014 season, a small trial was established on the Plant Pathology Farm located west of Stillwater to evaluate lines for reaction to *Septoria tritici* blotch (Figure 2). This trial was inoculated with spores of *Septoria tritici* just before a period of weather that would favor spore germination and infection. Incidence and severity of *Septoria tritici* blotch was not as high as desired, but lines could be rated. Future efforts will be directed to increase incidence and severity by moving this area into a no-till system so wheat straw is retained to carry inoculum into the next year. WIT also will continue to inoculate with spores of *Septoria tritici*, and can now provide moisture if and when needed to enhance disease. A second area also is being started in 2015-2016 to be used for tan spot testing.

Foliar diseases can significantly impact wheat yield in Oklahoma when weather conditions are conducive in the spring. Primarily, this involves stripe rust and leaf rust, but powdery mildew, tan spot and *Septoria tritici* blotch also can be involved. Hunger, Carver, and Edwards estimated stripe rust and

Figure 2. Field nursery in which advanced WIT experimental lines were evaluated for reaction to *Septoria tritici* blotch (STB) in 2015. Plants were inoculated in late winter with a concentrated suspension of spores of *Septoria tritici* (insert A) resulting in symptoms of STB in May (insert B).

leaf rust were severe and caused significant yield reductions on many cultivars in Oklahoma in 2015, with 25 percent and 6 percent losses for stripe rust and leaf rust, respectively. Carver's report highlights the value of genetic resistance to stripe rust last year in Oklahoma. Given the severity and the pace at which the pathogens causing these rusts can adapt to genetic resistance, fungicides should be on hand to help protect yield potential.

Consequently, fungicide testing has been a part of this program for many years. Results from testing fungicides during 2014-2015 are shown in Table 3. Fungicide testing was conducted near Stillwater using the cultivar OK Bullet, which is susceptible to powdery mildew, stripe rust and leaf rust, but is resistant to the WSBM/WSSM complex. This combination of traits, along with strong straw strength, makes OK Bullet an ideal cultivar to use in such testing. Timely rainfall of 10.5 inches from August to November 2014 facilitated emergence and stand establishment. A dry December through mid-April with only 3.5 inches of moisture stressed wheat and inhibited foliar disease development. A freeze in early April damaged some wheat across northern and northwestern Oklahoma, but only slight freeze damage was evident in this trial. Abundant moisture of 16 inches from mid-April through June extended the season and promoted development of light stripe rust and late leaf rust. However, this plentiful rainfall was timed such that the wheat in this trial was harvested with only minimal lodging and no sprouting. BYD symptoms were mild, scattered,and not associated with stunting. No symptoms indicative of BYD phytotoxicity were observed following fungicide application.

Powdery mildew was observed on lower leaves in March and April, but only reached 20 percent severity in the not-sprayed check April 29 (Table 3). Stripe rust, although severe across much of Oklahoma, did not reach a ratable level in this trial. In contrast, leaf rust was severe and reached 76 percent by May 12, 32 days after fungicide application, and 97 percent by May 18. Yield from this trial ranged from the not-sprayed check of 62 bushels per acre to 90 bushels per acre for treated wheat. Test weight ranged from 56 to 60 pounds per bushel for non-treated and treated wheat, respectively. In summary, leaf rust was the primary foliar disease in this trial. The average yield of the 24 fungicide treatments was 82 bushels per acre, a 32 percent increase over the non-sprayed check (62 bushels per acre). The average test weight of the 24 fungicide treatments was 59.6 pounds per bushel, a 6.6 percent increase over the not-sprayed check (55.9 pounds per bushel).

Late and abundant moisture extended the season and revealed the longevity of fungicide treatments. A waning of protection provided by some treatments applied April 10 could be observed May 12, 32 days after application. This waning of protection was even more evident May 18. However, at 38 days after application, one treatment (treatment number 19 on Table 3) applied with .125 percent Induce surfactant still only showed 1 percent severity of leaf rust. These results indicate several fungicides provide control of leaf

Table 3. Management of powdery mildew and leaf rust of OK Bullet with foliar fungicides in a trial conducted near Stillwater during 2014-2015.

Treatment Number	Fungicide; rate	GS[a] applied	Date applied	PM (%)[b] April 29	LR (%)[b] May 12	LR (%)[b] May 18	Yield bu/A	Test weight lb/bu
1	Not-sprayed check	-----	-----	20.0	76.3	96.8	61.9[g]	55.9
2	Twinline®; 3.5 oz/ac FB[c] Twinline®; 3.5 oz/A[d]	6 FB[c] 10	Mar 27 FB April 10	1.0	23.8	65.0	86.2	59.5
3	Priaxor®; 2 oz/ac FB Twinline®; 7 oz/A[d]	6 FB 10	Mar 27 FB April 10	3.0	1.8	30.0	90.0	60.4
4	Priaxor®; 2 oz/ac FB Caramba® 5 oz /A[d]	6 FB 10	Mar 27 FB April 10	2.0	10.3	48.8	86.4	59.3
5	Aproach®; 6 oz/ac FB Aproach Prima® @ 6.8 oz/A[d]	6 FB 10	Mar 27 FB April 10	0.0	5.0	30.0	88.2	60.1
6	Tilt®; 4 oz/A	10	April 10	4.3	32.5	85.0	75.3	59.1
7	Folicur®; 4 oz/A	10	April 10	8.8	12.5	72.5	79.1	60.0
8	Fortix®; 5 oz/A[d]	10	April 10	3.0	15.0	76.3	80.7	59.6
9	Topguard EQ®; 3 oz/A	10	April 10	3.0	32.5	81.3	74.6	58.9
10	Topguard EQ®; 6 oz/A	10	April 10	2.5	4.0	35.0	82.7	60.2
11	Equation SC®; 4 oz/A	10	April 10	16.3	36.3	87.5	76.4	58.8
12	Equation SC®; 8 oz/A	10	April 10	11.5	10.0	62.5	76.4	59.2
13	Equation XL®; 10.5 oz/A	10	April 10	4.0	7.8	60.0	80.9	59.9
14	Quadris®; 8 oz/A	10	April 10	11.3	12.5	68.8	77.6	59.4
15	Twinline®; 9 oz/A[d]	10	April 10	5.3	4.5	52.5	88.7	59.9
16	Aproach Prima®[d]; 6.8 oz/A	10	April 10	0.5	6.3	30.0	80.4	59.9
17	Aproach®; 6 oz/A[d]	10	April 10	6.5	32.5	81.3	78.2	58.6
18	Quilt Xcel®; 10.5 oz/A[e]	10	April 10	3.0	3.3	62.5	83.1	60.1
19	A15457; 4 oz/A + Quilt Xcel®; 10.5 oz/A[e]	10	April 10	2.0	0.0	1.0	87.6	59.7
20	A15457; 4 oz/A + Quilt Xcel®; 10.5 oz/A[f]	10	April 10	2.0	0.3	50.0	86.9	60.1
21	A15457; 4 oz/A + Quadris®; 6 oz/A + Tilt®; 4 oz/A[e]	10	April 10	2.0	4.0	16.3	83.8	59.9
22	Stratego YLD®; 4 oz/A[e]	10	April 10	5.5	28.8	75.0	78.9	59.4
23	Prosaro®; 5 oz/A[e]	10	April 10	6.5	38.8	75.0	74.0	59.0
24	Prosaro®; 6.5 oz/A[e]	10	April 10	0.5	10.0	52.5	85.1	60.1
25	Prosaro®; 6.5 oz/A[e]	10.5.1	April 20	8.8	0.0	3.0	85.6	60.4
LSD (P=0.05)		-----	-----	5.6	11.2	17.9	61.7	55.9

[a] GS=Growth Stage reported according to Feekes' scale; GS 6=first node detectable; GS 10=full boot; GS 10.5.1= start of anthesis.
[b] PM=powdery mildew (lower leaves); LR=leaf rust; values are percent rust severity on flag leaves as rated visually.
[c] FB=followed by.
[d] Plus 0.25 percent Induce (v/v).
[e] Plus 0.125 percent Induce (v/v).
[f] Plus 1.0 percent crop oil concentrate (v/v).
[g] Rep 1 in this treatment was treated as missing data in the analysis because of a mis-adjustment of the combine at the start of harvest.

rust for four to five weeks following application, which is longer than previously believed. There also was indication that using Induce surfactant may promote this longer efficacy as compared to use of crop oil concentrate (compare lines 19 on Table 3 to treatment number 20).

Through funding provided by the OWRF, field research was conducted over the past several years to determine if fungicides increase chlorophyll content of wheat as claimed for the strobiluron class of fungicides, and, if wheat sprayed with fungicides in the absence of disease show increased yield or test weight. The 2013-2014 wheat season provided an excellent test environment, as drought through much of the season precluded development of wheat foliar diseases. This experiment was conducted in both a dryland and an irrigated setting using the hard red winter wheat cultivars Duster, which is resistant to many foliar diseases, and OK Bullet, which is susceptible to most foliar diseases. Three commercially available fungicides were used, including Headline® (a strobiluron), Caramba® (a triazole), and Twinline® (a mixture of these two fungicides). No foliar disease was observed in either trial. Results from only the irrigated trial are shown in Table 4, because results from the dryland trial were similar with the only difference being lower yield and test weight. Fungicide did not increase relative chlorophyll content in flag leaves or grain yield and only slightly increased the test weight of Duster compared with not-sprayed plants (Table 4). Hence, results do not support plant health benefit claims by foliar fungicide application in winter wheat cultivars in the absence of disease.

A second set of experiments examined the effect of fungicides on suppression of the hypersensitive response (i.e., flecking) expressed by resistant wheat cultivars resulting from inoculation with spores of the leaf rust pathogen *Puccinia triticina*. In controlled environment studies, Duster and OK Bullet plants were sprayed with the same fungicides as used in the field and inoculated with urediniospores of *Puccinia triticina*. Relative chlorophyll content was determined before and after fungicide application and after inoculation. Green leaf area was determined at the end of the experiment. In these studies, sprayed plants of both cultivars had the same relative chlorophyll content as the not-sprayed and not-inoculated control plants. Hence, fungicide did not increase chlorophyll content (Table 5). However, the early fungicidal action by the fungicides likely killed spores before or just after penetration. In so doing, the hypersensitive response (flecking) was avoided, which helped to maintain green leaf area compared with the non-sprayed and inoculated control plants (compare values in shaded boxes to boxes shaded in orange in Table 5). This could explain why resistant cultivars occasionally show a yield response to a fungicide applied in the presence of foliar disease.

Finally, timely electronic updates on the status of wheat diseases were provided to wheat producers, Extension educators and others in the wheat industry. The 2015 Oklahoma wheat crop was tested for the presence of Karnal bunt. Results

Table 4. Effect of foliar fungicide on yield, test weight and relative chlorophyll content of winter wheat flag leaves before and after fungicide application in an irrigated field experiment in the complete absence of foliar disease.

		Yield	Test weight	Relative chlorophyll content[b]				
Cultivar	Fungicide treatment[a]	bu/A	lb/bu	7 DBF[c]	2 DBF[c]	3 DAF[d]	7 DAF[d]	12 DAF[d]
Duster	Not-sprayed control	59	59 ab	49	54	55	54	53
	Caramba®	58	58 b	50	53	55	54	53
	Headline®	64	59 a	50	54	54	53	55
	Twinline®	60	59 ab	50	55	55	54	55
	p value	0.26 (NS)	0.04	0.93 (NS)	0.18 (NS)	0.94 (NS)	0.74 (NS)	0.09 (NS)
OK Bullet	Not-sprayed control	54	60	47	49	52	50	52
	Caramba®	54	60	47	50	51	50	52
	Headline®	57	61	47	50	51	51	51
	Twinline®	53	60	47	50	51	50	52
	p value	0.18 (NS)	0.51 (NS)	0.89 (NS)	0.15 (NS)	0.48 (NS)	0.91 (NS)	0.18 (NS)

[a] Fungicides (all BASF Corporation, Research Triangle Park, NC, USA): Caramba® (metconazole); Headline® (pyraclostrobin); Twinline® (a pre-mixture of Headline and Caramba).

[b] Relative chlorophyll content was determined using a SPAD 502 Plus Chlorophyll Meter (Spectrum Technologies Inc.).

[c] Number of days before fungicide application.

[d] Number of days after fungicide application.

[e] NS=no significance.

Note: Means followed by the same letter within a column and cultivar are not significantly different.

Table 5. Effect of foliar fungicide on relative chlorophyll content and percent green leaf area of winter wheat plant leaves inoculated with urediniospores of *Puccinia triticina* in a controlled environment.

		Relative chlorophyll content[b]					Green leaf area[c] (%)
Cultivar	Treatment; rate[a]	2 DBI[d]	0 DBI[e]	5 DAI[f]	7 DAI[f]	9 DAI[f]	9 DAI
Duster	Not sprayed & not inoculated control	38	42	45 a	44 a	43 a	100 a
	Not sprayed & inoculated control	37	42	41 b	37 c	31 c	68 b
	Caramba; 17 fl oz/A	36	41	41 b	40 b	39 b	97 a
	Headline; 9 fl oz/A	38	41	43 ab	42 ab	41 ab	99 a
	Twinline; 9 fl oz/A	37	41	43 ab	42ab	41 ab	100 a
	p value	0.88 (NS)[g]	0.96 (NS)	0.01	<0.0001	<00001	<0.0001
OK Bullet	Not sprayed & not inoculated control	37	41	44	44 a	41 a	100 a
	Not sprayed & inoculated control	38	42	41	35 c	31 b	32 b
	Caramba; 17 fl oz/A	37	41	42	40 b	39 a	94 a
	Headline; 9 fl oz/A	38	42	43	42 ab	41 a	94 a
	Twinline; 9 fl oz/A	38	42	42	40 b	39 a	95 a
	p value	0.78 (NS)	0.82 (NS)	0.053 (NS)	<0.0001	<0.0001	<0.0001

[a] Fungicides (all BASF Corporation, Research Triangle Park, NC, USA): Caramba (metconazole); Headline (pyraclostrobin); Twinline (pre-mixture of Headline and Caramba).
[b] Relative chlorophyll content was determined using a SPAD 502 Plus Chlorophyll Meter (Spectrum Technologies, Inc.).
[c] Percent green leaf area was determined using Assess 2.0 disease quantification software (Lamari, 2008, American Phytopathological Society).
[d] Reading was taken 2 days before inoculation and before fungicide application.
[e] Reading was taken 48 hours after fungicide application and immediately before inoculation.
[f] Readings were taken 5, 7, and 9 days after inoculation.
[g] NS=no significance

Note: Means followed by the same letter within a column and cultivar are not significantly different.

from this testing were used to certify Oklahoma wheat was produced in areas not known to be infested with Karnal bunt, which allows Oklahoma wheat to move freely into the export market.

Gene Discovery and Genomic Technology

Liuling Yan
Plant and Soil Sciences

In research previously funded by OWRF, the quantitative trait locus *QYr.osu-5A* was discovered on the long arm of chromosome 5A in wheat cultivar Jagger. This locus is associated with adult-plant resistance to multiple stripe rust races in Washington (Pst-114 and Pst-116), Kansas (Pst-100) and China (CYR32). As indicated in previous Partners in Progress reports, the gene at *QYr.osu-5A* was uniquely discovered in hard red winter wheat cultivars. During 2013-2014 OWRF funding, single nucleotide polymorphism markers were used to saturate the *QYr.osu-5A* region, which in turn has led to identification of a new QTL at this genomic region (Figure 3a). Comparative and syntenic regions between the wheat SNP marker region (Figure 3b) and the rice genomic region (Figure 3c) were used in this funding period to identify candidate genes for *QYr.osu-5A*. *TaXA21-A1*, which is considered a wheat orthologue of the *OsXA21*-like gene on chromosome 9 in rice (Figure 3D), was mapped under the peak of the *QYr.osu-5A*. This *OsXA21*-like gene is similar at the protein level to *OsXA21* on rice chromosome 11, which protects against bacterial leaf blight. *TaXA21-A1* not only explained the phenotypic variation in reaction to different stripe rust races, but also showed significant effects on reaction to powdery mildew and Hessian fly biotype GP (Figure 3a). Further research has revealed specific changes in amino acid sequence in deduced *TaXA21-A1* proteins between Jagger and 2174, another winter wheat cultivar lacking the effective allele which confers partial stripe rust resistance. Frequency of the effective allele at *TaXA21-A1* is about 50 percent in a small subset of Great Plains wheat cultivars and in a set of advanced experimental WIT lines. Development of a gene-based marker in 2015 for the *QYr.osu-5A* QTL will enable more efficient selection for pest resistance within the WIT variety development program.

In other previously funded OWRF research, a key discovery was made in the cultivar Duster for having two copies of the *Lr34-D* gene (*Lr34-D1* and *Lr34-D2*). During 2013-2014 OWRF funding, genotyping-by-sequencing was used to determine the sequences and chromosomal locations of the two *Lr34* genes in Duster. To re-summarize briefly, the sequence of *Lr34-D1* was the same as the resistant *Lr34-Dr* in 2174 in the gene region, and *Lr34-D2* was the same as the susceptible *Lr34-Ds* in Billings, except for one SNP in intron 4 (Figure 4). Both *Lr34-D1* and *Lr34-D2* were mapped in loose linkage with two GBS marker clusters but in tight linkage with *csLV34* and *Xgwm1220* on the short arm of chromosome 7D (Figure 4). Both *Lr34-D1* and *Lr34-D2* were expressed. The Duster *Lr34-D1*/

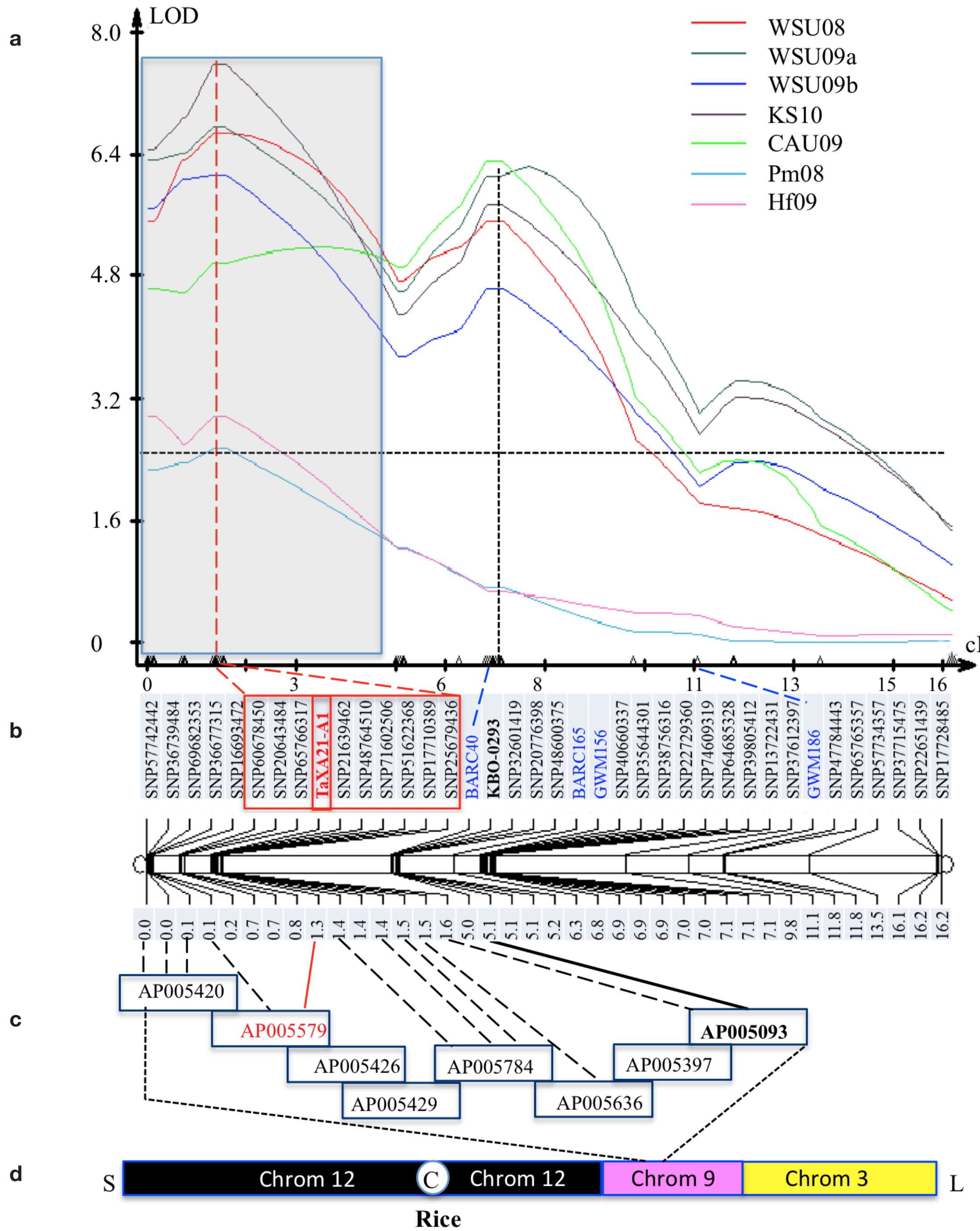

Figure 3. Fine genetic map and physical map of *QYr.osu-5A*. a) *QYr.osu-5A* on the short arm of chromosome 2A. The various colored curves indicate QTLs derived from results generated by different collaborators at Washington State University, Kansas State University and at China Agricultural University. All curves represent phenotypes for stripe rust reaction, unless otherwise indicated as for powdery mildew (Pm) and for Hessian fly (Hf). Logarithm of the odds (LOD) threshold for significance was 2.5, indicated by the horizontal dotted line. b) 8-digit SNP markers along the chromosome are placed as centimorgans on the horizontal axis. *TaXA21-A1* marker is indicated in red, and previous SSR markers are indicated in blue. c) Schematic diagram for the physical order of BAC clones from rice chromosome 9. d*)* Schematic diagram for the rice collinear chromosome of *QYr.osu-5A* on wheat chromosome 5A. The rice orthologous gene of *TaXA21-A1* is in BAC AP005579, indicated by the red rectangle.

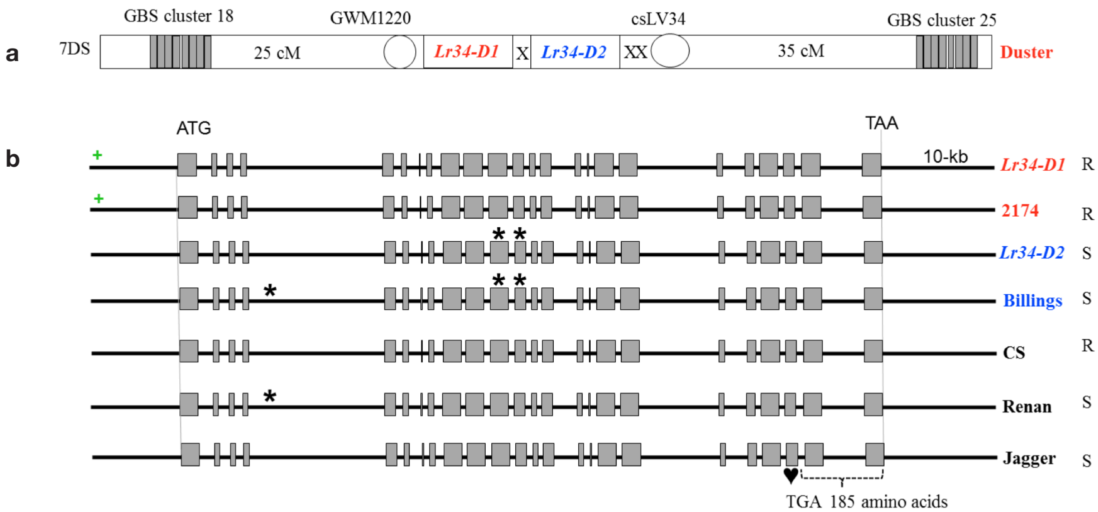

Figure 4. Diagram of haplotypes at *Lr34-D*. a) Location of the Duster *Lr34-D1* and *Lr34-D2* genes on chromosome 7D. The two genes are linked with GWM1220 and csLV34 but separated from the two GBS markers clusters. b) Comparison between different *Lr34-D* genes. Star (*) symbol indicates positions of three reported polymorphisms in intron 4, exon 11, and exon 12 in the susceptible allele Renan compared with the resistant allele of Chinese Spring (CS). Plus (+) symbol indicates positions of four mutations present in the promoter of *Lr34-D* between Duster *Lr34-D1* and 2174 *Lr34-Dr.* Heart (♥) symbol indicates the position of the polymorphism in exon 22 of *Lr34* in the susceptible allele Jagger compared with the resistant allele 2174. Locations of crossovers observed in the Duster x Billings DH population are indicated with an X. The position of the premature stop codon TGA resulting in a lack of 185 amino acids in Jagger is indicated. R represents resistant and S represents susceptible.

Lr34-D2 haplotype was associated with tip necrosis and showed significant effects on seedling leaf rust reaction and on adult-plant field reaction to stripe rust in a Duster x Billings doubled haploid population. The co-existence of two *Lr34* copies in Duster makes it plausible that two effective *Lr34* genes can eventually be pyramided into a single line through conventional crossing of Duster or its *Lr34-D1*/*Lr34-D2* progeny with 2174 or any similar *Lr34-Dr* genotype. Critical to that process was development in 2015 of a PCR marker to allow detection of both native *Lr34-D1* and *Lr34-Dr* resistance genes.

Aluminum toxicity in acidic soils is a major constraint to winter wheat productivity in the southern Great Plains. Because Jagger and 2174 are known to differ in tolerance to acidic soil conditions, their recombinant inbred line progeny were evaluated in a low-pH field environment to map genes for acidic soil tolerance. A major QTL, *QAlmt.osu-4D*, was mapped in this population and was centered on chromosome 4DL (Figure 5). A gene called *TaALMT1*, known to confer aluminum tolerance, was mapped under the peak of the QTL. Further sequencing indicated Jagger carried an allele having Type V of triplicated sequence repeats in *TaALMT1-1*, whereas 2174 carried an allele having Type IV of two (A-B) block sequences in *TaALMT1-2*. The Jagger *TaALMT1-1-V* allele was expressed at a significantly higher

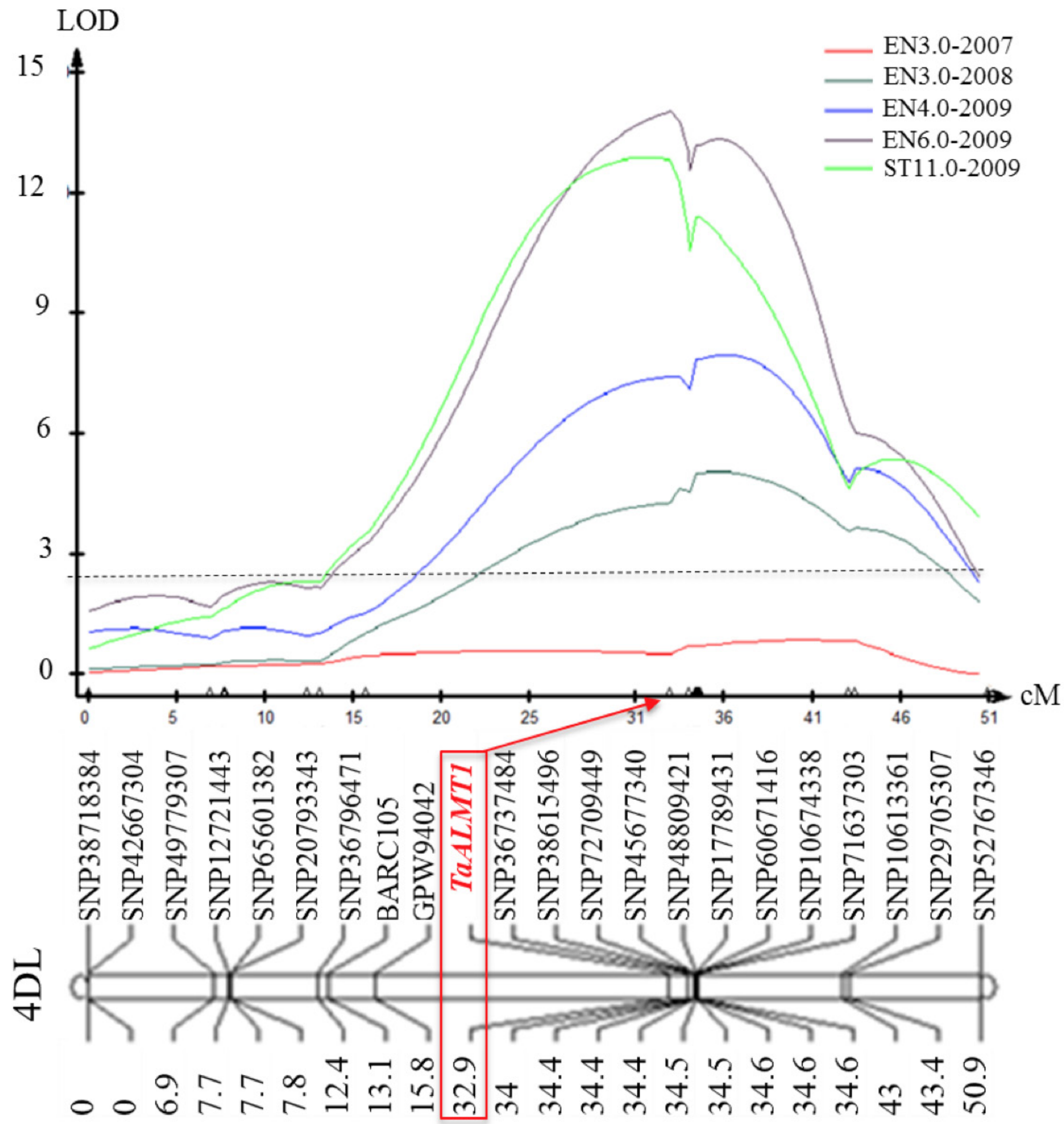

Figure 5. Genetic effects of three QTLs for acid soil tolerance in a RIL population from the cross, Jagger x 2174. *TaALMT1* was mapped under the peak of the QTL *QAlmt.osu-4D* on chromosome 4DL. The various colored curves indicate QTLs derived from acid-soil tolerance ratings collected at Enid (EN) or Stillwater (ST) in 2007 through 2009. The 8-digit SNP codes served as the reference number for each SNP. Logarithm of the odds (LOD) threshold for significance was 2.5 for the presence of the QTL.

level than the 2174 *TaALMT1-2-IV* allele, a genetic difference that is consistent with phenotypes observed under acid soil conditions in Oklahoma. An additional two QTLs/genes on chromosome 2DL and 7BL were identified, and if combined with *TaALMT1-1* could generate progenies that confer greater tolerance to acidic soils than those with *TaALMT1-1* alone.

Drought and Heat Tolerance Mechanisms

Gopal Kakani
Plant and Soil Sciences

Rapid and more efficient selection protocols are needed at the plant and canopy levels to develop wheat cultivars better adapted to the combined effects of drought and heat stress. This project was commissioned to examine levels of variation that may exist for key yield-determining physiological traits under natural field conditions in the Duster x Billings DH population. In past OWRF-supported research, this project showed genotypes that maintain higher leaf area index and lower canopy temperature under water stress and high-temperature conditions may have higher grain-filling rates and lower canopy temperature and under water stress and hence, higher yield. Emphasis in 2015 was given to carbohydrate remobilization from stem tissue to spikes, additional leaf parameters besides LAI and photosynthetic properties.

The change in stem dry weight from anthesis to final harvest varied among 100 DHs from -0.74 grams to 0.36 grams (Figure 6). Some DHs actually lost stem dry weight during the reproductive period. During the same period, the change in spike weight varied from 0.32 g to 1.64 grams. Some progeny that exhibited an increase in stem dry weight during the reproductive period showed a greater increase in spike dry weight.

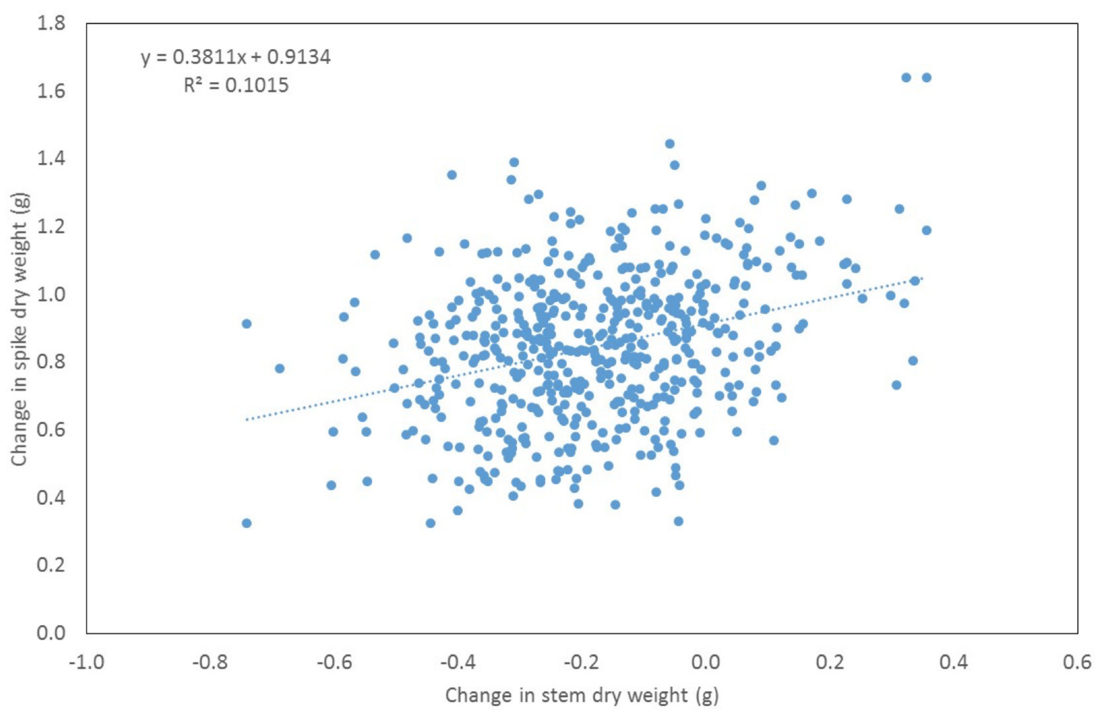

Figure 6. Relationship between changes in stem dry weight and spike dry weight from anthesis to harvest during the 2014-2015 growing season at Stillwater among doubled haploid progeny of Duster x Billings.

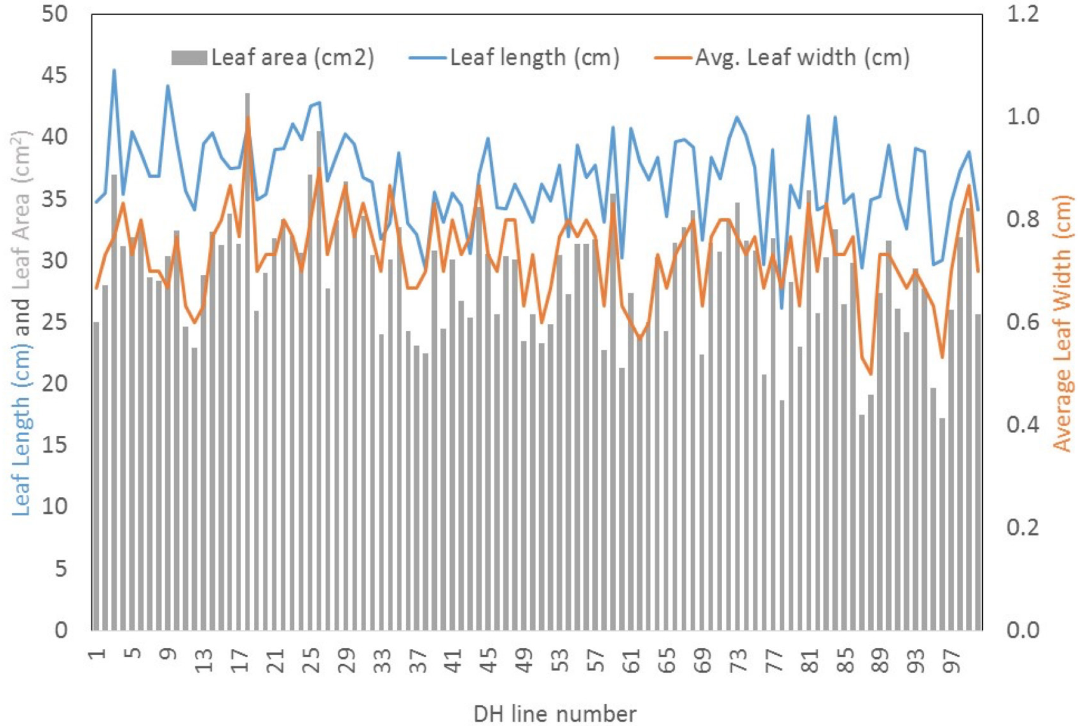

Figure 7. Variability in leaf length, width and area under greenhouse conditions at Stillwater among doubled haploid progeny of Duster x Billings.

This may be attributed to a higher photosynthetic rate of these lines and/or higher rates of carbohydrate remobilization. Further analysis would be required to identify the lines with most efficient carbohydrate accumulation and remobilization under field conditions.

The same set of DH progeny showed significant variation in flag leaf length, width and area. Leaf length varied from 26.1 centimeters to 45.5 centimeters, leaf width varied from 0.5 centimeters to 1.0 centimeters, and LAI varied from 17.2 centimeters squared to 43.6 centimeters squared (Figure 7). As expected, leaf length and leaf width were highly correlated with leaf area ($r > 0.82$). These traits are informative, because the leaves intercept sunlight and produce assimilates for plant growth and yield. Optimum leaf size is essential to enhance light distribution in the canopy and also for efficient water and nutrient use. Moving forward, analysis of leaf traits will be combined with other photosynthetic and physiological traits to understand the relationship between traits at the whole plant level in providing water stress and high temperature tolerance.

Among the same set of DHs, both net CO_2 assimilation, an indicator of photosynthetic capacity, and stomatal conductance generally increased with an increase in day/night temperature from 22/18 degrees to 32/28 degrees Celsius. Specifically the change in net assimilation rate varied from -1.48 to 22.12 $\mu mol\ m^{-2}\ s^{-1}$, while the change in stomatal conductance varied from 0.06 to 0.59

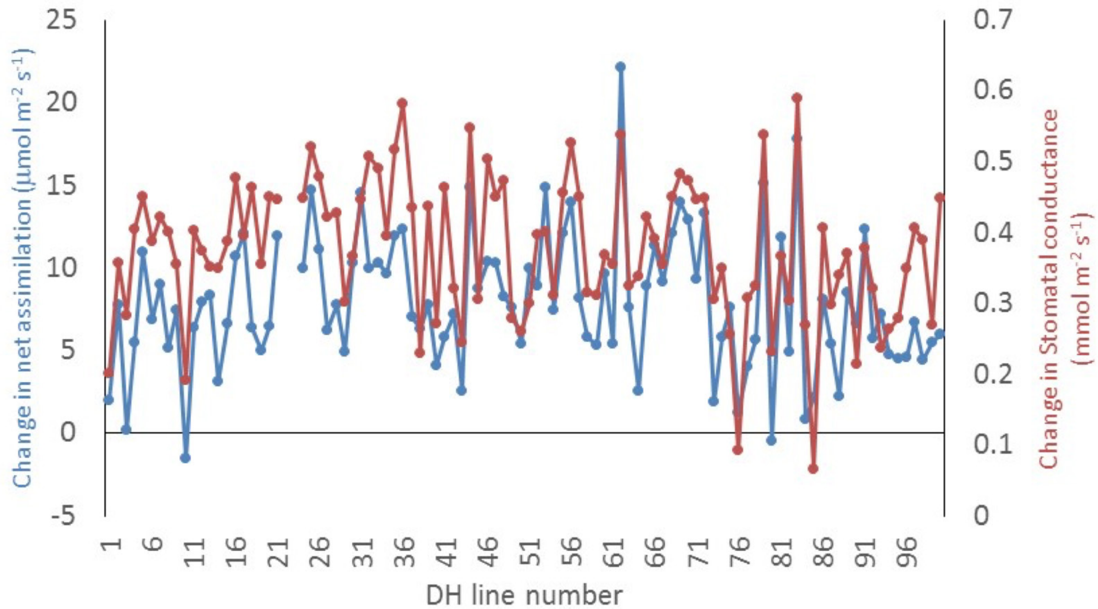

Figure 8. Change in net assimilation rate and stomatal conductance of plants grown at 32/28°C compared to those grown at 22/18°C day/night temperature in controlled environment chambers at Stillwater.

mmol m^{-2} s^{-1}(Figure 8). These results showed an increase in net assimilation is not necessarily associated with increase in stomatal conductance. Hence, selection for these traits can be independent of each other to improve water use efficiency under high-temperature and water-stress conditions.

Wheat Breeding and Cultivar Development

Brett Carver
Plant and Soil Sciences

What was learned in 2015

Stripe rust returned in 2015 to lead a battalion of conditions that attacked the 2015 wheat crop and greatly influenced final yield. These included early- and mid-season drought stress that was no stranger in the two previous years, leaf rust wherever stripe rust did not first eliminate the leaf canopy, and BYD in situations of early planting. Fusarium head blight, or head scab, played a significant role in yield discrimination in breeding nurseries planted near Okmulgee. Finally, WIT had one of its best years to select from more than 2,000 early-generation experimental lines at Lahoma for reaction to the WSBM/WSSM complex. This provided a head start on the normal schedule of WSBM/WSSM selection, which typically begins in the following generation under Dr. Hunger's watch. What was learned from this experience is WIT's capacity for WSBM/WSSM selection remains highly critical, even though virtually all of the cultivars released by this program feature an effective level of resistance. The majority of parental

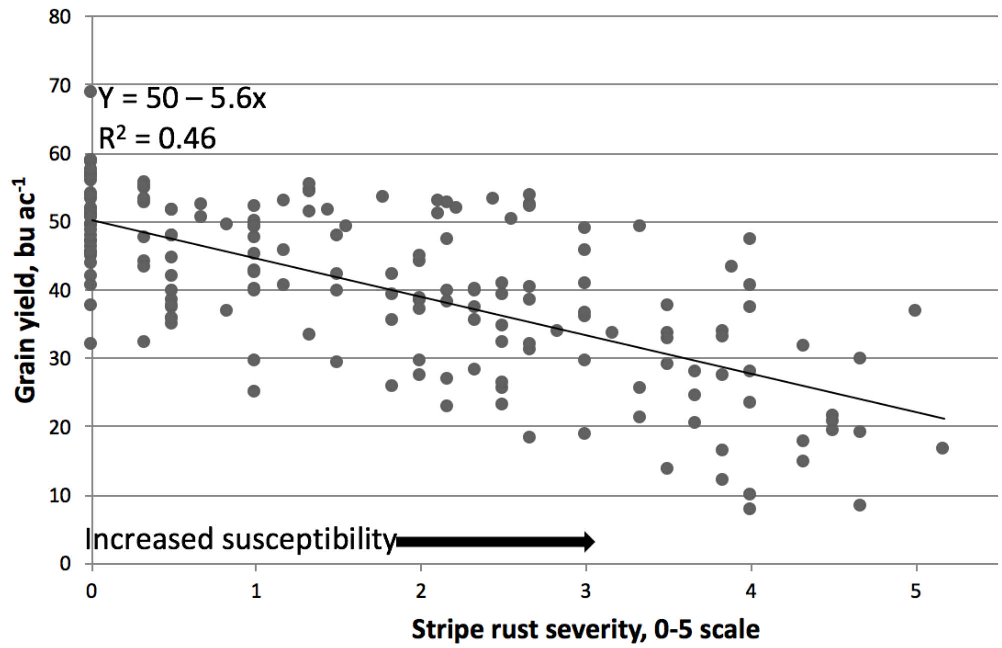

Figure 9. Grain yield at Lahoma versus severity of stripe rust presence in May 2015 for 174 advanced experimental WIT lines.

materials introduced from external breeding programs, however, will not carry resistance, and thus their progeny must be selected for this trait from designed crosses.

Stripe rust was so damaging because it started early in March and April 2015 and spread fast and wide. WIT was fortunate to find that the 2015 infection had minimal negative impact on the most elite lines in the variety development pipeline, as many of these lines had previously passed a similar test during the stripe rust epidemic of 2012. As expected, Gallagher provided a much stronger defense in 2015 than its half-brother Iba, confirming a clear genetic difference between them. Iba features the gene complex *Lr34/Yr18*, and possibly other non-race specific, adult-plant resistance genes, whereby this kind of partial resistance can be overwhelmed in the face of severe and prolonged infection. Gallagher, on the other hand, carries one or more unknown genes, which may confer race-specific, adult-plant resistance. This form of stripe resistance may not be durable but is quite common among WIT breeding populations.

The effect of stripe rust on final yield in WIT breeding nurseries was best ascertained at Lahoma where other diseases had less impact and therefore, exerted less bias in yield comparisons. Figure 9 vividly illustrates a linear yield decline with gradually increasing levels of susceptibility. In other words, yield was negatively impacted along the entire spectrum of genetic resistance levels. Grain yield steadily declined by 5 to 6 bushels per acre with each incremental loss in stripe rust resistance. Between experimental lines rated as highly resistant versus those rated as highly susceptible, the total decline in yield was 28 bushels per acre, or more than one-half of the yield potential expressed in this environment. Under these conditions,

Table 6. Distribution of stripe rust response categories among three U.S. locations for 77 elite experimental lines in the OSU wheat improvement program. Data collected by Carver, Hunger, Bowden and Carter.

Location of disease	Resistant	Moderately resistant	Moderately susceptible	Intermediate	Very susceptible
			- - - - - - - - - - %	- - - - - - - - - -	
Oklahoma (statewide)	33	33	10	15	9
Rossville, Kansas	24	27	25	12	12
Central Ferry, Washington	9	37	18	11	25

partial resistance was only partially effective. That may not always be the case, as observed in WIT nurseries at Goodwell, where stripe rust infection was still severe but started later during grain filling. Stripe rust reactions could not be obtained in 2015 at Altus but if they had been, the yield penalty would have likely exceeded what was observed at Lahoma.

Resistance to stripe rust remains a high-priority breeding objective. However the target moves as pathogen races change, making this objective problematic. One strategy increasingly being used by WIT is marker-assisted selection for known candidate genes conferring desirable levels of resistance, such as adult plant rust resistance loci *Lr34/Yr18* and *Lr46/Yr29*, and a relatively new gene, *TaXA21-A1*, discovered by Yan and discussed in his report.

WIT also has turned to other cooperators for assistance in its field selection efforts, particularly those located in Manhattan, KS with USDA-ARS, and in Pullman, WA with Washington State University. This collaboration ensures constant selection pressure for stripe rust resistance in years which the disease is not present in Oklahoma, such as 2013 and 2014. Experimental line ratings collected in all three environments illustrated an important point about expression of stripe rust resistance in wheat and disease resistance in general: the reaction manifested by a given line is determined by 1) the genetics of the plant, 2) the genetics of the pathogen and 3) the environment in which those two forces collide.

Two-thirds of the WIT elite breeding lines reported in Table 6 showed a moderately resistant or resistant reaction to stripe rust across several locations in Oklahoma. This proportion was similar to expectations based on ratings collected in 2012, but it was reduced to about 50 percent in Kansas, where infection was artificially enhanced and symptoms were more severe. Moreover, twice as many lines were considered to have an intermediate level of protection under those conditions than under natural, but severe, infection in Oklahoma. In Washington, the proportion of lines classified as resistant was reduced even further, with 25 percent of the lines deemed highly susceptible. From a variety development perspective, reactions of some breeding lines were stable and consistent across all

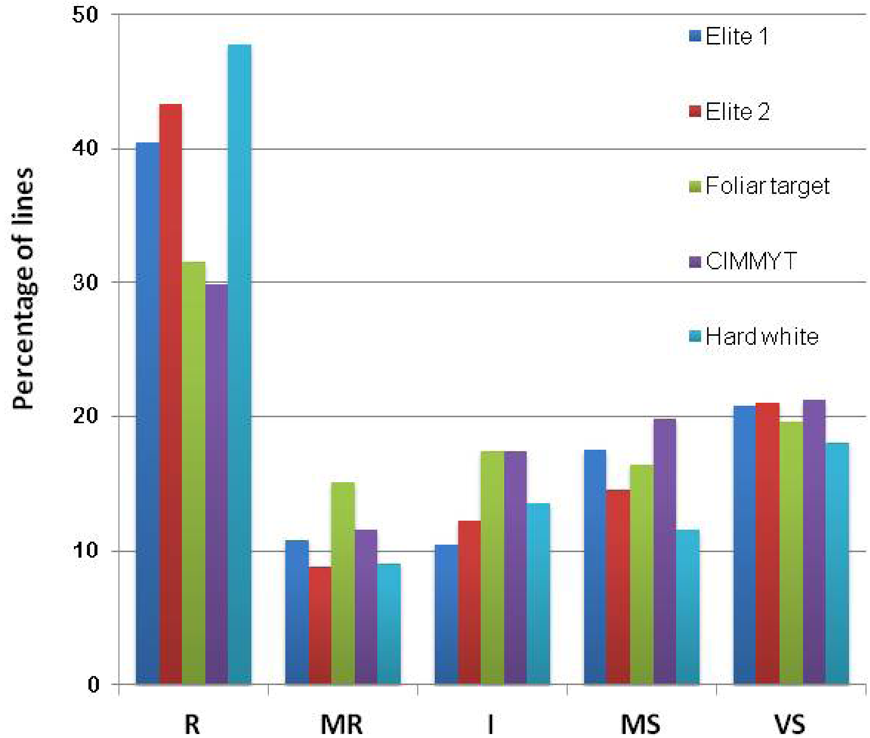

Figure 10. Frequency of stripe rust response categories among 2,158 mid-generation experimental WIT lines tested in the 2015 Dual-Purpose Observation Nursery at Lahoma. R=resistant, MR=moderately resistant, I=intermediate, MS=moderately susceptible and VS=very susceptible.

locations, providing crucial results for selection and advancement. From an epidemiological perspective, the evidence indicated stripe rust resistance in our most advanced and elite germplasm is partial, and again, likely expressed as adult-plant resistance.

The breeding materials discussed above represent a small but important component of the OSU wheat improvement program–that which constitutes the end of the VDP. This prompts the question, to what extent is the program at risk in the future to a stripe rust epidemic similar to the one in 2015? To answer this question, stripe rust reactions were needed for materials further upstream in the pipeline. The WIT collected this crucial information from field nurseries at Lahoma comprised of thousands of experimental lines three to five years away from release. About 50 percent of the lines at this juncture in the pipeline exhibited a desirable level of protection against stripe rust (Figure 10), a rate that exceeded WIT's expectations. What was even more enlightening was that among the various subsets of lines with contrasting breeding histories, the hard white subset was perhaps better equipped to handle stripe rust than two elite subsets of hard red winter lines. The subset with predominately International Maize and Wheat Improvement Center, or CIMMYT,

Table 7. Reactions to wheat streak mosaic and Triticum mosaic under controlled environment and field conditions at Lincoln, Nebraska, and presence or absence of genes which confer resistance to these diseases, among advanced experimental lines. Disease reaction data provided by B. Graybosch, USDA-ARS. Genotypic data provided by Powers and Yan.

		Disease		Gene presence/absence		
Experimental line	Pedigree	Wheat streak mosaic	Triticum mosaic	*Wsm1*	*Wsm2*	*Cmc4*
OK118036	N02Y5078/TX01V5314//OK Bullet	MR	?	–	–	–
OK12P433	KS03HW156/OK01817	IC	MR	–	+	–
OK12612	N02Y5078/OK05741W	R	R	–	–	–
OK09P86146W	N02Y5106/OK03716W	IC	MR	?	+	–
OK13P803W	N02Y5078/TX01V5314//OK Bullet	R	R	?	?	–
OK13804W	NW03Y2016/RonL	IC	IC	+	+	–
OK13805W	NW03Y2016/RonL	IC	IC	–	+	–
OK13123	STARS0601W/OK05312	R	R	–	–	+

parentage was expected to carry genes conferring partial resistance to stripe rust and leaf rust, and thus, these lines showed a lower frequency of all-out resistance.

One other disease resistance breeding target that warrants mentioning, given the amount of effort expended in 2015, is wheat streak mosaic. WIT activity in this area was entirely dedicated to the laboratory, where selection is currently not feasible in the field, except for a screening test performed by USDA-ARS near Lincoln, Nebraska on a restricted number of experimental lines. WIT's strategy remains focused on a three-pronged approach of selecting for molecular markers either in close linkage with or inherently part of genes *Cmc4*, *Wsm1* and *Wsm2*. Potentially adapted segregating populations and fixed lines have resulted from this work, leading to extensive field testing in 2015-2016 for agronomic and quality traits other than those targeted by the molecular markers. The core of those materials, or parental sources thereof, is listed in Table 7. Some lines remain a mystery such as OK118036 and OK12612, because they appear to offer protection to curl-mite transmitted virus diseases, yet they do not appear to carry the targeted genes.

See the report provided by Hunger to learn about breeding efforts devoted intensively to other diseases. The one disease to which WIT may be most vulnerable in moving forward with release decisions is leaf rust because leaf rust reactions have not been highly relevant to experimental line advancement since 2009. However, WIT had a tight window to monitor leaf rust reactions

Figure 11. Experimental line OK12621 shown in a 2015 Stillwater yield trial subjected to simulated grazing during the fall and winter in the presence of barley yellow dwarf. OK12621 was the highest yielding entry in the statewide 2015 Oklahoma Elite Trial, and as shown here remained photosynthetically active and mostly asymptomatic of BYD through physiological maturity on May 19, 2015. Other plots surrounding OK12621 were void of any photosynthetically active canopy on this date.

at Goodwell in late May 2015. Two candidate lines are known to be weak in leaf rust protection, OK10959060-3 and OK11755W, though most other lines were not considered to suffer significant yield loss from the observed level of leaf rust pressure. Nevertheless, an extended absence of a disease such as leaf rust can wreak havoc on a wheat breeding program that depends on natural occurrence for selection pressure. One factor 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, or even appropriate, 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. Hence, it is the combined work of Hunger and Yan who keep WIT relevant in the game for leaf rust protection. Another positive factor is the omnipresence of Duster and Billings, or progeny thereof, in the OSU wheat breeding program. Each one offers a different form of leaf rust resistance that remains highly effective even today.

Likewise, BYD always can be counted on somewhere in WIT breeding nurseries across the state. This was indeed the case in 2015 for early planted nurseries located at Stillwater. One trial featuring the most elite experimental lines showed hardly any sign of disease pressure except for a severe level of BYD. Hence, this rare opportunity allowed WIT to identify and advance lines with a relatively high level of BYD resistance. One line that stood out, but

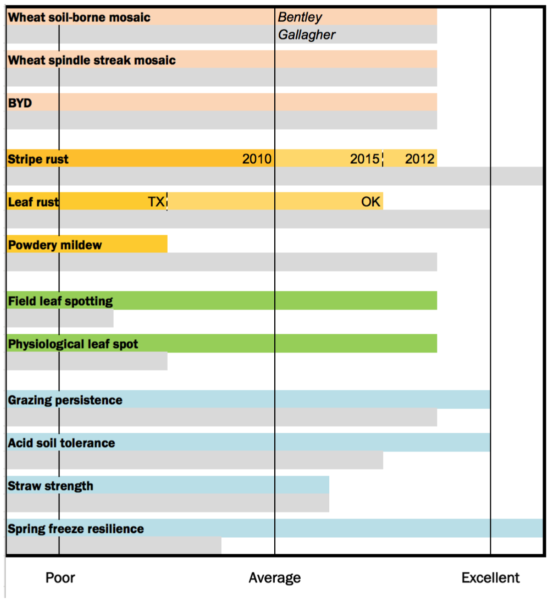

Figure 12. Trait comparisons of Bentley (top bar) versus Gallagher (bottom gray bar).

not surprisingly given prior targeted selection for two BYD resistance genes, was an offspring of Duster and a Purdue University experimental, called OK12621 (Figure 11).

Combining the source of resistance in Duster with that from Purdue provides highly effective BYD protection under the most intense disease pressure. The WIT's biggest limitation has been tracking the two-gene combination, a task that requires molecular marker tools. That work was carried out in 2014 by Guihua Bai thanks to a subaward from OWRF to jumpstart marker-assisted breeding of the stacked BYD trait. To help WIT carry that work forward is Carol Powers, postdoctoral fellow in Yan's laboratory. OSU wheat cultivars that provide effective levels of BYD resistance are becoming more frequent as a result of the special emphasis given to this trait in the wheat improvement program. These include Endurance, Ruby Lee, Garrison, Gallagher, Iba and Bentley.

New to the neighborhood

Released by the OAES in July 2015, the new hard red winter cultivar Bentley is a descendent of TAM 303, developed by Texas AgriLife and Overley, developed by the Kansas Agricultural Experiment Station. This represents a significant departure in parentage compared with the recent releases of Ruby Lee, Gallagher and Iba. Two genetically similar cultivars currently in commercial production, but on small Oklahoma acreages, are WB4458 and LCS Mint, for which Overley constitutes 50 percent of their parentage. No hard red winter wheat cultivar currently in production claims TAM 303 as a parent. Bentley offers a unique but broad-utility genetic background that meets or exceeds performance expectations for several key trait domains (Figure 12). Bentley upholds WIT's reputation for delivering cultivars with adaptation to dual-purpose management systems under the *Graze*n*Grain*™ moniker.

Grain yield potential of Bentley equals or exceeds that of cultivar releases from other breeding programs (Table 8), while filling some critical gaps in disease reaction or in hardiness to climatic trends prevalent for the past four years. Specifically, Bentley has excelled relative to currently available cultivars in response to tan spot and other leaf spotting diseases, barley yellow dwarf, acidic soil conditions, grazing, reduced nitrogen conditions and early spring freeze events. Though based only on empirical data collected in yield trials, Bentley appears to offer a level of drought resistance that exceeds the majority of cultivars tested in 2011 through 2014, thus enabling its adaptation range to extend into some of the driest areas of the state where Duster may have experienced some difficulty.

Bentley's probable area of adaptation and limitations

Bentley is best adapted to the central and southwestern regions of Oklahoma. This target zone may shift further west where drought tolerance is a primary need, or further north into southcentral Kansas, pending additional variety testing. It is also well adapted to acidic areas of the same regions. Bentley is well suited for dual-purpose grazed systems given its observed ability to rapidly accumulate fall vegetative biomass, regenerate vegetative biomass upon removal, and maintain viable tillers after grazing termination. One caveat to its grazing potential, however, is that Bentley may express high-temperature germination sensitivity based on controlled-environment experiments. Thus, the ideal planting window for Bentley may be pushed back into early September. Very early sowing would be highly discouraged for Bentley. Whereas tiller abortion is not a weakness of Bentley, to reach its full yield potential under any management system, it needs to tiller well in the fall, similar to its parent Overley and to the cultivar WB-Cedar.

Owing to its moderate resistance to tan spot, Bentley is better suited for high-residue management systems than Duster or its derivatives, Gallagher and Iba. More direct comparisons with Garrison are needed to ascertain a meaningful difference in their reaction to other leaf spotting diseases, including physiological leaf spot. One note of caution relative to other diseases common in Oklahoma concerns leaf rust. Juvenile plants of Bentley exhibit resistance to multiple races of leaf rust but not all. Not knowing the predominant races to occur in future infections, a fungicide application may be needed for supplemental protection, especially under severe leaf rust pressure from races virulent to resistance genes present in Bentley. Those include *Lr21* and *Lr39/41* from *Aegilops tauschii* and *Lr37* from *Triticum ventricosum*.

Protection against stripe rust may be environment-specific, because Bentley offers race-specific adult-plant resistance built upon a genetic foundation of *Yr17* and other minor resistance genes. Hence, the precise reaction observed on Bentley will depend on the amount of *Yr17* virulence present in a given environment. The last year in which *Yr17* virulence was predominant in Oklahoma was 2010, the second year in which Bentley was tested statewide and advanced in the VDP.

Though its shattering tolerance appears to be improved compared with Overley, Bentley is moderately susceptible to shattering but highly inconsistent. Shattering was not typically expressed by Bentley in breeding nurseries across the state since 2009 and was not always expressed even in environments where shattering was common among other entries. Hence, as a general precaution, those conditions that promote shattering may constitute a limitation to its use, such as accelerated dry-down following physiological maturity and/or a

Table 8. Grain yield and test weight performance of Bentley (OK09125) in OSU wheat variety trials conducted from 2013 to 2015. Sites are arranged by state region: southwest, central, northcentral, and northwest. T indicates Bentley was tied with one or more other varieties at the rank position given. Yields in boldface indicate Bentley was in the statistical top-yielding group for that trial; those in red represent underperformance (significance not stated) of Bentley for that trial. Data provided by Edwards and OCES.

	3-yr mean, 2013-2015			2-yr mean, 2014-2015			2015 only			
Trial site	Rank	Grain yield	Diff. from Gallagher	Rank	Grain yield	Diff. from Gallagher	Rank	Grain yield	Diff. from Gallagher	Diff. from trial
		- - - - - bu/ac - - - - -			- - - - - bu/ac - - - - -			- - - - - bu/ac - - - - -		lb/bu
Altus	--	--	--	1	39	*+12*	2	**56**	*+9*	+2.1
Apache	--	--	--	1	53	*+8*	2	**57**	*+7*	-0.4
Apache plus fungicide	--	--	--	2T	60	*+7*	2	**67**	*+2*	0.0
Walters dual purpose	--	--	--	10T	28	*-3*	9T	28	0	-2.4
Chickasha	--	--	--	18T	43	*-8*	30	39	*-19*	-3.9
Chickasha intensively managed	--	--	--	5T	60	*+3*	18T	**74**	*-1*	-0.6
Thomas	1	**25**	*+1*	1	30	*+2*	1	**42**	*+1*	--
Union City	--	--	--	--	--	--	9	39	*-10*	-1.6
Kingfisher	2T	**49**	+5	4	49	*+3*	4	**60**	*+4*	-0.9
McLoud	--	--	--	--	--	--	9T	**58**	*+13*	-2.5
Marshall	3T	**40**	*+2*	7T	31	*+1*	8T	41	*-2*	-3.7
Marshall dual-purpose	6T	**34**	*+1*	4T	29	*+1*	10T	35	*-6*	-3.6
Lahoma	2T	**59**	*-2*	4	54	*-4*	12T	56	*-6*	+0.3
Lahoma plus fungicide	2T	**64**	*-1*	4T	60	0	6T	**72**	0	-1.1
Homestead	1	**41**	+5	1T	31	*+6*	1	**32**	*+8*	+2.8
Kildare	--	--	--	1T	58	*+14*	1	**53**	*+11*	+3.6
Cherokee	--	--	--	--	--	--	9T	**48**	*-4*	-2.0
Alva	--	--	--	--	--	--	2	**56**	*+11*	-0.6
Buffalo	--	--	--	--	--	--	4	**64**	*+16*	-0.6
Average difference, from Gallagher (yield) or from trial mean (test wt.)			**1.6**			**3.0**			**1.8**	**-0.8**

Partners in Progress WHEAT

standing mature and highly erect crop subject to hail or wind damage.

In all, Bentley offers strengths currently lacking in contemporary cultivars, particularly those derived from Overley. Its yielding ability is superlative under wide-ranging conditions, yet it is this superiority that creates a conundrum. The benefit of what Bentley can provide in how much it weighs out of the field, or yield, may be partially deducted by how it weighs across the scales, or test weight. In 2015, Bentley's test weight averaged 0.8 pounds per bushel less than the average of all cultivars included in OSU wheat variety trials (Table 8). Beyond test weight, Bentley has shown above-average to exceptional milling and baking characteristics.

By the numbers

The moving parts of a plant breeding program, including this one, can be likened to a musical canon in which essentially the same music is being played or sung starting at different times. Likewise, the same fundamental breeding procedure is followed starting with a new set of hybridizations each year. A freeze frame of the breeding program at any point in time reveals different parts of the process in motion, as enumerated and discussed further in Figure 13.

Candidate cultivar lineup

Among 39 experimental lines placed under breeder seed increase at the Oklahoma Panhandle Research and Extension Center in Goodwell, 14 of them also are under increase by OFSS. Eleven of those are featured in Table 9; the remaining three are

Table 9. OSU candidate cultivars placed under seed increase in fall 2015 with Oklahoma Foundation Seed Stocks, Inc.

Candidate	Pedigree	Increase status	Feature traits
OK09915C-1	N91D2308-13/OK03908C//OK03928C	Pre-release	Improved Doublestop CL+ (stripe rust reaction)
OK10728W	OK Rising/OK98G508W-2-49	Pre-release	Sprout-tolerant hard white for northcentral Oklahoma
OK11D25056	Gallagher/OK05511	Pre-release	Stacked greenbug and Hessian fly resistance
OK10126	OK Bullet/OK98680	Pre-release	Short straw, lodging resistant
OK1059060-3	Fuller/OK01307	Year 2	Fuller type with acid soil and WSM tolerance
OK12621	Duster/P961341A3-2-2	Year 2	Two-gene resistance to BYD
OK13625	Billings/Fannin sib	Year 2	High nitrogen-use efficiency (under further test)
OK11231	Deliver/Farmec	Year 2	Beardless with statewide adaptation
OK11P228	Deliver/Farmec	Year 1	Beardless with statewide adaptation
OK12912C	N91D2308-13/OK03926C//OK03928C	Year 1	Next generation of Clearfield Plus
OK12DP22002-042	Billings/OK08328	Year 1	Best adapted to western Oklahoma

2,245	The number of segregating populations subjected to the ***Graze*** n***Grain*** breeding system at Marshall, Lahoma, and Altus, OK. About one-third of these populations were sufficiently inbred to allow extraction of experimental lines for eventual testing and selection. One segregating population usually generates 96 experimental lines.	
65,457	The number of first-generation F_5 experimental lines planted in 3-foot headrows, by far the largest set of headrows evaluated by OSU in a single season among records dating back to the early 1980s. This record will probably stand for some time, as the spike was created by a temporary flux of experimental lines selected from Dr. Art Klatt's segregating populations.	
2,158	The number of second-generation lines dedicated to our centerpiece breeding nursery, the Dual-Purpose Observation Nursery (DPON), and key turning point for lines borne out of the ***Graze*** n***Grain*** breeding system. Only those progeny superior for grazing persistence and grain-only yield potential are advanced for statewide yield testing.	
997	Second-generation lines that did could not fit into the DPON, as they exceeded the field space allowable at Lahoma and Stillwater, OK. Out of this set will come experimental lines under accelerated increase (very high priority for yield and disease resistance) or in the Clearfield Plus branch of the VDP.	
922	Intermediate to advanced lines assigned to replicated multi-location yield and quality trials across Oklahoma, if not beyond, from which about 20-30% were advanced for further testing in 2016. About 24 of these, often called the elite set, go on pubic display with the OSU variety trials at Kingfisher and Cherokee, OK.	
3 x 11	Across the board, 11% of all experimental lines evaluated in 2015 were 1) hard white (HW), 2) doubled haploid, or 3) CLEARFIELD. Some lines carried two of these features. Market pressures suggest the percentage of HW lines should be increased, but producer demand runs counter. The candidate cultivar, OK11D25056, is a hard red winter doubled haploid.	
1000	Crosses planned in 2015 and almost attained by dedicated effort of two full-time staff and about 5 part-time OSU undergraduate students. It only takes 1 cross to produce a variety, but all of the numbers above are necessary to determine which experimental becomes that variety. 220 of these crosses could potentially produce either HRW or HW lines.Crosses made today should reflect industry needs 10 years from now.	

Figure 13. The OSU wheat improvement program, by the numbers, for the 2014-2015 crop season.

either soft wheat lines or a beardless wheat. OK09915C-1 is a single-plant selection from Doublestop CL+ that out-performed the parent variety by 6 to 10 bushels per acre at every location in Oklahoma in 2015. It also exhibited better stripe rust protection than Doublestop CL+. Otherwise, the two are phenotypically similar. OK09915C-1 is currently included in the OSU and KSU wheat variety trials. The second Clearfield candidate, OK12912C, also exceeded Doublestop CL+ by 6 to 10 bushels per acre at all locations in Oklahoma, except at Goodwell and Stillwater. The beardless candidate OK11231 had the distinguishing feature of placing first in the OET at Okmulgee in 2015, where yields were primarily limited by FHB. The doubled haploid, OK12DP22002-042, was first in its class for statewide grain yield in both 2014 and 2015. The lack of WSBM resistance pushes its target region to western Oklahoma, but its best relative performance may be in the panhandle anyway.

Right on the heels of Bentley 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 Bentley, 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*. A release decision is pending further testing in variety trials in northern Oklahoma and southern Kansas.

Among several promising hard white advanced lines, OK10728W could be the strongest candidate with statewide adaptation, tan spot resistance, and resistance to shattering and lodging. It also fits the ***Grazen**Grain*™ mold, though BYD susceptibility and early dormancy release are weaknesses when managed for grazing. If released, this experimental would be specifically targeted toward northcentral Oklahoma, where it is best adapted for grain production. Its resistance to pre-harvest sprouting, 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, early maturity and a high level of tolerance to low pH soils. A release recommendation may be forwarded to OAES in February 2016.

Wheat Variety Trials

Jeff Edwards
Small Grains Extension Specialist
and Department Head,
Plant and Soil Sciences

Robert Calhoun
Senior Agriculturalist

Romulo Lollato
Graduate Assistant

Giovana Cruppe
Graduate Assistant

Brett Carver
Wheat Breeder

Bob Hunger
Extension Plant Pathologist

At the time of this report, the 2015 Oklahoma wheat production was approximately 104 million bushels, roughly double the 2014 production (Table 10). While this certainly is an improvement from the previous year, 2015 will not be remembered as a banner year for Oklahoma wheat.

Table 10. Oklahoma wheat production for 2014 and 2015 as estimated by OK National Agricultural Statistics Service, July 2015.

	2014	2015
Harvested Acres	2.8 million	3.7 million
Yield (bu/A)	17	28
Total bushels	48 million	104 million

Most of the Oklahoma wheat crop was sown into limited topsoil moisture with little or no subsoil moisture to serve as backup. There were a few large rainfall events in fall 2014, but the smaller, timely rainfalls that fell across much of Oklahoma were just enough to build and maintain an adequate to bumper fall forage crop.

Even though subsoil moisture was never recharged, the wheat crop went into winter dormancy with good potential. Some of the later-sown wheat was small, but tillering was adequate and a few small moisture events kept the crop viable. Coming out of dormancy in February and March, many areas of Oklahoma were poised to make a bumper crop, but it soon became clear the crop was living on borrowed time. Warm winds in early March reduced a wheat crop appearing to have 60 bushels per acre potential, to 20 bushels per acre potential in about three days. Soon thereafter, fields browned and tillers were sloughed.

Rain in late March and early April brought new life to the wheat crop in southcentral and southwestern Oklahoma. Rain was not as plentiful in northcentral and northwestern Oklahoma, but there was enough to keep the crop going. Rain started falling in early May, wheat rebounded and it appeared the Oklahoma wheat crop would be saved at such a late time. Rains continued throughout May, however, setting records and reducing wheat yield and quality.

Wheat in southwestern Oklahoma was mature by June 1, but rains delayed harvest until mid June. Dry weather allowed most of the Oklahoma wheat crop to be harvested by July 4. Test weights varied from 45 pounds per bushel to more than 65 pounds per bushel, but most were in the mid-50 pounds per bushel range. Reductions in test weight were due to a variety of factors. Foliar disease and Fusarium head blight claimed test weight in susceptible varieties. Many wheat fields lodged early, resulting in poor grain fill and some sprouting damage. Finally, waterlogged soil conditions were less than optimal for the final half of grainfill, which resulted in shriveled kernels.

Insect problems in 2015 included bird cherry oat aphid, greenbugs, winter grain mite, brown wheat mite and Hessian fly. Producers were faced with the need to invest money into pesticides to control greenbugs and mites in an extremely drought-stressed crop. Many chose not to treat. Hessian fly was troubling for many Oklahoma no-till wheat farmers in 2015. The last few years have been relatively Hessian fly-free, but the resurgence of this insect pest in 2015 reinforced the importance of genetic resistance as the most effective tool for combatting this pest in the southern Great Plains.

While 2014 was virtually disease free, foliar and viral diseases of wheat were plentiful in 2015. Wheat streak mosaic continued its progression into central Oklahoma, and several fields in the Enid area were infected with the wheat curl mite-transmitted disease. Free moisture, moderate temperatures and plentiful disease inoculum made conditions right for Fusarium head blight primarily in eastern Oklahoma, where several fields were affected with varying levels of damage either from the fungus, reducing yield and test weight, or from the toxin DON associated with Fusarium head blight infections.

While both wheat streak mosaic and Fusarium head blight were issues in 2015, the agronomic and economic impact of these two diseases pale in comparison to that of stripe rust. Reports from Texas made it clear stripe rust inoculum was plentiful and 2015 had the potential to be a major stripe rust year. Producers were aware of this potential, but they were confronted with the fact that at the time fungicides should have been applied, the wheat crop was still in the stranglehold of drought. Once rains came and conditions improved, it was either too late or fields were too wet to apply many of the fungicides available. Perhaps no variety more clearly conveys the impact of stripe rust than Pete. At Chickasha, without a fungicide, the stripe rust-susceptible variety made just 10 bushels per acre with a test weight too low for the machinery to measure. In the Chickasha Intensive Wheat Management trial in the same field, Pete made 78 bushels per acre, with a 59.7 bushels per acre test weight. This stark contrast in production illustrates not only the yield-robbing power of stripe rust, but also the yield-protecting power of foliar fungicides.

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 cone-seeded, small-plot research. With the exception of dryland locations in the Panhandle, plots were planted 25 feet long and trimmed to 20 feet at harvest with the plot combine. Panhandle dryland locations were 35 feet long at planting and trimmed to 30 feet at harvest. Wheel tracks were included in the plot area for yield calculation, for a total plot width of 59 inches. Experimental design for all sites was a randomized complete block with four replications, with the exception of Lahoma and Apache. Lahoma and Apache were a split-block arrangement of a randomized complete block with four replications, where whole plots were fungicide treated or nontreated and sub-plots were wheat variety.

Conventional till plots received 50 pounds per acre of 18-46-0 in-furrow at planting. No-till plots received 5 gallons per acre of 10-34-0 at planting. The Marshall dual-purpose trial, Union City, Walters and forage trials were sown at 120 pounds per acre. All other locations were sown at 60 pounds per acre. Grazing pressure, nitrogen 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. Maximum and minimum grain moisture for all plots at a location typically ranged no more than 1 percent. Lamont and Goodwell nonirrigated plots were harvested, but data are not reported as the coefficient of variation exceeded 20.

Additional information on the Web

A copy of this publication, as well as additional variety information and more information on wheat management can be found at:

Website: wheat.okstate.edu

Blog: osuwheat.com

Twitter: @OSU_smallgrains

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Area Extension Agronomists
Mark Gregory, Southwest District

Brian Pugh, Northeast District

County Extension Educators
Thomas Puffinbarger, Alfalfa County
Loren Sizelove, Beaver County
David Nowlin, Caddo County
Sug Farrington, Cimarron County
Ron Wright, Custer County
Rick Nelson, Garfield County
Kassie Junghanns, Grant County
Darrell McBee, Harper County
Gary Strickland, Jackson County
Corbin Dewitt, Kay County
Zack Meyer, Kingfisher County

Jeff Parmley, Ottawa County
Mindy Hittle, Texas County
Greg Highfill, Woods County

Station Superintendents
Erich Wehrenberg, Agronomy Research Station, Stillwater
Richard Austin, North Central Research Station, Lahoma
Cameron Murley, Oklahoma Panhandle Research and Extension Center, Goodwell
Michael Pettijohn, South Central Research Station, Chickasha
Rocky Thacker, Southwest Research and Extension Center, Altus

Student Workers
Abigael Hughes
José Pinto

We sincerely thank our variety trial cooperators for donation of land, time and resources. Variety trial cooperators not otherwise listed in this document include:

Kirby Farms, Lamont

Participating Seed Companies

AGSECO, Inc.
Steve Ahring
P.O. Box 7
Girard, KS 66743
800-962-5429
steve@delangeseed.com
agseco.com
Varieties: Hot Rod, TAM 113

Colorado Wheat Research Foundation (PlainsGold)
Darrell Hanavan
4026 S. Timberline Rd. Ste. 100
Fort Collins, CO 80525
970-449-6994
dhanavan@coloradowheat.org
Varieties: Byrd, Brawl CL Plus, CO11D174

Kansas Wheat Alliance
Daryl Strouts
1990 Kimball Ave.
Manhattan, KS 66502
785-320-4080
kwa@kansas.net
kswheatalliance.org
Varieties: 1863, Everest, KanMark, Oakley CL

Limagrain Cereal Seeds
Marla Barnett
6414 N Sheridan
Wichita, KS 67204
316-253-6839
marla.barnett@limagrain.com
limargraincerealseeds.com
Varieties: LCS Mint, LCS Pistol, LCS Wizard, T153, T154, T158, LCH11-1117, LCH13DH-20-87, LCH13DH-14-91,

Monsanto/WestBred
John Fenderson
1616 E. Glencoe Rd.
Stillwater, OK 74075
620-243-4263
john.m.fenderson@monsanto.com
westbred.com
Varieties: WB4458, WB-Cedar, WB-Grainfield, WB-Redhawk, Winterhawk

Oklahoma Genetics Inc.
Mark Hodges
P.O. Box 2113
Stillwater, OK 74076
405-744-7741
okgenetics.com
Varieties: Billings, Centerfield, Doublestop CL Plus, Duster, Iba, Gallagher, Garrison, NF101, OK Bullet, OK Rising, Pete, Ruby Lee

Oklahoma Foundation Seed Services
Jeff Wright
2902 W. 6th Ave.
Stillwater, OK 74074
405-744-7741
oklahomaseed.com
Varieties: Endurance, Deliver

Syngenta Seeds
Greg Gungoll
1517 Osage Ave.
Enid, OK 73703
405-714-2839
greg.gungoll@syngenta.com
agriprowheat.com
Varieties: Greer, Jackpot, SY Drifter, SY Flint, SY Llano, SY Southwind

Watley Seed
Andy Watley
Box 51
Spearman, TX 79081
806-659-3838
watleyseed@valornet.com
watleyseed.com
Varieties: TAM 112, TAM 204

Wheat protein data are available in Extension Current Report CR-2135 Protein Content of Winter Wheat Varieties in Oklahoma, 2015.

2015 Oklahoma Wheat Variety Trial Yield Summary

Variety	Afton	Altus	Alva	Apache	Apache Fungicide	Balko	Buffalo	Cherokee	Chickasha	Chickasha IWM	Goodwell Irrigated	Homestead
	grain yield (bu/A)											
1863	-	46	-	-	-	-	-	-	53	79	76	-
Billings	74	46	45	-	-	-	50	41	59	78	66	26
Brawl CL Plus	-	44	45	39	60	69	63	46	40	71	66	26
Byrd	-	36	48	30	61	69	67	44	17	58	37	25
Centerfield	-	37	-	-	-	-	-	-	47	59	66	-
Deliver	-	44	-	-	-	-	-	-	52	64	54	-
Doublestop CL Plus	65	50	48	47	64	68	61	58	41	60	62	30
Duster	56	43	41	31	49	78	60	48	42	59	60	21
Endurance	64	48	46	40	54	69	60	51	37	64	53	26
Everest	68	43	45	44	60	75	48	52	31	76	70	27
Gallagher	64	47	41	50	65	64	50	42	58	75	80	24
Garrison	50	40	46	32	62	62	53	45	20	60	39	26
Greer	-	46	-	50	66	-	-	-	50	80	51	27
Hot Rod	-	42	-	-	-	-	-	-	66	81	92	-
Iba	57	50	49	45	64	75	61	55	48	73	67	27
Jackpot	64	44	37	48	64	55	49	54	44	77	63	27
KanMark	-	57	46	-	-	69	57	42	46	73	69	-
LCS Mint	-	42	52	-	-	78	60	46	28	69	40	30
LCS Pistol	57	48	47	40	60	75	60	51	34	65	68	23
LCS Wizard	52	36	-	-	-	-	-	-	32	67	53	25
NF101	-	42	-	-	-	-	-	-	45	62	52	-
Oakley CL	-	48	-	-	-	-	-	-	52	68	80	-
OK Rising	-	39	-	-	-	-	-	-	37	68	61	-
Pete	-	36	-	-	-	-	-	-	10	78	39	-
Ruby Lee	75	42	42	41	58	53	49	43	25	64	50	28
SY Drifter	-	48	-	-	-	-	-	-	47	64	70	-
SY Flint	-	52	-	-	-	-	-	-	61	76	79	-
SY Llano	-	26	-	48	56	-	-	-	58	70	-	-
SY Monument	-	41	-	-	-	-	-	-	59	74	78	-
SY Southwind	65	43	-	-	-	-	-	-	53	69	67	30
T153	-	37	-	54	59	-	-	-	58	78	89	-
T154	66	40	44	48	59	-	48	54	56	76	81	-
T158	-	44	-	-	-	77	-	-	47	79	66	-
TAM 112	-	33	38	-	-	62	52	45	23	59	34	-
TAM 113	-	43	41	-	-	70	58	46	37	52	42	-
TAM 114	-	45	55	-	-	75	68	53	53	79	56	-
TAM 204	-	44	53	-	-	74	60	46	53	69	84	-
WB-Cedar	67	50	45	-	-	-	50	41	66	80	64	27
WB-Grainfield	-	43	-	62	73	83	-	-	54	74	80	-
WB-Redhawk	65	36	-	-	-	-	-	-	34	76	55	30
WB4458	76	43	46	56	60	63	53	43	63	80	94	29
Winterhawk	-	51	59	49	63	72	67	46	48	65	64	-
Mean	***64***	***43***	***46***	***45***	***61***	***70***	***57***	***48***	***45***	***70***	***64***	***27***
LSD (0.05)	***8***	***10***	***9***	***7***	***6***	***9***	***8***	***10***	***6***	***8***	***13***	***6***

2015 Oklahoma Wheat Variety Trial Yield Summary (cont'd)

Variety	Hooker	Keyes	Kildare	Kingfisher	Lahoma	Lahoma Fungicide	Marshall Dual Purpose	Marshall Grain Only	McLoud	Thomas	Union City	Walters
	grain yield (bu/A)											
1863	-	-	-	-	62	78	-	-	-	-	-	-
Billings	-	-	31	54	56	64	29	41	55	36	37	-
Brawl CL Plus	58	78	45	50	52	69	35	45	57	27	34	25
Byrd	59	86	33	59	32	70	31	20	53	16	23	24
Centerfield	-	-	-	-	42	54	-	-	-	-	-	-
Deliver	-	-	-	-	53	62	-	-	-	-	-	-
Doublestop CL Plus	54	82	46	57	53	66	38	36	58	36	43	34
Duster	52	81	40	57	45	59	43	34	31	26	36	34
Endurance	53	58	39	54	50	68	38	32	54	23	31	26
Everest	45	71	44	54	43	74	36	42	60	26	35	29
Gallagher	59	73	42	56	62	72	41	43	45	41	49	28
Garrison	52	86	33	44	34	63	19	22	60	15	15	13
Greer	-	-	50	59	49	71	33	39	59	37	38	37
Hot Rod	-	-	-	-	61	70	-	-	-	-	-	-
Iba	50	87	45	55	56	67	37	44	53	30	41	32
Jackpot	48	93	36	59	50	66	30	33	66	32	35	26
KanMark	63	83	-	-	45	65	-	-	-	-	-	-
LCS Mint	54	80	45	-	47	67	27	28	-	-	-	-
LCS Pistol	39	67	40	59	47	65	35	37	51	27	34	35
LCS Wizard	-	-	39	51	34	59	26	27	65	23	29	-
NF101	-	-	-	-	57	69	-	-	-	15	14	11
Oakley CL	-	-	-	-	58	71	-	-	-	-	-	-
OK Rising	-	-	-	-	46	65	-	-	-	-	-	-
Pete	-	-	-	-	35	59	-	-	-	-	-	-
Ruby Lee	43	71	38	54	47	64	34	34	51	21	35	22
SY Drifter	-	-	-	-	47	64	-	-	-	-	-	-
SY Flint	-	-	-	-	55	69	-	-	-	-	-	-
SY Llano	-	-	-	50	52	64	-	-	61	39	42	27
SY Monument	-	-	-	-	64	73	-	-	-	-	-	-
SY Southwind	-	-	39	-	56	65	44	42	-	-	-	-
T153	-	-	-	-	59	72	-	-	-	-	-	25
T154	-	-	-	61	53	60	-	-	58	34	46	23
T158	48	102	-	-	50	61	-	-	-	-	-	-
TAM 112	45	74	-	-	35	62	-	-	-	-	-	-
TAM 113	61	80	-	-	42	54	-	-	-	-	-	-
TAM 114	42	67	-	-	64	72	-	-	-	-	-	-
TAM 204	60	78	-	-	53	78	-	-	-	39	46	27
WB-Cedar	-	-	38	55	61	68	46	53	58	38	50	-
WB-Grainfield	52	103	-	-	64	78	-	-	-	-	-	35
WB-Redhawk	-	-	40	62	46	65	36	34	60	26	23	-
WB4458	51	62	50	62	58	70	35	47	67	41	45	26
Winterhawk	61	88	-	-	47	64	-	-	-	-	-	37
Mean	***52***	***80***	***41***	***56***	***51***	***67***	***35***	***37***	***56***	***29***	***36***	***27***
LSD (0.05)	***12***	***21***	***8***	***8***	***7***	***7***	***6***	***6***	***9***	***7***	***7***	***5***

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RESEARCH