Partners in Progress
WHEAT

Wheat Research at OSU 2012

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 Service

P-1038

Printed on recycled paper using soy-based ink.

This report of the Oklahoma Agricultural Experiment Station is printed and issued by Oklahoma State University as authorized by the Dean and Director of the Division of Agricultural Sciences and Natural Resources and has been prepared and distributed at a cost of $1,640.00 for 500 copies. 0113 JA.

Table of Contents

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 2011-2012. 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*.

Jonathan Edelson
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.

Now is the Accepted Time for Improved Wheat Production

"Now is the accepted time, not tomorrow, not some more convenient season. It is today that our best work can be done and not some future day or future year. It is today that we fit ourselves for the greater usefulness of tomorrow. Today is the seed time, now are the hours of work, and tomorrow comes the harvest."– W.E.B. Du Bois

As I read the above quote, I think it is important to remind Oklahoma wheat producers that the support made possible through the Oklahoma Wheat Commission (OWC) and Oklahoma Wheat Research Foundation (OWRF) continues to make our wheat variety improvement program at Oklahoma State University (OSU) second to none.

During the past year, we have continued to face difficult times with the significant drought. While the 2012 summer wheat harvest for Oklahoma is considered to have been one of the best harvest seasons in the past five years, as I write this article in December 2012, it looks like Oklahoma wheat producers are going to have a more challenging year ahead with this coming harvest due to the serious lack of moisture. Although it seems times might get more difficult, let us not forget the technologies we have available today that we did not have during the Dust Bowl. These technologies include better wheat varieties and better farming practices allowing producers to be more versatile.

While we have items that we are constantly working on for better quality wheat production, we keep making new advances with research on new wheat varieties that will benefit Oklahoma wheat producers in regards to drought tolerance and nitrogen efficiency. This year we continued to see an increase in wheat varieties released from OSU being planted on Texas, Oklahoma and Kansas acres. USDA/NASS reported more than 45 percent of varieties planted in our state were variety releases from OSU. By focusing on drought tolerant and nitrogen efficiency traits we are able to release wheat varieties through OSU that give producers the benefits of increased yield. We also are working on creating varieties that have higher protein levels for grain that is marketed into both the domestic and export markets. The hard work of the OSU Wheat Improvement Team (WIT) allows producers to have more options available to them with new seed varieties that are sure to meet the needs of any individual producer.

As with anything, in order to have a good product in the end, we must remember that it is important to start with good quality. 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 quality 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 percent of protein in flour is important to buyers because it helps create higher gluten levels. Gluten gives a framework to a baked good by swelling as it absorbs water. A higher protein flour absorbs more moisture than a lower protein flour. Higher protein flours also create stronger products that have firmer rising characteristics, which allow for better consistencies on the bakery product line.

The OWC, along with the OSU WIT and OSU's Division of Agricultural Sciences and Natural Resources, continue to work on items that both our foreign and domestic customers are looking for in wheat. We continue to make great strides with the breeding program at OSU. The OSU WIT prepares for planting by spending numerous hours on research and planning for a harvest that will give them the tools to help make our wheat producers more competitive, and therefore, become *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

Genetic Improvement and Varietal Release of Hard Winter Wheat

Wheat Improvement Team

2011-2012 progress made possible through OWRF/OWC support

- Published variety trial data at www.wheat.okstate.edu within a few days of harvest for each location and generated more than 11,000 page views during the harvest season.
- Provided reliable feedback on candidate line performance in one of the very few wheat variety testing programs in the U.S. that routinely integrates fungicide application with yield estimation.
- Delivered wheat yield and phenology data to more than 8,000 Oklahomans through the *2012 Wheat Seed Book* distributed by the *High Plains Journal* to all Oklahoma subscribers. The Oklahoma Wheat Commission (OWC) was recognized as a funding agency on the cover of this publication.
- Provided 16 timely wheat disease updates to wheat growers, consultants, Extension educators and researchers via an electronic communication.
- Allowed producers to prioritize applications and make well-informed decisions through educational efforts regarding application of wheat foliar fungicides.
- Conducted nearly 3,000 disease evaluations on more than 650 Oklahoma State University (OSU) experimental lines, including reactions of 1,030 lines to the wheat soilborne mosaic virus/wheat spindle streak mosaic virus (WSBMV/WSSMV) complex. For about 350 of these lines, the enzyme-linked immunosorbent laboratory assay was used to test for virus presence to better define the reaction of the lines to both viruses.
- Determined additional reactions of 427 Wheat Improvement Team (WIT) experimental lines to leaf rust, 170 lines to tan spot, 105 lines to septoria leaf blotch, 540 lines to powdery mildew and 495 lines to barley yellow dwarf virus.
- Determined additional reactions of more than 400 experimental lines from outside Oklahoma to wheat leaf rust and to the WSBMV/WSSMV complex through cooperative investigations with USDA-ARS.
- Discovered the resistance gene *Lr34* in 2174 produced only a fraction of correctly spliced transcripts that were moderated by plant age. The majority of *Lr34* transcripts were incorrectly spliced due to multiple intron retention or exon skipping events.
- Discovered the reason for heterogeneous DNA patterns expressed with polymerase chain reaction (PCR) markers for the *Lr34-D* gene in Duster after experimentally excluding the possibility that the novel DNA patterns resulted from contaminated seeds or impurity of genetic background. These findings suggest that Duster may have two copies of *Lr34-D*.
- Discovered from field observations that the wheat foliar disease spot blotch may play a bigger role than previously thought in the leaf spot disease complex in Oklahoma.
- Determined genotypes of 209 OSU 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.
- Produced negative results for Karnal bunt in 34 wheat grain samples from 10 counties, and obtained a phytosanitary certificate allowing Oklahoma wheat to move without restriction into the export market.

- **Documented sub-economic infestations of Hessian flies using adult pheromone sticky traps, in wheat fields throughout the major wheat growing regions of Oklahoma.**
- **Demonstrated that advanced experimental lines and available cultivars that have resistance to natural fly populations yielded well even in the absence of economic Hessian fly infestations.**
- **Conducted foundational studies to test the hypothesis that wheat varieties with high remobilization rates of stem reserves can ensure higher wheat yields under extended periods of drought and high temperature during grain filling.**
- **Characterized phosphorus (P)-use efficiency for the first time in OSU breeding materials and other accessions, and distinguished between efficiencies of P-uptake (ability to extract typically non-labile P) versus P-utilization (ability to produce biomass with minimal P taken up into the plant).**
- **Determined several lines were P-uptake efficient, P-utilization efficient, or both, depending on the soil being acid or calcareous; for both soil types, Ruby Lee displayed the highest combination of P-uptake and P-utilization efficiency.**
- **Determined spring back (elastic) and flow (viscosity) properties of gluten fractions isolated from 45 WIT lines and varieties to obtain a more direct assessment of dough strength versus extensibility. Billings maintained its high standard for both indicators and for overall dough functionality, while the candidate variety OK09634 holds equal promise.**
- **Identified a candidate 2-gene CLEARFIELD variety, OK09915C, worthy of continued foundation seed production and potential release in 2013, pending final data analysis and quality testing.**
- **Placed four additional hard red winter (HRW) candidates under preliminary seed increase or large-scale seed increase by Oklahoma Foundation Seed Stocks, Inc.:**
  OK09634, OK95616 seln/Overley
  OK09125, TAM 303/Overley
  OK09528, TAM 303/Ok102
  OK09729, OK98697/CIMMYT experimental//OK00114
- **Leveraged financial support of Oklahoma Wheat Research Foundation (OWRF)/OWC with funding from either USDA-ARS or Oklahoma Genetics, Inc. to develop experimental materials with resistance to the Ug99 stem rust race and to develop novel doubled haploid lines featuring stacked traits for insect and disease resistance.**
- **OSU-bred varieties Duster and Endurance remained the top two planted wheat varieties in Oklahoma for a second consecutive year.**

Faculty from three Division of Agricultural Sciences and Natural Resources (DASNR) academic units form the dynamic Wheat Improvement Team (WIT). The WIT combines fundamental and applied components of wheat research to propel a common cause — advancing Oklahoma's wheat industry with new, improved varieties and providing the know-how that best captures their genetic potential. Now in its 14th year of uninterrupted service, we take pride in elevating OSU's mission to *create, innovate and educate* to new heights.

Scientists on the WIT are **Jeff Edwards**, information exchange; **Bob Hunger** and **Art Klatt**, wheat pathology research and development of disease-resistant germplasm; **Kris Giles** and **Tom Royer**, Hessian fly diversity and resistance; **Patricia Rayas-Duarte**, cereal chemistry; **Liuling Yan**, gene discovery and genomic applications; and **Brett Carver**, wheat breeding and genetics. Assisting the WIT for the first time in 2011-2012 were two scientists **Chad Penn** and **Gopal Kakani,** who worked in critical needs areas of phosphorus-use efficiency and drought and heat tolerance mechanisms, respectively.

The 2012 crop season was fast and furious, giving us just enough moisture to usher in a new race, or two, of stripe rust. When the WIT now claims a line or variety to be resistant to stripe rust, the implication is that resistance broadly applies to race PST100 (the predominant race before 2010); the *Yr17*-virulent race, which surfaced in 2010 to attack Jagger and many of its derivatives; and the new race(s) appearing in 2012 that defeated the resistance in the cultivars Garrison and Armour. While Garrison lost one of the components of its defense system, several others remain intact, such as protection against the WSBMV/WSSMV complex, barley yellow dwarf virus, septoria leaf blotch, tan spot, powdery mildew and head scab.

Our mission continues unimpeded by the challenges thrown at us in 2012, yet not without some key losses. Candidates no longer in contention, barring a remarkable comeback in 2013, are the experimental lines OK08229, OK05312, OK09811W and OK0986146W. All of these came through the drought of 2011 with yield superiority, but dropped off disappointingly in 2012 to stripe rust.

In this report, read more about the work of the WIT, including instantaneous, reliable feedback on candidate line performance in one of the very few wheat variety testing programs in the U.S. that routinely integrates fungicide application with yield estimation. The report also covers the pursuit of a 2-gene CLEARFIELD variety to supplement or replace the acreage of Centerfield; the next generation of HRW candidates that feature parentage from Overley, TAM 303 and CIMMYT materials; groundbreaking research that opens up new possibilities for amplifying disease resistance without the need for transgenic modifications; and expansion of our research agenda to uncover genetic variation in phosphorus uptake and utilization efficiencies.

Information Exchange

Jeff Edwards
Plant and Soil Sciences

The information exchange component of the WIT focused on timely information delivery and screening of advanced experimental lines in 2012. 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 in each region to quickly access the data. Farmers were notified of new data postings via email and Twitter, and the site was accessed 4,590 times during May, June and July 2012, with 11,145 individual page views, a 30 percent increase over 2011. 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.

Much of the information exchange effort in 2012 was focused on making producers aware of the shift in stripe rust races and the potential benefits of foliar fungicides. Wheat varieties such as Everest, Armour and Garrison with rock-solid resistance to previous stripe rust outbreaks were found to be susceptible to the new race. Varieties such as Billings, Gallagher, Iba and WB Cedar were resistant to the new stripe rust race, but yield potential still justified fungicide application in many situations.

This mixed bag of resistances, responses and available fungicides emphasized the need for educational efforts. Our approach was to emphasize timely application and prioritization of the most susceptible varieties. This was the correct approach based on the results from Lahoma shown in Figure 1. Foliar fungicides nearly doubled the yield of the most stripe rust-susceptible varieties, and they increased the yield of resistant varieties, but to a lesser extent. This work will be continued at Lahoma and Apache in the 2013 season.

In addition to data on released varieties, we provided phenological, morphological and yield performance data on 10 experimental lines. One of the most promising of these lines, OK09915C, was tested against currently released varieties at eight variety trial locations and against other 2-gene CLEARFIELD lines at two locations. It performed well in all tests and showed excellent tolerance to imazamox (the active ingredient in Beyond® herbicide) when tank-mixed with a methylated seed oil (MSO). This is exciting, as the addition of an MSO to Beyond® herbicide should greatly increase activity on problem weeds such as feral rye. Further testing will be conducted in 2012-2013.

Wheat Pathology Research and Development of Disease-Resistant Germplasm

Bob Hunger
Entomology and Plant Pathology

Release of a wheat variety represents improvement of many agronomic traits including disease resistance. Hence, evaluation of breeder lines for reaction to

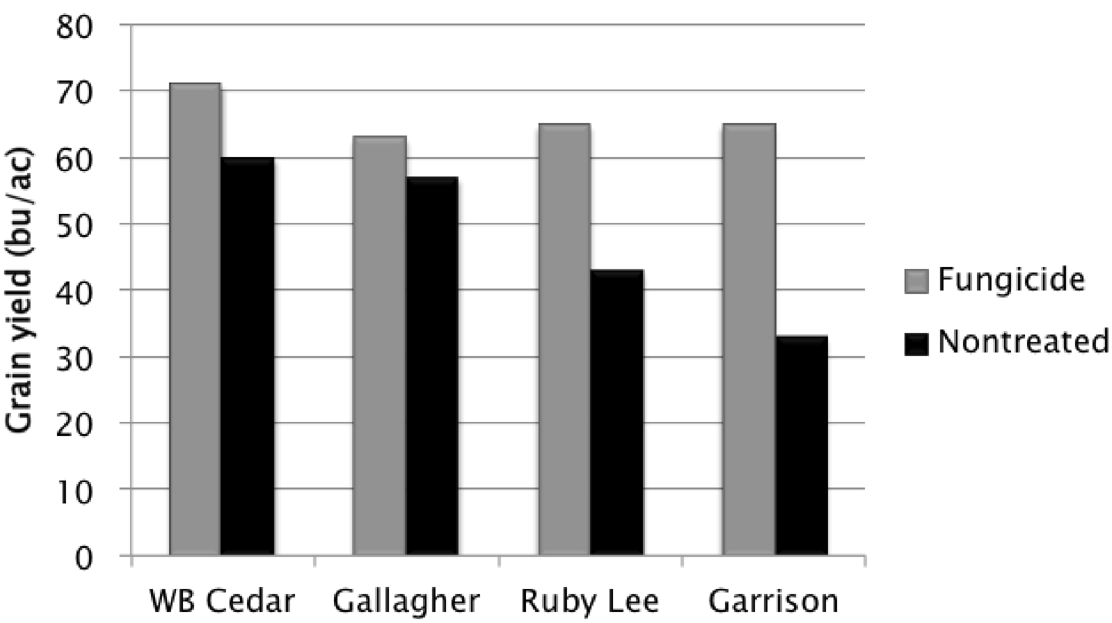


Figure 1. Grain yield of four wheat varieties differing in reaction to stripe rust in the presence or absence of a fungicide, measured at Lahoma, Okla., in the 2011-2012 Oklahoma Small Grains Variety Performance Tests.

diseases is vital in developing improved varieties. Selection for resistance to some diseases is often conducted outside Oklahoma because the natural occurrence of that disease is in another state or even another country. One such example is selection for resistance to stem rust, which is not a disease of great concern in Oklahoma. However, testing for disease reaction to diseases such as the WSBMV/WSSMV complex, leaf rust (LR), powdery mildew (PM), tan spot (TS), septoria leaf blotch (SEP) and barley yellow dwarf virus (BYDV) is critical and can be conducted in the state. Funds from the OWRF supported this testing.

Testing reaction to these diseases is conducted in the greenhouse/growth chamber (GH/GC) or the field, or both. During the past several years, funds from the OWRF have allowed expanded evaluation of reaction to PM, TS, SEP and BYDV both in the field and via extensive seedling assays conducted in the GH/GC. Results from this testing have identified lines either resistant or moderately resistant to PM, TS and BYDV as presented in Table 1. During 2012-2013, this field and GH/GC testing will continue to be refined and will help the WIT identify advanced lines worthy of advancement in the variety development track.

In the spring of 2012, it was observed that the foliar disease spot blotch may contribute more than previously thought to the wheat leaf spotting complex of diseases. Wheat foliage can be affected by many diseases including LR, stripe rust, PM, TS and SEP. Spot blotch, which is caused by the same fungus that causes common root rot, has previously been thought to have a minor impact. When spores of this fungus infect a leaf, a small black spot occurs (Figure 2). When infection is heavy, leaves can be killed. Spot blotch is typically seen every year in Oklahoma, but it is usually confined to lower leaves at a low incidence level. For some unknown reason in the spring of 2012, spot blotch was observed at a higher than typical incidence level, primarily in northern Oklahoma. This will continue to be monitored in 2013.

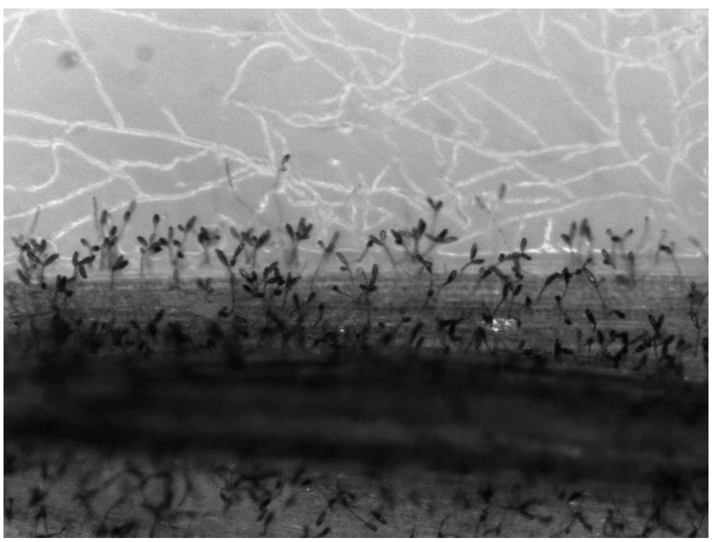
Finally, funds provided by the OWC supported testing the 2012 Oklahoma wheat crop for presence of Karnal bunt. Results were used to certify that Oklahoma wheat was produced in areas not known to be infested with Karnal bunt, which allows Oklahoma wheat to move freely into the export market.

Table 1. Number and percent of advanced experimental lines in the OSU Wheat Improvement Program resistant to powdery mildew (PW), tan spot (TS) and barley yellow dwarf virus (BYDV), as determined by field and/or greenhouse/growth chamber testing in 2012.

Disease tested (Number of lines tested)	*Number of resistant lines*	*Number of susceptible lines*	*Percentage of resistant lines*
PM (540)	198	342	37
TS (170)	67	103	39
BYDV (495)	235	260	47

(A) Black spots typical of spot blotch on wheat. Photo credit: A. Tekauz at http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm2394

(C) Wheat plants affected by common root rot. Note healthy, white-colored sub-crown internode (SCI) on the plant to the left compared to dark SCIs on the middle plant and the plant on the right.



(B) Spores of the fungus that causes spot blotch and common root rot of wheat.

Figure 2. Pictures of (A) spot blotch on wheat leaves, (B) spores of the fungus that causes spot blotch and common root rot coming out of a wheat leaf and (C) common root rot on wheat.

Hessian Fly Diversity and Resistance

Kris Giles and Tom Royer
Entomology and Plant Pathology

During the 2012 growing season, we continued to monitor Hessian fly populations in Oklahoma and determined the level of field tolerance resident to the OSU wheat improvement program. Our overall objective was to complement greenhouse seedling assays for Hessian fly reaction, so that the most complete sources of Hessian fly resistance would be perpetuated in the form of breeding stocks or candidate varieties. We relied on pheromone sticky traps from the previous field season to identify locations (Blackwell and Marland) where flies were active, and then deployed replicated Oklahoma Elite Trial (OET) experiments for the 2012 season. In addition, traps were set throughout the state at research sites during the 2012 season to verify fly activity.

We succeeded in collecting Hessian fly adults in pheromone traps from the major wheat growing areas of Oklahoma. Flies were captured throughout most of the state, but counts were highest at the two OET sites. At those sites, relatively high numbers of adult flies were captured during both fall 2011 and spring 2012 (Figure 3). During peak flight, shortly after a rainfall event, trap catches averaged more than 500 and 1,300 (sum of two traps) in Blackwell and Marland, respectively. However, counts in pheromone traps were no indication of infestation levels in

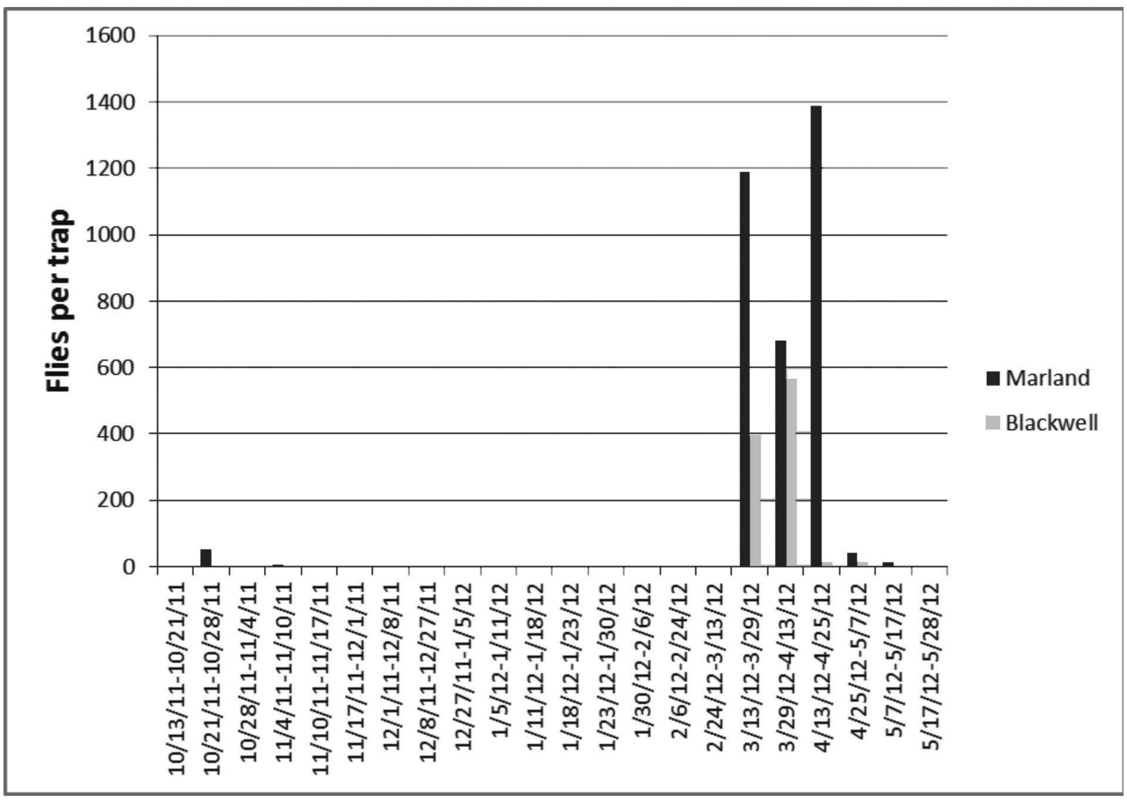


Figure 3. Mean number of adult Hessian flies caught in pheromone traps (two traps per location) at Blackwell and Marland during the 2012 growing season.

the OET experiments. Flies either avoided the plot area, or more likely, the pheromone traps were effective at "trapping out" active adults in the area. The sub-economic fly infestations in our plot area continued a trend of lowering intensities (number of flies per tiller) throughout the region over the past six years, which has been observed since a shift to planting resistant cultivars, especially Duster. Biotyping data from Kansas continued to indicate the Hessian fly biotype GP is the most common in Oklahoma.

At both locations, the plot area was established in moist soil, which contributed to relatively high yields of the OET (Table 2). A total of 9,250 tillers were dissected to document larval and pupal intensities. The natural fly infestations were lower than any year we have evaluated the OET (Table 2). The highest fly intensity observed (Marland) was only 1/20 of the economic injury level of one fly per tiller. Because of low fly pressure, it was not possible to separate out the impact of resistance and fly infestations on yields. However, this past field season Ruby Lee, which harbors some Hessian fly resistance, yielded near the top, even when fly populations were low and the wheat was moisture stressed.

Wheat producers have high yielding resistance options for Hessian flies. Regional fly populations appear to have been driven down, in part because of strategic deployment of resistant varieties, and we recommend a continued proactive approach to managing Hessian fly through rotation of locally adapted varieties that periodically provide protection against fly buildup.

Gene Discovery and Genomic Applications

Liuling Yan
Plant and Soil Sciences

Wheat grown in Oklahoma is bread wheat, which is an allohexaploid species with three genomes that arose through hybridization of three related diploid wheat species. A key leaf rust resistance gene, *Lr34-D*, resides on chromosome 7D. As expected for an allohexaploid species, two homoeologous genes can also be found: *Lr34-A* on chromosome 7A and *Lr34-B* on chromosome 4A in a region that was translocated from chromosome 7B. In previous studies supported by OWRF/OWC, only a single copy of *Lr34* was detected in each of the three homoeologous genomes of hexaploid wheat or in the D genome of the diploid wheat ancestor *T. tauschii* or in other diploid grass species such as *Oryza sativa* (rice) and *Sorghum bicolor* (sorghum). The three homoeologous genes of *Lr34* have been mapped in wheat using a population of inbred lines derived from the Jagger x 2174 cross (Figure 4).

The availability of the three homoeologous *Lr34* genes has facilitated developing polymerase chain reaction (PCR) markers to investigate genetic effects of these genes in a population of doubled haploid lines generated from a Duster x Billings cross, two OSU winter wheat varieties. In this past year, however, we discovered the co-existence of two copies of *Lr34* in Duster. When we used PCR markers, based on variation in two coding regions of the gene, to genotype OSU germplasm, Duster

Table 2. Hessian fly infestations and grain yield in decreasing yield order for the 2011-2012 Oklahoma Elite Trial.

Blackwell Plots				Marland Plots		
Entry	bu/ac	HF/tiller		Entry	bu/ac	HF/tiller
Ruby Lee	60.4	0		OCW02S029T-1	87.1	0
Billings	58.2	0		Ruby Lee	81.2	0
Endurance	47.5	0		Chisholm	65.9	0
Garrison	47.2	0		OK08214	65.2	0.003
OK09621	46.9	0		OK07209	64.5	0
OK08229	46.1	0		OK09915C	64.5	0
OK09634	45.3	0		OK09811W	61.6	0
OK09125	44.6	0		OK0986146W	59.0	0
OK08413	44.2	0		Greer	58.8	0.044
OK1059060	43.8	0		OCW02S158T-2	56.9	0.010
OK098055C	43.7	0		OK09634	56.6	0
OK0986146W	43.7	0		Everest	55.8	0
Chisholm	43.5	0		OK08707W	55.5	0
OK08328	42.8	0		OK08328	55.2	0.011
Duster	42.2	0		OCW00S063S-1B	54.0	0.028
OK09811W	41.9	0		Billings	53.9	0.010
Armour	41.7	0		Endurance	53.9	0
OK1059014	41.5	0		Duster	52.1	0.010
OK1080105	40.8	0		OK09621	52.0	0
Everest	40.4	0		OK09528	47.8	0
OK09729	40.4	0		Armour	47.5	0
OK1059018	39.9	0.004		OK09729	47.4	0.014
OK07218	38.4	0		OK098055C	46.7	0
OCW02S029T-1	37.2	0		OK1059018	46.3	0.005
Greer	36.8	0		OK07218	46.1	0
OK09915C	35.9	0		OK1080105	46.0	0
OK09935C	35.6	0		OK07214	46.0	0
OK09528	34.4	0		OK09935C	45.0	0
OCW00S063S-1B	34.3	0		OK08413	44.7	0
OK08707W	33.3	0		OK08127	43.5	0.017
OCW02S158T-2	33.1	0		OK08229	40.7	0
OK07209	31.2	0		OK09125	37.2	0
OK08214	30.8	0		OK1059014	35.7	0.024
OK07214	29.2	0		Garrison	31.5	0
OK08127	23.4	0		OK1059060	31.3	0.011

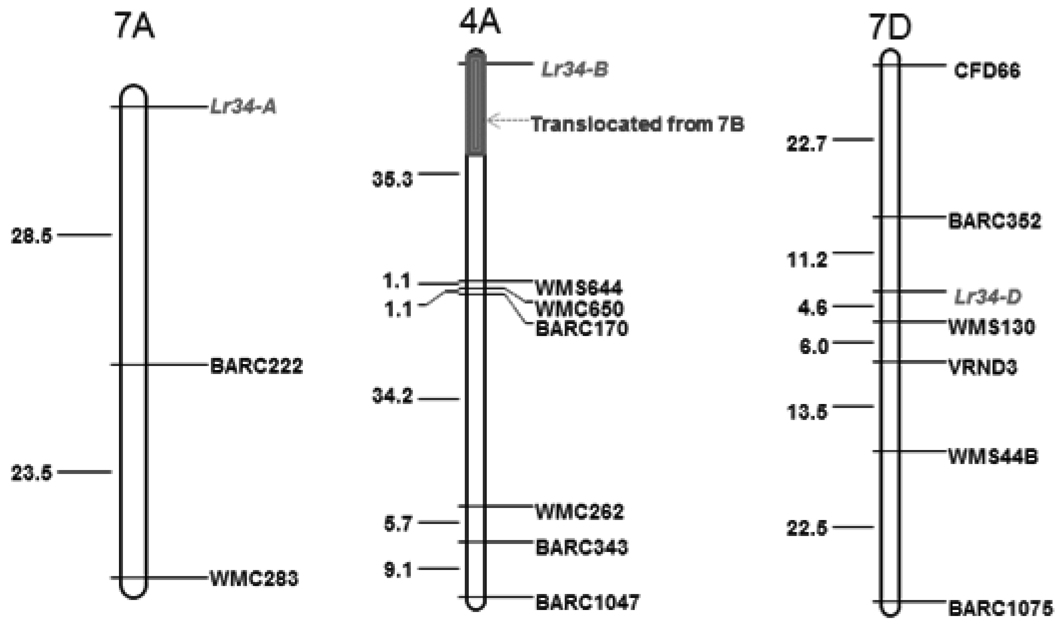


Figure 4. Chromosomal locations of *Lr34-A*, *Lr34-B* and *Lr34-D*. Numbers on the left represent genetic distance between two neighboring markers. The highlighted fragment in chromosome 4A was translocated from chromosome 7B.

showed heterogeneous DNA patterns (Figure 5). The two bands from *Lr34* showed similar intensity, suggesting that this cultivar may have two copies of *Lr34* (*Lr34-D* and *Lr34-X*). We have confirmed both *Lr34-D* and *Lr34-X* were not from *Lr34-A* or *Lr34-B* by sequencing the appropriate PCR products. We also have experimentally excluded the possibility the heterogeneous DNA patterns resulted from contaminated seeds or an impurity in the genetic background.

Commercial acceptance of Duster is partly due to its consistent adult-plant resistance to leaf rust, stripe rust and powdery mildew. It has shown leaf rust resistance with ratings of 0 to 1 on a scale of 0 (no visible symptoms) to 4 (severe symptoms) from 2005 to 2010. Our research raises an exciting and novel hypothesis: Is the durable

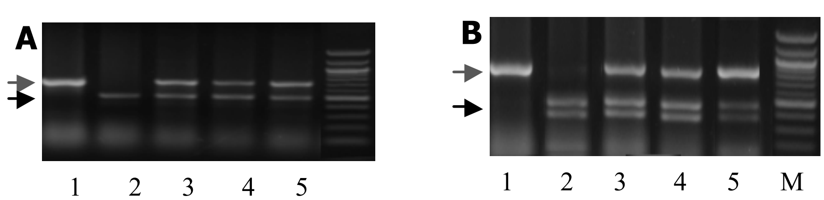


Figure 5. Discovered two copies of *Lr34* in Duster. (A) Duster in lanes 3 to 5 shows heterogeneous band patterns for Lr34E11. Lane 1, 2174, and lane 2, Billings, represent the resistant allele and the susceptible allele, respectively. (B) Duster in lanes 3 to 5 shows heterogeneous band patterns for Lr34E12. Lane 1, 2174, and lane 2, Billings, represent the resistant allele and the susceptible allele, respectively.

resistance of Duster to multiple foliar diseases attributable, at least in part, to the two copies of *Lr34-D*? So far, deployment of the *Lr34-D* gene is still based on the conventional breeding approach, by which a resistant allele from a donor is introduced to a recipient cultivar carrying a susceptible allele; therefore, only a single copy of the resistant *Lr34-D* allele can be expected in the progeny. Our finding has offered a unique opportunity that two copies of the resistance *Lr34* gene can be pyramided into a single variety. We will introduce, via a conventional crossing method, a functional and resistant *Lr34-X* gene from one donor such as Duster to a recipient such as 2174 that already carries the resistant *Lr34-D* gene, and vice versa; hence, a novel wheat variety may possess both *Lr34-X* and *Lr34-D* to increase plant resistance to multiple foliar disease pathogens.

Another exciting result from this year is that we found the majority of *Lr34* transcripts to be incorrectly spliced (nonfunctional). We set out to test if disease resistance may be increased to near-immunity levels by overexpressing *Lr34* in a variety that already possessed a resistant allele. We attempted to amplify the complete *Lr34-D* cDNA from 2174. There we found that the majority of the endogenous *Lr34* transcripts from leaves were spliced incorrectly due to intron retention (a complete or partial intron was not spliced out) or exon skipping (a complete or partial exon was incorrectly spliced out). We are testing transgenic wheat plants that have the over-expressed *Lr34-D* for increased resistance to leaf rust and stripe rust. We intend to increase the level of *Lr34-D* resistance by eliminating or mutating regulators that cause missplicing events in wheat.

Cereal Chemistry

Patricia Rayas-Duarte
Biochemistry and Molecular Biology

The performance of wheat flour directly depends on gluten quality. A large portion of the variation in baking and machine performance depends on the types of gluten proteins present and the polymer formed by their interaction. Another important parameter is the quantity of protein in the flour. Hence a combination of quality and quantity of gluten proteins provides a reasonable description of the variability of flour performance in baking applications.

We have chosen to measure two attributes of gluten – strength and extensibility – for their importance in predicting processing characteristics. Strength is described by the elastic behavior, or elastic recovery, of gluten and is related to the response of the gluten structure when subjected to a force or load. If a load is imposed to deform the gluten, there will be a response to resist the deformation proportional to the mechanical or physical properties of the three-dimensional structure formed. The structure will determine how easily the gluten is deformed and, more importantly, how easily it returns to its original shape. Both strength and extensibility also are directly proportional to the energy in the gluten structure. This energy can be lost or recovered in the form of heat. Some of the gluten proteins respond like a spring by returning the gluten complex to its original shape quite rapidly. The closer gluten reforms to its original shape, the stronger its structure, i.e., more energy is recovered. In viscoelastic materials like gluten, one part of the energy is lost, meaning the gluten is deformed and will delay its reformation (delay of elasticity) and be deformed for a period of time or permanently. This implies that the gluten is extensible. The more it flows and/or deforms permanently (by loss of energy) the more extensible the gluten. All of these changes are due to the interactions of gluten proteins. The WIT attempts to develop varieties with the optimal blend of strength and extensibility, but better methods are needed to precisely and independently measure these attributes.

We have developed original methods using compression loads to analyze the quality of the gluten in advanced experimental lines and popular varieties. Spring back (strength) and flow or viscosity (extensibility) are two parameters that complement the more traditional quality characteristics used by the WIT and give a more complete picture of the overall quality and quantity profile of flour protein.

With these new methods, we are able to measure indirectly the chemical bonds or interactions of gluten proteins at work. We can analyze the three-dimensional gluten structure to obtain information on the types of gluten that are attracted to or repelled by each other, thus affecting the gluten structure energy and thus its behavior in a dough sponge. This information may be used to distinguish OSU experimental lines and varieties in strength and extensibility. We also compare the relationship between protein quantity and quality.

Described in Figure 6 is the two-dimensional relationship of gluten spring back as recoverability (RCY), gluten flow as viscosity (J-Jr) and flour protein content for 45 samples from three OET in 2011. RCY and J-Jr, the two quality attributes, accounted for almost 70 percent of the variance in this set of samples. Gluten quantity, represented by flour protein content in the vertical axis, accounted for an additional 24 percent of the variance. All three attributes provided a near-complete account of the variance present in this sample set.

Figure 6 enables the identification of lines that possess a more viscous or extensible character versus those with a more spring back or strength character, both in the horizontal dimension. On the other hand, the vertical dimension enables separation of lines on the basis of protein quantity. The samples with data points residing closest to the FP arrow are associated with higher protein quantity. Experimental lines highly associated with gluten deformation were OK08229, OCW02S029T-1, OK09528 and OCW02S158T-2. Gluten fractions of these lines were more easily deformable. The top five lines or varieties highly associated with gluten spring back were OK09520, OK09208, Greer, OK09634 and Billings. These would be expected to contain high molecular-weight glutenin subunits that lend a dough sponge high spring back capability important in the baking process.

We have made significant improvements to the way we measure gluten quality. This will assist us in determining the combination of strength and extensibility that withholds the gas produced during fermentation and expansion during baking. If the combination is not correct, the cell walls of the dough break very easily and the bread will exhibit a number of defects, including low volume. We continue to ask questions on how to extract more information from the complex

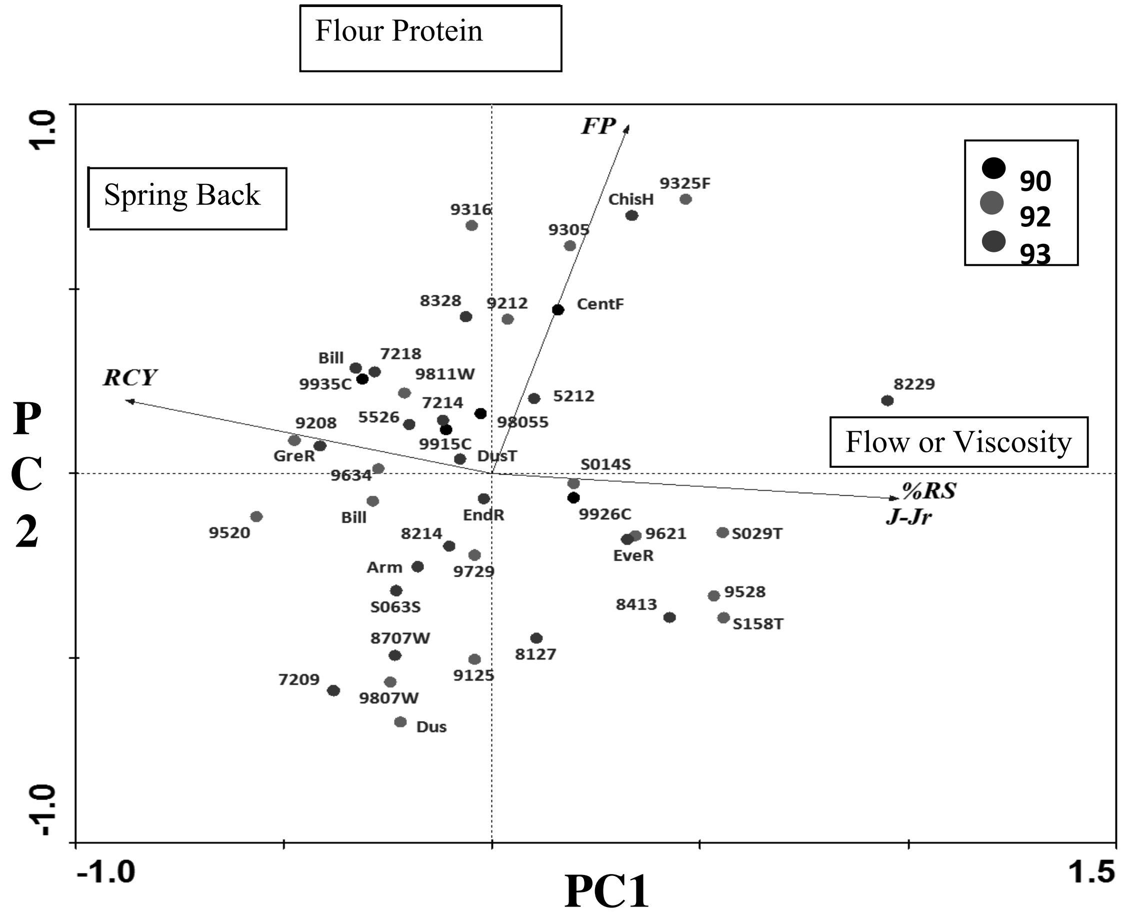


Figure 6. Principle component analysis of three OET nurseries conducted in 2011 involving three indicators of gluten quality: spring back or percent recovery (RCY), deformation or viscosity (J-Jr) and percent recoverable strain (%RS), plus one indicator of gluten quantity, flour protein (FP).

system that forms gluten proteins, so that varieties can be developed with desirable quality for the intended marketplace.

Drought and Heat Tolerance Mechanisms

Gopal Kakani
Plant and Soil Sciences

A pilot experiment was conducted to ascertain key whole-plant morpho-physiological traits in lines that have historically exhibited drought and heat tolerance during grain filling. Our underlying hypotheses were that drought and heat stresses may enhance senescence and thereby enhance carbohydrate and nitrogen remobilization to the developing grain, and that lines with different tolerance levels may differentially alter biomass partitioning to enhance survival and yield under stressful conditions.

Four varieties were chosen with putative differential tolerance to drought and heat. TAM 112 and OK08707W (a hard white advanced line adapted to dryland conditions in the Oklahoma panhandle) were chosen for high tolerance, Duster represented intermediate tolerance and

2174 served as the susceptible control. Vernalized plants were grown in growth chambers until each variety reached 50 percent anthesis under a day/night temperature and photoperiod regime of 23/15°C and 14/10 hours, respectively. Four temperature treatments were then imposed with the same photoperiod, using the value shown inside the parentheses as the treatment code, which is the midpoint value for the day/night temperature regime, for reporting the results: 23/15°C (19), 26/18°C (22), 29/21°C (25) and 32/24°C (28). For each of the temperature treatments, a pair of irrigation treatments was further imposed to represent well-watered conditions or water-stressed conditions, which was 20 percent of the amount of water applied in the well-watered treatment.

Tillers were sampled at 50 percent anthesis and each tiller was separated into phytomers. Each phytomer included the internode, node, leaf sheath and leaf lamina. Similarly, at physiological maturity a tiller with a fertile spike was harvested and processed. Phytomers and spikes were weighed separately. The difference in phytomer dry weight collected at anthesis and at physiological maturity was used to calculate carbohydrate remobilization. Similarly, the difference between spike dry weight at anthesis and physiological maturity was used to measure the increase in spike weight.

The growth chamber environment was effective in revealing varietal differences in response to temperature and irrigation treatments. Both temperature and irrigation treatments influenced growth, total biomass and grain yield at physiological maturity. Though considered in the field to be drought susceptible, 2174 produced taller plants under well-watered and water-stressed conditions across all temperature treatments (Figure 7). Tiller number and, in turn, spike number per plant were reduced at temperatures of 25°C and 28°C (Figure 7). The increase in temperature significantly reduced all yield components of all varieties (Figure 8). The advanced experimental line, OK08707W, generally produced higher total kernel weights on a per-plant basis across all temperature treatments under well-watered conditions, but surprisingly, 2174 was the superior genotype for total kernel weight under water-stressed conditions.

Analysis of the yield components revealed that OK08707W had higher spike weight, kernel number and kernel weight (Figures 9, 10, 11) at 19°C on par with TAM 112 and 2174, but greater than Duster. However, the sensitivity of yield components to temperature and water stress interaction was genotype dependent. As temperature increased under well-watered conditions, spike and kernel weight decreased at temperatures greater than 19°C for all genotypes, while it was at greater than 25°C for Duster. In contrast, under water-stressed conditions, a decline in spike and kernel weight occurred at temperatures greater than 25°C for OK08707W compared to a decline at greater than 22°C for Duster and 2174 and at greater than 19°C for TAM 112.

Phytomer analysis of the genotypes revealed that more carbohydrates (based on dry weights) were remobilized from the stem to the spike and kernels under water-stressed conditions than under well-watered conditions (Figures 12 and 13). Only 11 percent was remobilized from the stem for kernel filling under well-watered conditions (Figure 13A). In contrast, about 49 percent of stem

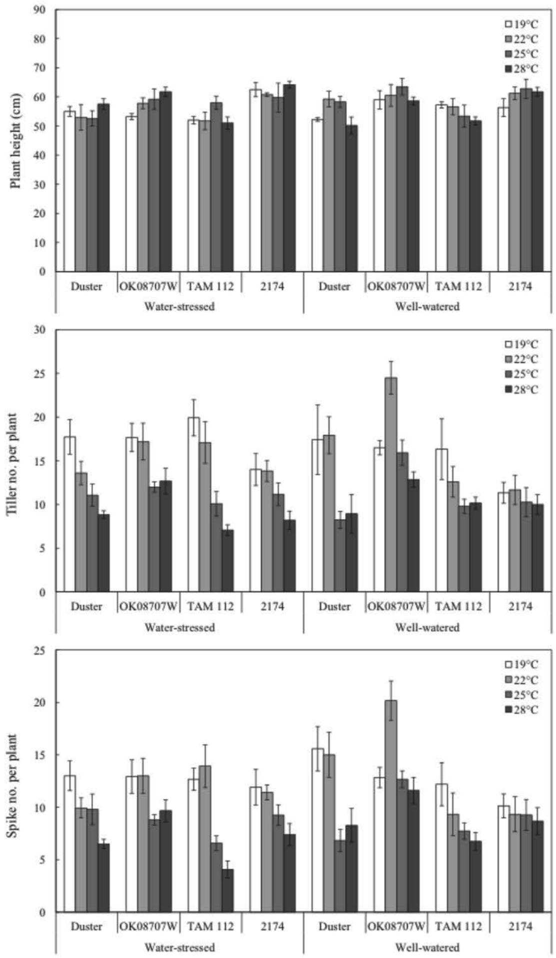


Figure 7. Effect of temperature and irrigation treatments on plant height, tiller number and spike number per plant of four wheat varieties. Plants were harvested at physiological maturity, 45 days after anthesis.

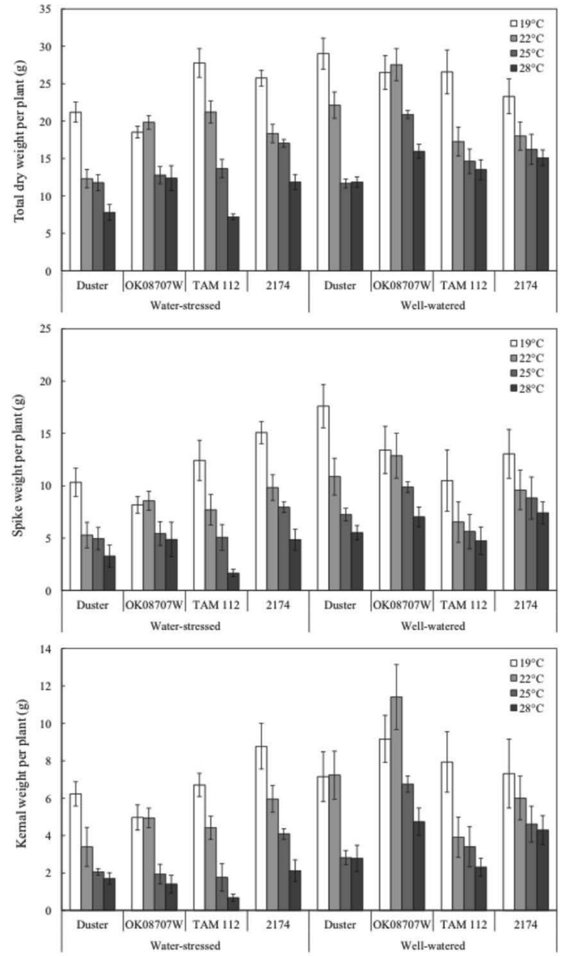


Figure 8. Effects of temperature and irrigation treatments on total, spike and kernel dry weight per plant of four wheat varieties. Plants were harvested at physiological maturity, 45 days after anthesis.

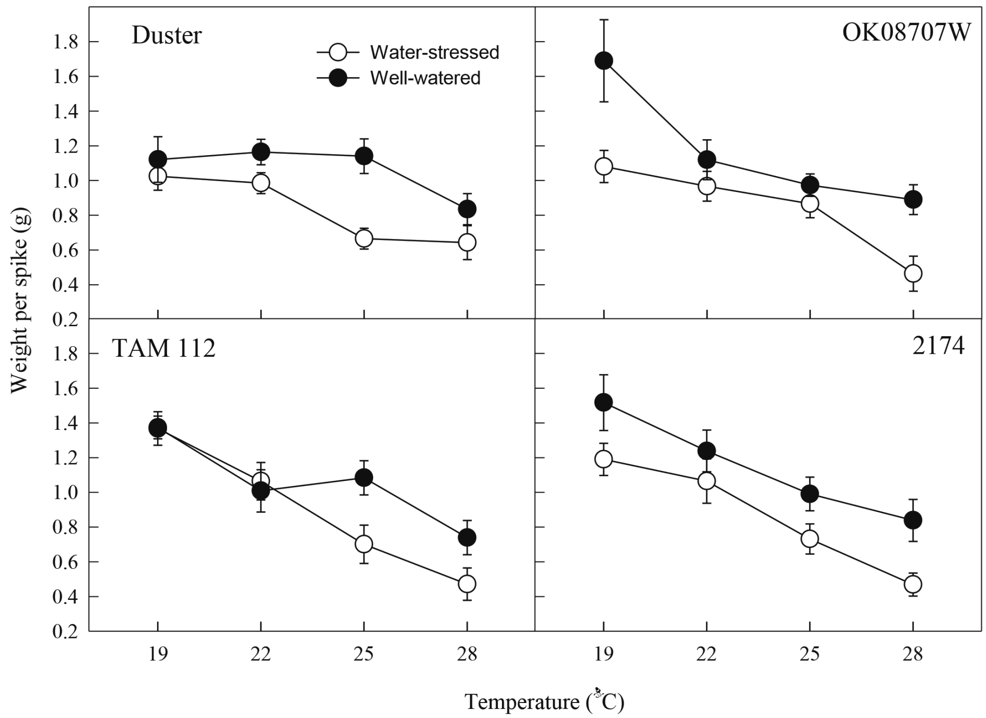


Figure 9. Varietal differences in spike weight in response to temperature and irrigation treatments. Tillers were harvested at physiological maturity, 45 days after anthesis.

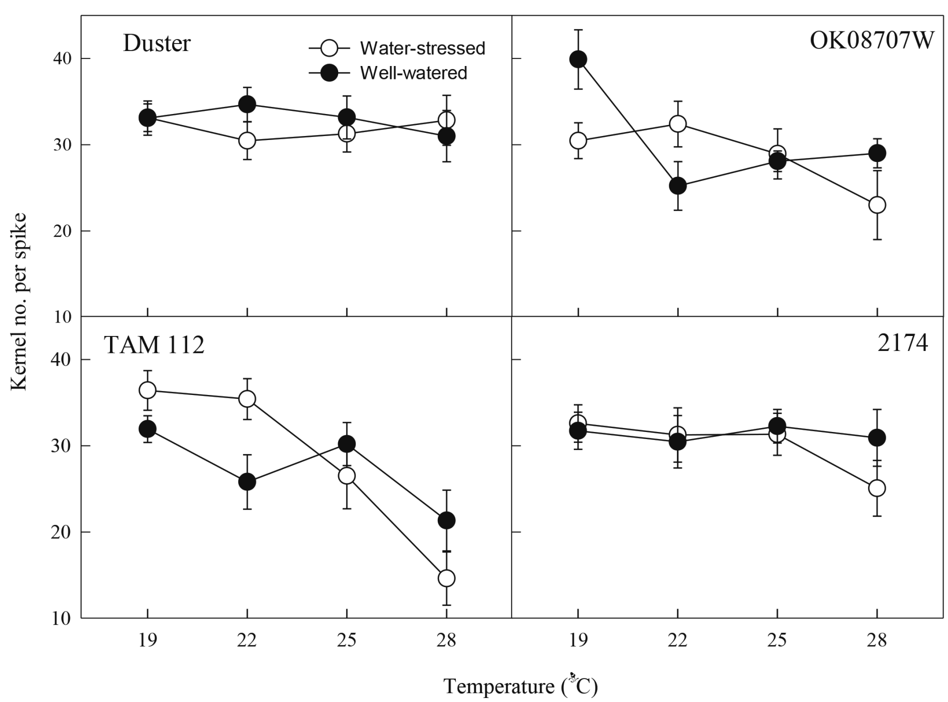


Figure 10. Varietal differences in kernel number per spike in response to temperature and irrigation treatments. Tillers were harvested at physiological maturity, 45 days after anthesis.

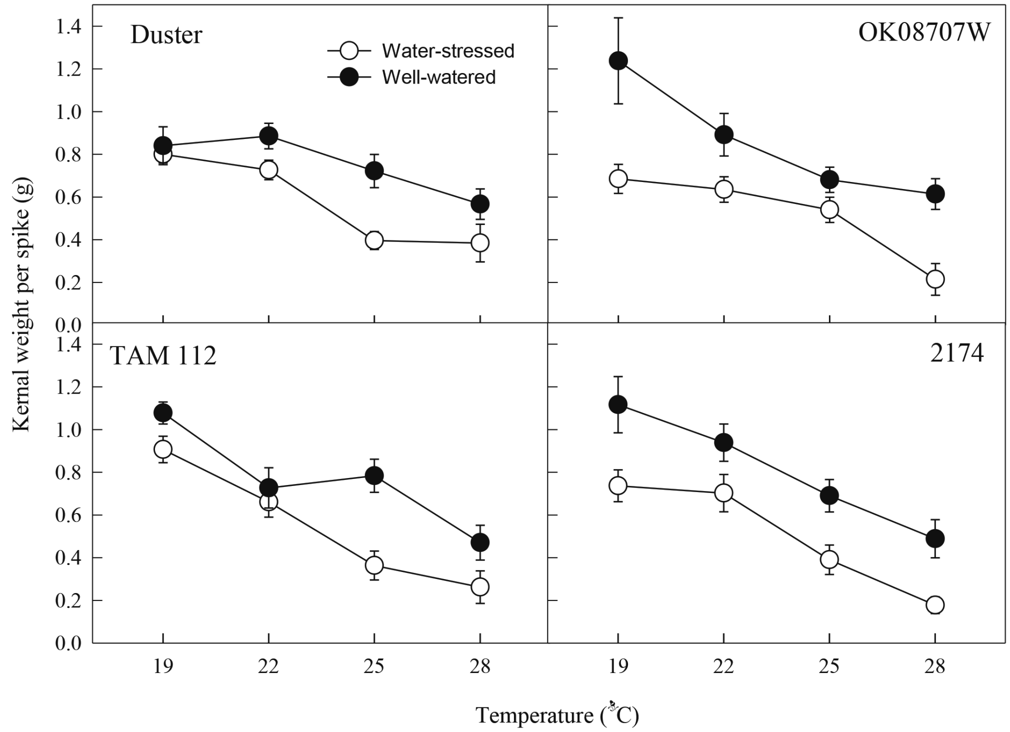


Figure 11. Varietal differences in kernel weight per spike in response to temperature and irrigation treatments. Tillers were harvested at physiological maturity, 45 days after anthesis.

dry weight was remobilized for kernel filling under water-stressed conditions (Figure 13B). Averaged across both irrigation treatments, remobilization percentage was greatest for OK08707W and lowest for TAM 112: [OK08707W (37 percent); Duster (33 percent); 2174 (29 percent); TAM 112 (25 percent)].

Based on this preliminary study, we can conclude that remobilization of stem reserves plays a major role in kernel filling under water-stressed conditions. This remobilization is further modified by high-temperature conditions. Further morpho-physiological evaluation of wheat germplasm and elucidation of genetic mechanisms will help in the development of stress-tolerant varieties to provide the best fit for Oklahoma grain-filling conditions.

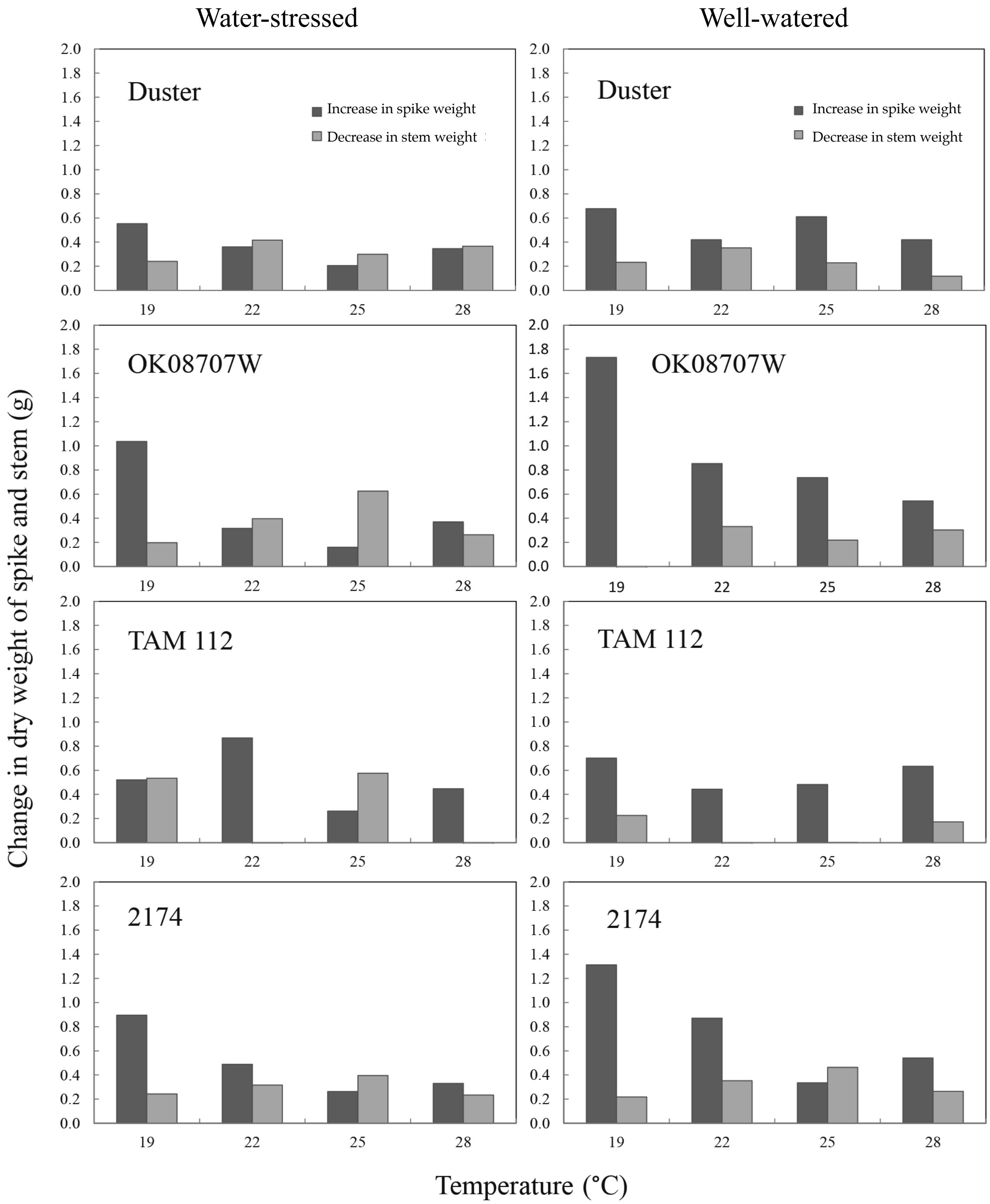


Figure 12. Increase in spike weight and decrease in stem weight among four wheat varieties differing in field drought tolerance in response to temperature and irrigation treatments. Each differential represents the difference between stem or spike dry weights at anthesis versus at physiological maturity, 45 days after anthesis. Temperature and irrigation treatments were initiated at anthesis and continued until physiological maturity.

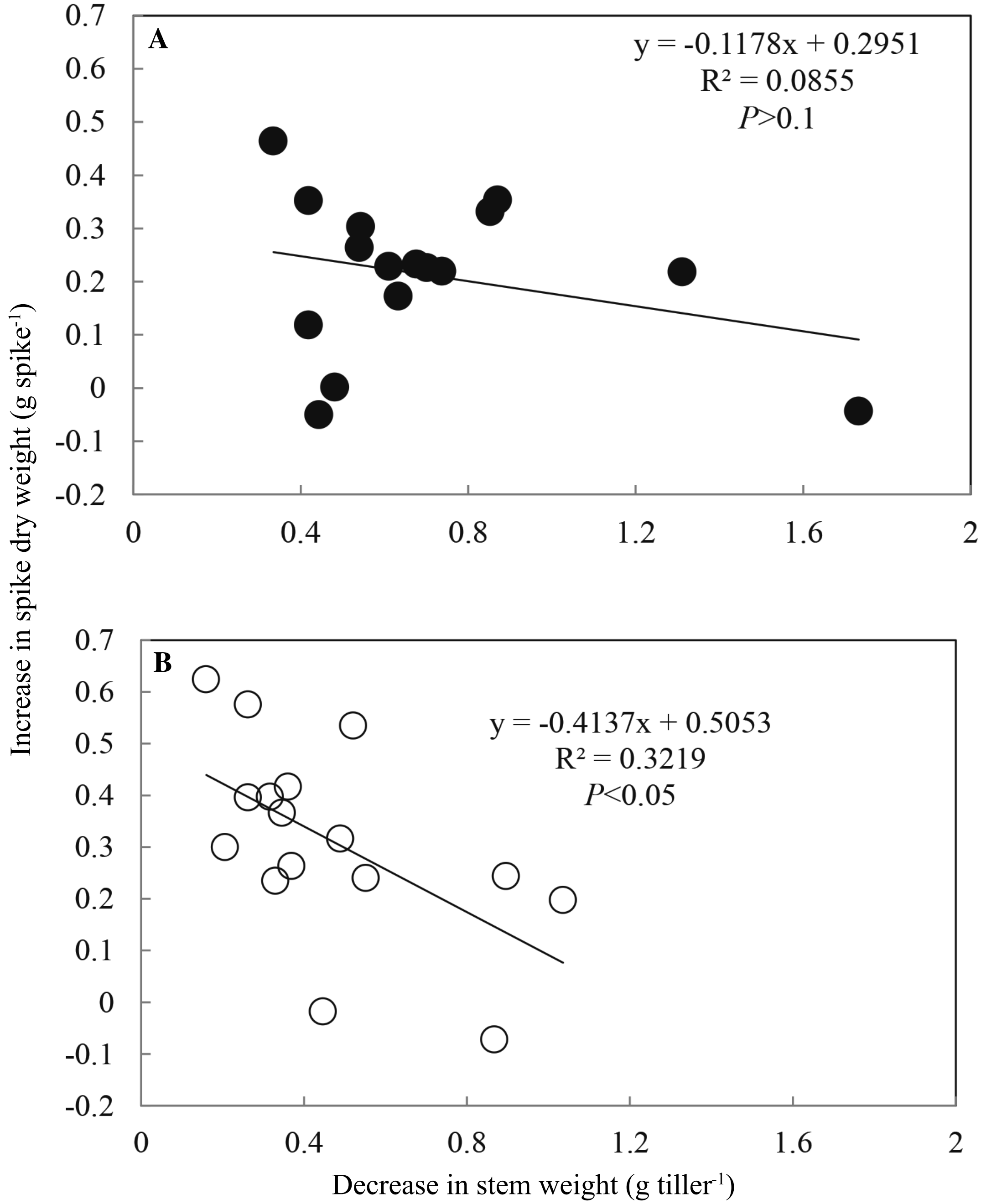


Figure 13. Shows the relationship between the increase in spike weight and decrease in stem weight for four wheat varieties in response to temperature under (A) well-watered conditions and (B) water-stressed conditions. Weight differentials represent the difference between stem or spike dry weights at anthesis versus at physiological maturity, 45 days after anthesis. Temperature and irrigation treatments were initiated at anthesis and continued until physiological maturity.

Phosphorus Use Efficiency

Chad Penn
Plant and Soil Sciences

Demand for phosphorus (P) is steadily rising for crop production, but P reserves are decreasing in both quantity and quality. These reserves are predicted to reach near exhaustion within the next 45 to 60 years. In addition, global demand for cereal crops is estimated to increase 31 percent by 2030. To meet this demand it is imperative resource efficiency, especially P efficiency, of all major crops be increased. Failing to do so could lead to the exploitation of marginal land and the resulting negative environmental and social consequences.

Greater P-use efficiency of wheat can be accomplished either by increasing the P-utilization efficiency or the P-uptake efficiency. P-utilization efficiency is characterized by a plant's ability to achieve high biomass with low amounts of P in plant tissue. In order to achieve P-utilization efficiency, plants respond via various metabolic, morphological and physiological mechanisms, such as using alternative metabolic pathways and increased root-to-shoot ratio. On the other hand, P-uptake efficiency involves the ability to achieve high yields in low available-P environments by extracting typically non-labile P.

The first step in developing wheat varieties with improved P-use efficiency is to identify available sources of P-use efficiency and to distinguish between P-uptake and P-utilization efficiency. We evaluated 22 accessions (Table 3) for P-use efficiency and distinguished between mechanisms by growing wheat in two different sized pots using a low-P acid (pH 4.8) and calcareous (pH 7.9) soil.

Figure 14 divides the cultivars into four response categories for acid (Figure 14A) and calcareous (Figure 14B) soils. Quadrant II would contain the predominately P-uptake efficient accessions, whereas quadrant III contains the predominately P-utilization efficient accessions. The P-use inefficient accessions reside in quadrant IV, and quadrant I contains both P-uptake and P-utilization efficient accessions. Essentially, accessions further left on the horizontal axis are more P-utilization efficient, and those higher on the vertical axis are more P-uptake efficient.

Under acid conditions, accession 2 (P03207A1-7) displayed the highest P-uptake efficiency, with the least interference from P-utilization efficiency. In opposite fashion, accession 7 (SD06165) displayed the highest P-utilization efficiency with the least P-uptake efficiency. Interestingly, both of these accessions were chosen because they have exhibited exceptional acid-soil tolerance near Enid, Okla., without the benefit of a clear or known mechanism for aluminum tolerance (i.e., they lack a critical allele at a locus that confers aluminum tolerance, also known as *ALMT1* for Aluminum-activated malate transporter enzyme). Accession 16 (Ruby Lee) was both P-uptake and P-utilization efficient in the acid soil. Ruby Lee also shows minimal aluminum tolerance, but its field performance in acidic soils has been slightly better than other aluminum-sensitive varieties.

For calcareous soils, no accessions clearly displayed P-use efficiency dominated by P-uptake efficiency only (quadrant II), but P03207A1-7 and accession 6 (SD06069) exhibited the

Table 3. Wheat varieties and experimental lines tested for P-use efficiency and plotted in Figure 14.

Code	*Accession*
1	TN801
2	P03207A1-7
3	W98008J1
4	MO4*5109
5	Jerry
6	SD06069
7	SD06165
8	TX05V5614
9	OK91G103
10	OK91G107
11	OK91G105
12	OK91G108
13	Duster
14	OK07209
15	Endurance
16	Ruby Lee
17	Karl 92
18	Jagger
19	Fuller
20	Garrison
21	OCW00S063S-1B
22	OK08328

highest P-uptake efficiency. Similarly, there was no accession that clearly displayed P-utilization efficiency alone (quadrant III), but accession 19 (Fuller) exhibited the highest P utilization efficiency. Fuller, an offspring of Jagger, is another aluminum-susceptible variety that can, under favorable moisture conditions, recover better than other susceptible varieties in acidic soils. Ruby Lee and accession 18 (Jagger) exhibited the highest combination of P-uptake and P-utilization efficiency. The consistent P-use efficiency pattern of Ruby Lee in acid or calcareous soils warrants further investigation as a potential genetic source. One of Ruby Lee's parents, Endurance, can be identified in Figure 14 as accession 15.

Wheat Breeding and Variety Development

Brett Carver
Plant and Soil Sciences

The mostly disease-free recess this breeding program enjoyed in 2011 was followed up in 2012 with renewed vengeance from multiple pathogens. Common across breeding nurseries from Lahoma to Granite to Goodwell was the natural presence of one or more of these diseases: barley yellow dwarf virus, powdery mildew, stripe rust, septoria leaf blotch, physiological leaf spot, and leaf rust. Hence, disease reaction once again dominated 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. As a critical supplement, field and laboratory reactions to viruses, which are summarized in Bob Hunger's report, were collected in the usual and intensive fashion, but severity of WSBMV and WSSMV reactions remained below typical levels in 2012. Underlying this broad exposure to diseases was the ability of certain experimental lines to flower early and mature rapidly. Those lines were likely the ones to be retained for further evaluation in subsequent years, leaving what we call a genetic footprint on the breeding program.

Genetic footprints of 2012

Environmental conditions to which the OSU wheat breeding program was exposed in 2012 will leave a lasting

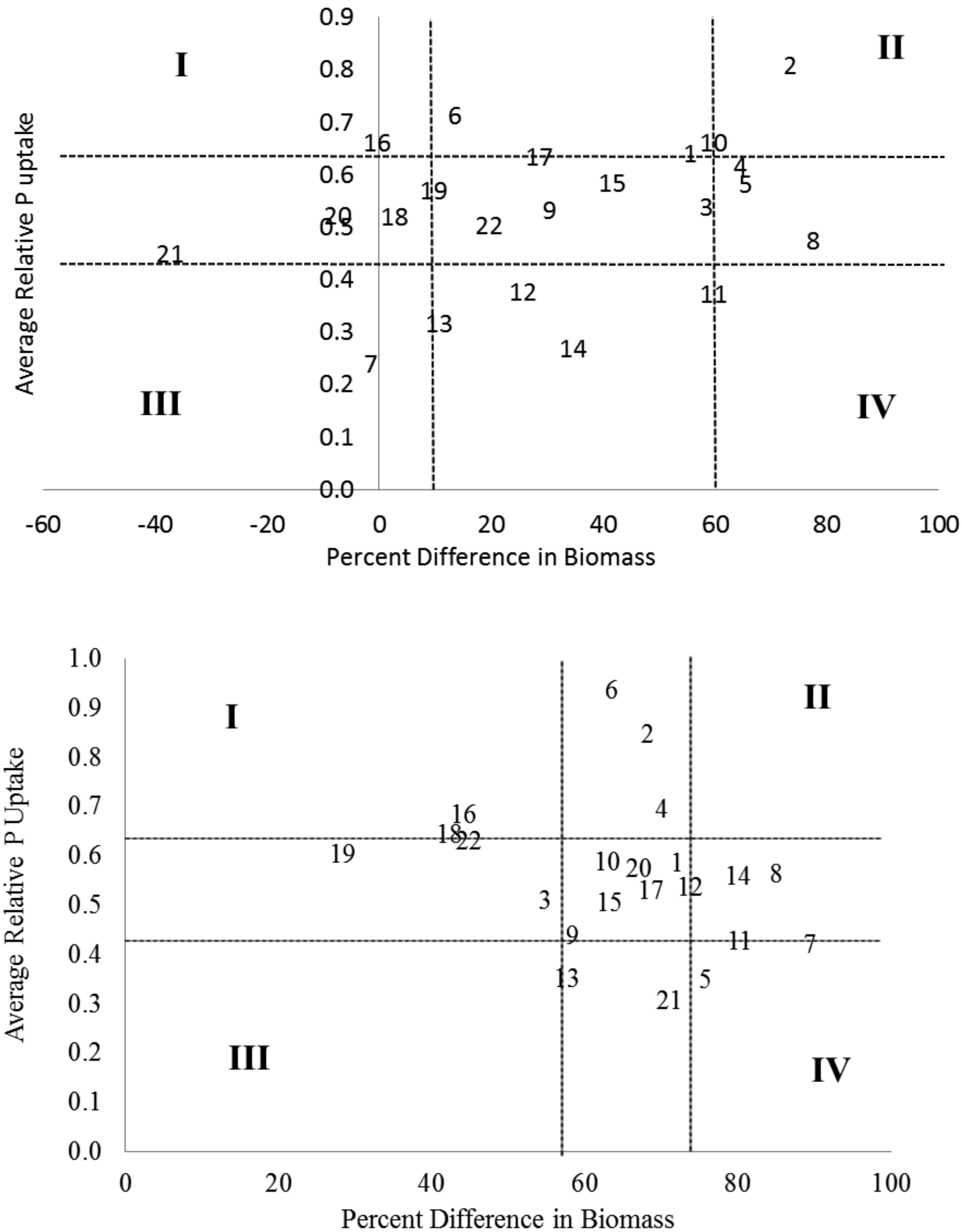


Figure 14. Phosphorus (P) use efficiency in low-P acid (A) and calcareous (B) soil. Numbers on the plot indicate accessions listed in Table 3.

impact on three key trait complexes: disease resistance, grain-filling capacity and maturity. As previously mentioned in the introduction of our report, selected progenies moving forward will carry a greater complement of resistance genes (either race specific or nonspecific) to withstand stripe rust. However, disease resistance will not end there, because multiple pathogens were present that produced severe leaf blight and premature senescence, including those causing powdery mildew (usually in the lower- to mid-canopy), septoria leaf blotch, and to a lesser extent, leaf rust and spot blotch. Furthermore, a nonpathogenic condition called physiological leaf spot was present at an unusual level in 2012, such that selection pressure could be effectively applied, and was applied, to eliminate progenies with a high level of sensitivity. For as much pressure that was applied for powdery mildew resistance, it should be considered only temporary that experimental lines now considered candidates for release all have one weakness in common, and that is moderate susceptibility to powdery mildew.

Oklahoma has now endured two consecutive blistering spring seasons in which the wheat crop went through grain filling with less than a full photosynthetic tank. A partially senesced wheat canopy must draw more of its carbohydrate supply, or energy, to complete kernel development, i.e., maintain kernel weight and thus grain yield, by transporting or remobilizing stored carbohydrate from the stem. The OSU wheat breeding program does not always have this so-called opportunity to impose selection for carbohydrate remobilization, but it is our belief selected lines from the past two years, and plants selected within segregating populations in the early inbreeding stages, may have this added capacity. There was truly no other option, because in most Oklahoma rainfed environments in 2012, the leaf canopy was rendered prematurely nonfunctional by the compounded stresses of multiple diseases along with heat and drought stress. The result was either a senesced canopy or a desiccated canopy. We have now engaged the research program of Gopal Kakani, who will assist us in learning more about water-soluble carbohydrate (WSC) remobilization in wheat. We are aware of research elsewhere that nearly one-half of the stem weight in wheat may be in the form of WSC. Remobilization of that energy reserve can reduce the negative effects of canopy loss from diseases and other stresses by minimizing loss of kernel weight, providing benefit to both the farmer and the miller.

The ability to more rapidly complete grain filling, i.e., to mature earlier, is a favorable characteristic for grain yielding ability in the southern Plains, especially under the hotter, drier conditions of 2011 and 2012. Maturity of winter wheat is a complex trait system that encompasses three key developmental stages: stem elongation (otherwise called first-hollow-stem), flowering or heading and physiological maturity. Each of these stages is influenced by genetic factors linked, in part, to a vernalization requirement and photoperiod response. Conditions in 2012 strongly favored early maturity patterns invoked by a low vernalization requirement and/or reduced photoperiod sensitivity. Experimental lines on the opposite end of that spectrum simply matured too late. In other words, lines that broke winter dormancy late or headed later than most were out of phase with the prevailing climate, and these types had a difficult time catching up, which could be observed as lower grain yield.

Figure 15 displays examples that could be found in our breeding materials at stem elongation in March and at heading in early April. The early maturity pattern characteristic of varieties such as WB Cedar and Billings played in their favor when final grain yields were measured, but this pattern is not always emphasized to the exclusion of later maturity (e.g., Duster and Endurance) in WIT materials, because early harvest maturity must be held in balance with delayed stem elongation to promote dual-purpose wheat production and also to avoid later winter freeze events.

CLEARFIELD taking center field

Experimental lines featuring the double-mutant CLEARFIELD PLUS trait for imazamox resistance (combination of genes *AHASL1D* and *AHASL1B*) constituted 1 percent to 8 percent of the total WIT materials at any given stage of selection in 2012. More advanced experimental lines naturally carry this trait at a lower frequency due to limited history of breeding with the two-gene combination. However, very promising advanced experimental lines have recently emerged as potential candidate varieties, one of which is OK09915C. The majority of WIT segregating populations is now fixed for *AHASL1D* but segregate for *AHASL1B*, which greatly simplifies future selection and fixation of the double-gene genotype. John Edwards now facilitates this component of our breeding efforts along with his Extension efforts that focus on delivering educational information relevant to CLEARFIELD technology to multiple publics.

Grain yield and quality characteristics of OK09915C have been outstanding since 2010. The yield of OK09915C exceeded the yield of Centerfield (*AHASL1D*) by 19 percent in 2010, 24 percent in 2011 and 5

Figure 15. Independent examples of delayed maturity at stem elongation (left) and at heading (right) observed among WIT experimental lines in 2012. In previous years, the observed delay may not have been so disadvantageous to final grain yield.

percent in 2012 (Table 4). Its yield advantage was suppressed in 2012 by late maturity, delayed in part by photoperiod sensitivity. OK09915C also possesses the yield potential equal to or better than Duster, a proven leader in the southern Plains and our most widely planted variety in 2012. Agronomic attributes of OK09915C, in addition to grain yield, are high test weight and resistance to WSBMV, characteristics lacking in most CLEARFIELD varieties.

Table 4. Grain yield (bu/ac) of OK09915C in the Oklahoma Small Grains Variety Performance Tests from 2010 to 2012, with comparisons to Centerfield (one-gene CLEARFIELD) and the non-CLEARFIELD variety, Duster.

	2010	*2011*	*2012*
OK09915C	56	41	45
Centerfield	47	33	43
Duster	56	—	46
Number of tests	4	4	3

Taking a broader look outside Oklahoma, OK09915C has exceeded the performance of AP503CL, the first two-gene CLEARFIELD variety in the southern Plains, and the performance of contemporary two-gene candidate lines from other breeding programs (Table 5) when exposed to a hotter formulation of imazamox herbicide containing MSO. Furthermore, OK09915C has shown no difference in grain yield in the absence of this formulation, indicating it exhibits a high level of herbicide tolerance and is well suited to a CLEARFIELD PLUS production system needed to control problem grassy weeds, including feral rye. A proposal to release OK09915C by the Oklahoma Agricultural Experiment Station is forthcoming in spring 2013.

The numbers

Field evaluation, molecular and greenhouse assays and extensive end-use quality testing were conducted on 3,002 breeding lines in preliminary (F_6), intermediate (F_7) and advanced inbreeding generations (F_8 and beyond), representing a 16 percent increase over 2011. Of those, 576 breeding lines (19

Table 5. Comparing grain yields of OK09915C with the control variety, AP503CL, and other experimental lines from the 2012 CLEARFIELD Qualification Trial.

Grain yield bu/ac	2x rate + MSO			
	Stillwater	Perkins	Hays, KS	Lincoln, NE
OK09915C	52	40	80	63
AP503CL	40	28	79	49
All entries[a]	43	29	73	37[b]

[a] Other entries included OK09935C, KS11HW3CL, NHH09655, NHH11569

[b] Includes four more entries at Lincoln

percent) belonged to the hard white class, with the balance being hard red winter or, in rare cases, soft red winter (less than 1 percent). A modified bulk population selection method was invoked in the early inbreeding generations (F_2 through F_4) using the ***Graze*n*Grain*** breeding system, whereas a small portion of the breeding lines would have originated by marker-assisted selection (less than 5 percent).

Only 740 unique hybridizations were performed in 2012, strictly for the purpose of cultivar development. This number represented an unplanned 35 percent decline from normal activity due to various technical difficulties. About 14 percent of these crosses will potentially lead to populations that contain genes fixed for white kernel color or otherwise segregate for kernel color. Less than 25 percent of these hybridizations were limited to elite local parentage, underscoring the emphasis placed on germplasm introgression from foreign sources. Introgression was principally focused on resistance to leaf rust, stripe rust, BYDV, Ug99 along with related races of stem rust and Hessian fly.

The genetic pipeline

Second-year testing of doubled haploid lines revealed high-yielding progeny carrying the targeted traits of leaf rust resistance based on *Lr34*, Hessian fly resistance and resistance to greenbug biotype E. A second year of replicated yield trials is planned for the 2012-2013 season across a wider area of the southern Plains.

Experimental lines featuring alternative dwarfing genes or with resistance to stem rust race TTKSK (Ug99) were retested in replicated yield trials across Oklahoma. Desirable progeny were identified for the intent of stacking alien resistance genes, with additional confirmation of the presence of *Sr57* pending. Recombinant inbred lines were generated in 2012 for the anticipated discovery and mapping of genes critical to predicting developmental stages in winter wheat and gene(s) that may confer tolerance to bird cherry-oat aphid.

In addition to our newest releases, Gallagher and Iba, the 2012 OSU Small Grains Variety Performance Tests (OSGVPT) included 10 advanced experimental lines at various stages of candidacy to allow scientific comparisons with contemporary varieties. Four lines demanded special attention for having the best combination of disease resistance, dual-purpose adaptation, yield potential and end-use quality. Their yield rankings in replicated yield trials across Oklahoma are shown in Table 6 for years 2009 through 2012. A lower rank sum score indicates consistently superior yield performance across such diverse environmental conditions. For comparison, but not shown in Table 6, Duster's rank sum was 21. All four lines demonstrated essentially inseparable yield records since 2009, though OK09634 has exhibited the highest yield potential in the less challenging environments.

An additional year of testing in the OSGVPT is needed to confidently forward a proposal for variety release for any one of the four candidates. They each have their unique strengths: very early maturity and outstanding leaf hygiene for OK09634, superior drought tolerance in western Oklahoma for OK09125, good powdery mildew and BYDV protection for OK09528, and multiple types of leaf rust resistance in OK09729. OK09634 and OK09528 are in their second year of seed multiplication by Oklahoma Foundation Seed Stocks, Inc.

After securing two of the top three ranking positions among 38 advanced experimental lines in the 2011 Southern Regional Performance Nursery (SRPN), OSU claimed the top ranking position in 2012 with the experimental line OK07214, now known as Gallagher. In 2012, the SRPN had 40 entries submitted by nine public and private breeding programs. Four of the six OSU entries in 2012 ranked 10th or higher, and one of those was OK09634 (fifth). Many of the advanced lines moving forward as candidates for release in Oklahoma have shown broad adaptation outside the state. This characteristic probably reflects the broad diversity of environmental conditions to which WIT breeding materials are exposed during their development. The genetic footprint mentioned above demands a large shoe size, providing stability of performance across the southern Plains.

Table 6. Four advanced experimental lines undergoing further testing in the OSGVPT and their yield ranks in statewide replicated yield trials from 2009 to 2012.

Candidate	2009	2010	2011	2012	Sum
OK09634 (OK95616 seln/Overley)	1	3	2	6	**12**
OK09125 (TAM 303/Overley)	2	2	15	2	**21**
OK09528 (TAM 303/Ok102)	3	1	4	7	**15**
OK09729 (OK98697/CIM//OK00114)	2	1	11	11	**25**

Wheat Variety Trials

Jeff Edwards

The extreme drought and widespread crop failure of 2011 was followed by a bumper wheat crop in 2012 for most Oklahoma farmers. The estimated 2012 Oklahoma wheat production is approximately 159.1 million bushels, which is roughly double the 2011 production (Table 1). The production increase is a result of an approximate 1.1 million acre increase in harvested acres and a 68 percent increase in average yield.

The 2012 wheat production season started slowly. The extreme drought of 2011 completely depleted soil moisture reserves in most of Oklahoma. Oklahoma farmers and ranchers entered September 2011 with almost no soil moisture and extreme heat that quickly dissipated the little rainfall that occurred. Hay supplies along with remaining pastures were gone, so the desperate need for forage pushed most producers to roll the dice and dust-in wheat for pasture. A break from the extreme heat and a few timely rains in late-September allowed wheat to establish itself, but did not provide much opportunity for growth. The pattern of just enough moisture to survive persisted throughout the winter in western Oklahoma and the Panhandle.

Central and west-central Oklahoma was a different story. What began as a slow wheat forage year turned into one of the best wheat pasture years in recent memory for farmers and ranchers in this region. Timely rainfall throughout October, November and December, combined with one of the warmest winters on record, resulted in rapid forage production and outstanding average daily gains. Residual soil nitrogen left by the 2011 failed crops sometimes exceeded 150 lbs/ac and spurred wheat forage production onward. In fact, many producers were unable to secure sufficient stocker cattle to keep up with wheat forage.

Temperatures during the 2012 season were never cold enough to hold wheat back more than a day or two. Wheat came out of winter dormancy

Table 1. Estimated Oklahoma wheat production for 2011 and 2012 by OK NASS, June 2012.

	2011	*2012*
Harvested Acres	3.2 million	4.3 million
Yield (bu/ac)	22	37
Total bushels	70.4 million	159.1 million

earlier than normal with an abundance of tillers. Tiller counts of 700 to 1,000 tillers/yd^2 were not uncommon versus the Oklahoma norm of 400 to 600 tillers/yd^2. The abnormally early crop and lush growth in March had everyone concerned about the possibility of a late-spring freeze. Only a few isolated areas sustained light freeze injury. However, on March 20, 2012, the morning temperature fell to 21°F in the Panhandle causing some damage and injury to the wheat heads and stems (see Goodwell Irrigated data, Table 3). This injury contributed to, but was not the only cause, of lodging at this site.

Weed problems such as feral rye, Italian ryegrass and rescuegrass were certainly present in 2012, but were not as severe as previous years. However, Oklahoma still has a long way to go before our weed control and the associated yield losses are at acceptable levels.

As previously mentioned, the failed crops of 2011 created a great deal of residual nitrogen in the soil profile. The absence of rainfall meant this nitrogen was easily accessible to the wheat crop. In addition, the favorable outlook in terms of yield and price resulted in many farmers deciding to make an investment in topdress nitrogen. In many cases, a heavy nitrogen investment was well justified. Although, in some instances, the topdress nitrogen, combined with high levels of residual soil nitrogen and excessive tillering, resulted in a lodged crop.

Other than winter grain mite activity in some of the drier areas of the state, fall 2011 was relatively insect free. However, in mid- to late-March, many producers chose to spray when a flush of bird cherry-oat aphids seemed to appear overnight. This aphid flush resulted in widespread barley yellow dwarf virus symptoms at heading. Symptoms were mostly restricted to yellowing/purpling of flag leaves with no stunting or reduction in plant height. Additionally, some producers were compelled to spray when armyworms invaded just prior to harvest, but in many cases the rapid ripening of the wheat crop negated the need for spraying.

A significant shift in the predominant stripe rust race made it a game-changing foliar disease season. While stripe rust was present statewide, the epicenter for stripe rust was in central Oklahoma. Among our locations, both trials at Marshall had severe stripe rust. As evidenced by the results and confirmed by visual observation, the resistance genes in Armour, Everest and Pete offered little protection against the stripe rust onslaught. Even some of the new varieties, such as Garrison, succumbed to stripe rust, though to a lesser degree. Fortunately, varieties such as Gallagher, Billings, Iba, WB Cedar and CJ seemed to weather the stripe rust storm fairly well. Foliar diseases such as tan spot, septoria leaf blotch, powdery mildew and leaf rust also were present in 2012, but never reached the severity of stripe rust. The combination of all of these foliar diseases led to a 10 bu/ac average yield advantage for fungicide-treated wheat at Lahoma and an 8 bu/ac advantage at Apache.

A heat wave hit Oklahoma in mid-April and soil moisture reserves were quickly depleted. This was especially true in areas south of Highway 51 and west of Highway 81 where fields quickly took on a blue cast. In early May temperatures moderated and moisture returned, but the damage already had been done. White heads and aborted tillers quickly began to appear. In a few instances, these were due to dryland root rot and/or take-all, but by and large the white heads were due to drought and heat stress.

Harvest was in full swing by mid-May, approximately 65 percent complete by June 1, and essentially finished by the second week of June. Yields were better than expected in most locations and reports of field averages in the 60 to 80 bu/ac range in central Oklahoma were not uncommon. Lodging combined with delayed harvest resulted in low test weights in a few locations and some isolated pre-harvest sprouting. Low test weights were also common in many areas of western Oklahoma due to shriveled grain caused by excessive heat and drought stress during grainfill.

Methods

Cultural practices

Conventional plots were eight rows wide with 6-inch row spacing. No-till plots were seven rows wide with 7.5-inch row spacing. Plots were 20 feet long and wheel tracks were included in the plot area for yield calculation. Conventional till plots received 50 lbs/ac of 18-46-0 in-furrow during planting. No-till plots received 5 gals/ac of 10-34-0 at planting. The El Reno and Marshall dual-purpose trials were sown at 120 lbs/ac. All other locations were sown at 60 lbs/ac. 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.

Additional information

Visit www.wheat.okstate.edu for the complete 2012 OSU Small Grains Variety Performance Tests results, additional information on varieties and information concerning wheat management.

Marketing rights

In many cases the breeding program does not market the wheat varieties. For this reason, a list of wheat seed companies and the varieties they market is provided in Table 2.

Table 2. Wheat seed companies and varieties offered.

AgriPro	AGSECO	CO Wheat Res. Found.	Husker Genetics	Kansas Wheat Alliance	Limagrain Cereal Seeds	OK Foundation Seed	Oklahoma Genetics	WestBred	Watley Seed
AP503CL2	TAM 113	Bill Brown	Mace	Everest	T153	2174	Billings	Armour	TAM 112
CJ		Hatcher		Fuller	T158	Deliver	Centerfield	Santa Fe	
Doans				Jagger		Endurance	Duster	WB Cedar	
Greer							Gallagher	Winterhawk	
Fannin							Garrison		
Jackpot							Iba		
TAM 111							OK Bullet		
TAM 203							Pete		
TAM 401							Ruby Lee		

Table 3. 2011 Oklahoma wheat variety trial yield summary.

Variety	Afton	Alva	Apache	Apache Fungicide	Balko	Buffalo	Chattanooga	Cherokee	El Reno	Gage	Goodwell Irrigated	Goodwell Nonirrigated
	grain yield (bu/ac)											
2174	-	-	-	-	-	-	-	-	-	-	-	-
AP503CL2	-	48	-	-	-	19	-	-	-	23	-	-
Armour	44	48	50	60	24	25	38	45	40	16	40	14
Bill Brown	-	-	-	-	27	-	-	-	-	-	32	15
Billings	42	51	60	68	26	30	40	48	44	40	65	16
Centerfield	-	46	-	-	-	31	-	46	-	32	-	-
CJ	39	45	-	-	27	33	-	43	45	29	39	16
Deliver	-	-	48	53	-	-	38	47	37	-	-	-
Doans	43	46	47	51	28	31	34	41	50	31	41	16
Duster	27	51	36	51	28	29	40	52	34	28	48	15
Endurance	24	48	39	50	28	28	34	46	38	33	41	15
Everest	58	52	59	66	-	32	39	49	49	27	-	-
Fannin	-	-	36	41	-	-	37	-	30	-	-	-
Fuller	46	46	60	62	-	25	38	48	52	24	-	-
Gallagher	53	56	57	64	29	30	41	56	45	-	64	18
Garrison	43	49	44	57	23	24	37	47	35	14	41	12
Greer	24	41	46	54	25	24	38	50	36	26	42	13
Hatcher	-	-	-	-	29	-	-	-	-	-	43	13
Iba	32	51	42	50	30	32	39	55	35	-	56	15
Jackpot	25	46	51	60	26	27	42	45	46	29	48	14
Jagger	28	44	51	62	24	24	39	47	35	20	41	15
Mace	-	-	-	-	19	-	-	-	-	-	23	7
OK Bullet	30	44	48	55	-	25	33	48	35	29	-	-
Pete	-	-	47	68	-	-	37	47	38	-	-	-
Ruby Lee	39	57	57	64	31	36	49	48	54	27	54	16
Santa Fe	20	-	-	-	-	-	-	49	39	-	-	-
T153	-	-	-	-	30	-	-	-	-	-	61	16
T158	-	-	-	-	27	-	-	-	-	-	62	16
TAM 111	-	49	-	-	26	25	-	-	-	20	40	9
TAM 112	-	48	-	-	27	22	-	-	-	18	35	16
TAM 113	-	49	-	-	26	20	-	-	-	26	38	13
TAM 203	-	-	51	59	-	-	45	-	-	-	-	-
TAM 401	-	-	53	60	-	-	44	43	45	-	-	-
WB Cedar	46	-	-	-	-	-	-	-	59	-	74	-
Winterhawk	-	53	-	-	28	31	-	57	-	26	58	16
OCW00S063S-1B	-	-	-	-	-	-	-	-	-	-	-	16
OK05312	-	-	-	-	27	-	-	-	-	-	32	11
OK08229	-	-	-	-	27	-	-	-	-	24	31	12
OK08328	-	53	48	52	26	23	31	-	43	22	46	14
OK08413	27	-	-	-	-	-	-	-	-	-	-	-
OK08707W	-	-	-	-	28	-	-	-	-	-	36	13
OK09125	-	-	-	-	-	-	-	-	-	-	-	11
OK09634	-	51	60	63	-	-	-	-	36	-	-	-
OK0986146W	-	-	-	-	-	-	-	-	-	-	27	-
OK09915C	-	50	-	-	-	22	-	-	44	30	-	-
Mean	37	49	49	58	27	27	39	48	42	26	47	14
LSD (0.05)	14	5	8	10	3	3	8	7	6	5	8	3

Table 3. 2011 Oklahoma wheat variety trial yield summary (continued).

Variety	Homestead	Hooker	Keyes	Kildare	Kingfisher	Lahoma	Lahoma Fungicide	Lamont	Marshall DP	Marshall GO	McLoud	Olustee	Thomas
	grain yield (bu/ac)												
2174	-	-	-	-	-	-	-	-	-	-	57	-	-
AP503CL2	-	-	-	-	-	-	-	-	-	-	-	-	-
Armour	50	28	26	43	53	30	53	36	22	14	72	29	18
Bill Brown	-	33	24	-	-	-	-	-	-	-	-	-	-
Billings	59	33	19	54	64	52	63	36	37	53	72	26	37
Centerfield	-	-	-	-	52	-	-	-	-	-	-	-	-
CJ	43	36	20	42	63	50	55	29	46	51	64	-	-
Deliver	48	-	-	43	51	49	50	33	38	42	-	29	28
Doans	47	36	21	41	56	46	48	37	47	45	56	26	36
Duster	44	35	21	46	58	46	59	28	49	46	55	27	26
Endurance	47	37	21	46	55	51	56	31	44	47	62	29	16
Everest	58	-	-	62	55	47	58	35	39	40	73	29	30
Fannin	-	-	-	-	-	-	-	-	-	-	-	25	25
Fuller	59	-	-	48	62	51	55	34	41	44	62	30	21
Gallagher	60	35	20	53	66	57	63	33	37	56	75	29	23
Garrison	44	32	18	59	49	33	65	31	20	22	73	24	20
Greer	54	26	20	55	60	52	61	30	31	42	71	27	21
Hatcher	-	32	21	-	-	-	-	-	-	-	-	-	-
Iba	57	38	24	62	58	54	63	31	48	51	67	25	45
Jackpot	57	37	26	52	62	54	64	36	38	42	69	31	27
Jagger	50	35	23	41	61	50	58	33	28	39	66	33	13
Mace	-	31	15	-	-	-	-	-	-	-	-	-	-
OK Bullet	49	-	-	45	54	46	52	35	31	37	63	23	21
Pete	43	-	-	49	43	35	58	27	18	14	-	31	20
Ruby Lee	57	37	24	63	64	43	65	44	38	39	77	31	29
Santa Fe	54	-	-	50	55	49	55	40	39	41	52	-	-
T153	-	37	23	-	-	-	-	-	-	-	-	-	-
T158	-	29	24	-	-	-	-	-	-	-	-	-	-
TAM 111	-	33	17	-	-	-	-	-	-	-	-	-	-
TAM 112	-	33	29	-	-	-	-	-	-	-	-	-	-
TAM 113	-	30	24	-	-	-	-	-	-	-	-	-	-
TAM 203	-	-	-	-	-	-	-	-	-	-	-	31	26
TAM 401	45	-	-	43	59	49	51	29	37	47	-	26	34
WB Cedar	60	-	-	57	63	60	71	47	45	65	71	-	-
Winterhawk	-	34	26	-	-	-	-	-	-	-	-	30	34
OCW00S063S-1B	-	-	22	-	-	-	-	-	-	-	-	-	-
OK05312	-	34	22	-	-	-	-	-	-	-	-	-	-
OK08229	-	34	23	-	-	-	-	-	-	-	-	-	-
OK08328	61	34	20	-	59	48	59	-	43	-	62	29	34
OK08413	-	-	27	57	-	-	-	-	-	-	60	-	-
OK08707W	-	-	-	-	-	-	-	-	-	-	-	-	-
OK09125	-	-	-	-	-	-	-	-	-	-	-	-	-
OK09634	-	-	-	-	72	52	60	-	-	47	-	-	-
OK0986146W	-	32	15	-	-	-	-	-	-	-	-	-	-
OK09915C	-	-	-	-	56	53	62	-	-	46	-	-	-
Mean	52	34	22	50	57	48	58	34	37	42	66	28	26
LSD (0.05)	5	5	7	6	6	5	5	10	7	7	13	5	18