Partners in Progress
WHEAT

Wheat Research at OSU 2008

Supported by the

Oklahoma Wheat Commission

and the

Oklahoma Wheat Research Foundation

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

Partners in Progress – Our long-standing partnership with the Oklahoma Wheat Commission 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 it also provides valuable input from producers that helps to 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 each section is a summary of accomplishments for fiscal year 2007-2008. 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*.

Clarence Watson,
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.

Quality…The Customer Speaks

Partners in Progress
WHEAT

The Oklahoma Wheat Commission utilizes a multifaceted approach to international marketing programs. One such facet is to cooperate with other wheat commissions across the United States to pool resources and address common issues and customer concerns. The organizational structure is known as U.S. Wheat Associates. U.S. Wheat has two offices domestically and 15 offices (servicing more than 100 countries) internationally and recently conducted an "Export Wheat Quality Competitiveness Survey" to determine what factors make Oklahoma wheat desirable (or in some cases undesirable) to our customers. The results were predictable, but serve to quantify and support the quality based marketing program the Oklahoma Wheat Commission began a decade ago.

The survey contained 47 questions which included Kernel Quality (17 factors), Milling Quality (8 factors), Dough Quality (13 factors) and End Product Quality (9 factors). All six classes of wheat were surveyed, but the focus for this publication will be the major class produced in Oklahoma, Hard Red Winter (HRW) and were rated compared to the major competitors by country.

As a summary, factors that provided HRW the greatest advantage across all customers world-wide were:

Gluten as a Quality Improver – there are virtually no international customers that use US HRW as a 100% grind in their mills, rather they utilize a blend of local wheat available, usually some percentage of Soft Red Winter (because of price differential with HRW) and then determine how much US HRW they will need to improve the quality to the point the resulting flour will produce an acceptable end product.

Ratios of Resistance to Extension and Extensibility – HRW not only has protein, but functional protein. Resistance to extension and extensibility requires wheat that has functional protein, considering the types of end use products that HRW targets.

Dough Machinability - processing performance (dough development into superior handling characteristics).

These are the major reasons our customers purchase HRW, they have (and continue) to tell us how important quality is in the marketplace. So the question becomes, do wheat producers get paid for delivering quality. The answer is yes (and no), yes, (in the sense there is at the very least an implied quality that delivered wheat will make an acceptable loaf of bread). However, the answer is also no, in the sense we still need critical mass, so an individual producer can on very few occasions share in the premiums when providing quality.

An alternative way for a producer to extract increased net profit is to support a breeding program that is committed to releasing varieties that have quality characteristics our customers seek to acquire (and are willing to pay for). Oklahoma State University wheat breeder, Dr. Brett Carver has, and continues to be, a leader in this respect. He continues to meet with our customers (domestic and international) and discuss quality attributes in varieties released from his program to ensure they are meeting their needs. The Wheat Improvement Team's two newest releases, Billings and Pete, reflect that commitment to quality. These two varieties were developed over the last 10 to 12 years via a partnership between Oklahoma State University and Oklahoma wheat producers (through the Oklahoma Wheat Commission), a partnership that will continue to strengthen because of a common tie in the marketing chain all the way to the end user. Additionally, this partnership will become even more important in future years as federal and state funding continue in a downward trend. We are, and will continue to be, truly "Partners in Progress."

Mark Hodges, Executive Director
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Genetic Improvement and Varietal Release of Hard Winter Wheat

Wheat Improvement Team

2007-2008 progress made possible through OWRF/OWC support

- **Delivered wheat yield and phenology data to approximately 8,000 Oklahomans through the 2008 Wheat Seed Book distributed by the *High Plains Journal* to all Oklahoma subscribers. The Oklahoma Wheat Commission was recognized as a funding agency on the cover of this publication.**
- **Provided timely information to Oklahoma wheat farmers through 24 issues of the *Plant and Soil Sciences Extension Newsletter*.**
- **Provided 20 wheat disease updates to wheat growers, consultants, Extension educators, and researchers via electronic format.**
- **Continued to serve as the only source for critical information such as coleoptile length, high-temperature germination sensitivity, and dual-purpose adaptability of new wheat varieties.**
- **Placed two candidate cultivars under foundation seed increase: Pete, a beardless GrazenGrain HRW wheat with the pedigree N40/OK94P455; and Billings, a bearded grain-only, premium quality HRW wheat with the pedigree N566/OK94P597.**
- **Tested more than 2,000 breeding lines from multiple states for reaction to the wheat soilborne mosaic virus, or WSBMV, and wheat spindle streak mosaic virus, or WSSMV, complex. A subset of 230 advanced lines from Oklahoma also was tested in the lab using the enzyme-linked immunosorbent assay, which can detect the presence of virus and clarifies if resistance is to WSBMV, WSSMV, or both.**
- **Continued developing a field nursery to evaluate the reaction of OSU advanced lines to tan spot and initiated a similar nursery to evaluate reaction to powdery mildew.**
- **Selected and advanced breeding materials with adult-plant resistance to leaf rust based on three or more non-race-specific genes. Some lines also may harbor genes for adult-plant resistance to stripe rust.**
- **Developed winter wheat synthetic derivatives for further multi-location testing and selection as potential breeding stocks.**
- **Continued the introgression of synthetics, but this time with a unique set of winter wheat synthetics recently introduced from CIMMYT.**
- **Confirmed the absence of Karnal bunt in 52 wheat samples from 14 counties in Oklahoma.**
- **Developed new protocols to show the magnitude of variation in coleoptile length and associated seedling traits was great enough to enable the WIT to breed more drought-tolerant wheat cultivars.**
- **First in the world to locate the gene that is primarily responsible for first hollow stem stage development in winter wheat.**

- **First to demonstrate that reproductive development of winter wheat is determined by three major quantitative trait loci, or QTLs, associated with three flowering time genes (*VRN-A1*, *PPD-D1*, and *VRN-D3*).**
- **Showed that 2174 and several local cultivars have a *Pm3a* allele, which confers resistance to powdery mildew in winter wheat, whereas Jagger lacks this allele resulting in high susceptibility to powdery mildew. The genetic source in 2174 and other cultivars can be used to breed for improved powdery mildew resistance.**
- **Documented the frequency of Hessian flies in major wheat growing regions of Oklahoma.**
- **Demonstrated reduced fly infestations and yield protection associated with OSU advanced breeding lines and available cultivars that have resistance to natural fly populations.**
- **Optimized the method of measuring *dough extensibility*, which is the functional complement of dough strength and a breeding target requiring immediate attention.**
- **Improved upon current laboratory procedures for discriminating more accurately among breeding lines for end-use quality or functionality of the grain. New predictive tests may feature the combination of creep-recovery, extensibility, and gluten quality measurements.**

Oklahoma State University's Wheat Improvement Team, or WIT, just turned 10. The WIT completed its first decade of discovering genetic solutions and creating greater economic opportunities for Oklahoma's wheat producers. Nine OSU scientists comprise this cohesive team that combines fundamental and applied components of genetic research to achieve a common goal. Our goal is to move the entire chain of Oklahoma's wheat industry forward with the infusion of new, improved varieties. Scientists on the WIT are **Brett Carver**, wheat breeding and genetics; **Liuling Yan**, wheat molecular genetics; **Jeff Edwards**, information exchange; **Bob Hunger** and **Art Klatt**, wheat pathology and development of disease-resistant germplasm; **Kris Giles** and **Tom Royer**, Hessian fly control; **Bjorn Martin**, drought resistance; and **Patricia Rayas-Duarte**, cereal chemistry. Yan, Giles, and Royer are the newest additions to the team, enabling us to capitalize on genomic technology and to better confront a relatively new insect to wheat production in Oklahoma.

The 2007-2008 season produced a banner crop of advanced lines from which to choose OSU's next wheat variety. The shelves were stocked so full the WIT will propose in 2009 the release of not one but two hard red winter wheat varieties. This pick-two strategy was prompted by two independent forces of nature. First, the abrupt change in leaf rust reaction of two varieties popular among Oklahoma wheat producers, OK Bullet and Overley, has produced a sudden need for alternatives with equally good quality. Second, while the beardless variety Deliver has won the attention of many producers from Texas to Kansas since its release in 2004, the wetter climate and higher yielding conditions of 2007 and 2008 also has forced attention on one of its weaknesses, susceptibility to lodging.

In this report, you can read more about these and other significant breakthroughs, such as:

- the molecular dissection of developmental traits, which define maturity from the first hollow stem stage to the physiological maturity stage;
- the introgression of new synthetic wheat germplasm, which now features a winter growth habit; and
- the development of new protocols that will enable the WIT to identify experimental lines with drought resistance or with improved breadmaking quality.

Information Exchange and Systems Research

Jeff Edwards
Plant and Soil Sciences

The information exchange component of the WIT team continued to focus on timely delivery of relevant information to the Oklahoma wheat farmer. This was accomplished through a variety of delivery methods and information outlets. We delivered timely information to Oklahoma wheat farmers through 24 issues of the *Plant and Soil Sciences Newsletter* in 2008. The e-mail distribution list for this publication continues to grow. Wheat variety trial results were, again, published in a timely fashion, which allowed farmers and seed producers to make well-informed decisions regarding seed purchases. To expand the readership and visibility of this publication, we partnered with *High Plains Journal* in 2008 and distributed the 2008 Wheat Seed Book to approximately 8,000 subscribers in Oklahoma. This partnership will be continued in 2009, as it increases our impact by providing timely information to a large number of stakeholders and recognizes the OWC and OWRF as funding agencies for the program.

Research efforts in 2007 and 2008 continued to focus on collecting and interpreting data that Oklahoma wheat farmers can use directly in their operations. Again in 2008, we looked at forage production in no-till and conventional till systems and found forage production in no-till systems might not measure up to that of conventional till systems. This research will continue for one more year to see if these trends hold. If they do, Extension recommendations will be revised accordingly and distributed. We continue to provide coleoptile length, post-harvest dormancy, and first hollow stem data on the newest wheat lines released in the Southern Great Plains. Our goal with continuing these investigations is to help farmers avoid problems before they start.

Wheat Pathology Research and Development of Disease Resistant Germplasm

Bob Hunger
Entomology and Plant Pathology

Knowing the reaction of experimental lines in the OSU wheat breeding program to the wheat rusts and the WSBMV/WSSMV complex is critical to developing improved wheat varieties.

These evaluations are conducted annually in the greenhouse and field. This includes testing advanced breeding lines for the presence of WSBMV and WSSMV using the serological test enzyme-linked immunosorbent assay, or ELISA, to determine if a line is resistant to one or both viruses. Seedling testing in the greenhouse for reaction to powdery mildew, tan spot, and septoria also is conducted when possible to help elucidate the reaction of breeding lines.

Evaluating disease reaction in the field is the most beneficial, so OWRF funds were used to initiate and develop field nurseries to test lines for reaction to tan spot and powdery mildew. The tan spot nursery is part of a doctoral research project of Kazi Kader, who is being jointly funded by the OWRF and the Oklahoma Agricultural Experiment Station, or OAES. Kader's project will contribute to an understanding of the effects of tan spot on wheat as related to no-till and low-till wheat production, which leaves significantly greater amounts of wheat residue on the soil surface. The fungus that causes tan spot survives on this residue, so tan spot incidence and severity increases in no-till and low-till wheat production systems. The field inoculation technique developed by Kader is being used to evaluate selected breeding lines in the field during the 2008-2009 crop season.

Funds provided by the OWC supported the testing of the 2008 Oklahoma wheat crop for the presence of Karnal bunt. Results from this testing were used to certify that Oklahoma wheat was produced in areas not known to be infested with Karnal bunt, which allowed Oklahoma wheat to move freely into the export market.

Art Klatt
Plant and Soil Sciences

The germplasm development program of the WIT has two primary objectives: 1) incorporate stable and durable leaf and stripe rust resistance into adapted winter wheat backgrounds for Oklahoma, and 2) transfer useful genes, especially genes for improved drought and heat tolerance and improved resistance to tan spot and the rusts, from synthetic wheat into adapted winter wheat backgrounds. The spring wheat breeding program at CIMMYT has generously provided primary synthetic hexaploid wheat lines and advanced breeding lines with adult-plant resistance, or APR, to leaf rust and stripe rust. Crosses between adapted winter wheat materials and these introduced materials have been made for the last eight years, and advanced materials derived from these crosses are in the final stages of testing and evaluation.

Advanced winter wheat lines with APR to leaf rust based on multiple, non-race-specific genes were tested for grain yield performance at several locations in the state. The majority of these materials contained the APR genes *Lr34* and *Lr46*, plus at least one or, in most cases, two additional APR genes of unknown designation. In addition, many of these advanced lines may have two or more APR genes for stripe rust resistance. If these materials prove to be well adapted in Oklahoma, they could lead to a more durable type of rust resistance, which would be highly beneficial to wheat producers of Oklahoma. Additionally, a large number of advanced lines with proven APR will be entered into preliminary yield testing in the 2008-2009 crop season.

More than 200 new crosses were made to synthetic wheat germplasm lines during the 2007-2008 crop season, including a large number of crosses to a collection of winter synthetics lines recently introduced from CIMMYT. The advanced materials derived from these crosses (i.e., synthetic derivatives) may provide new sources of genes for rust resistance, aphid resistance, enhanced drought tolerance, improved green-leaf retention, and better resistance to other foliar diseases, especially tan spot. Advanced synthetic derivatives will be evaluated in yield trials during the 2008-2009 crop, and these trials should give us a better idea of the overall potential for these unique materials.

A regional cooperative nursery near San Antonio, Texas, continues to serve as a primary selection site for leaf rust and stripe rust resistance. All introduced materials are screened in south Texas before being used as parents, and early-generation populations (F_2 and F_4) are initially evaluated under severe rust pressure at this site. All advanced materials described here, and all advanced lines undergoing yield testing in the wheat breeding program of the WIT, are evaluated in this nursery to confirm rust resistance.

A cooperative research effort with CIMMYT has shown spectral reflectance at selected wavelengths can be used as an indirect selection tool for grain yield and total biomass in spring and winter wheat. However, this technology has limited usefulness due to the lack of an inexpensive, light-weight sensor to take measurements in the field. Efforts are underway in cooperation with the Biosystems and Agricultural Engineering Department at OSU to develop a hand-held sensor that can be used by breeders. If successful, this sensor will increase the efficiency and effectiveness of selection for grain yield and biomass in wheat breeding programs.

Characterization of Hessian Fly Resistance

Kris Giles and Tom Royer
Entomology and Plant Pathology

We continued two Hessian fly experiments during the 2007-2008 growing season: 1) a survey of Hessian fly populations in Oklahoma, and 2) an evaluation of the reaction of advanced experimental lines in the OSU breeding program. Our overall objective was to identify sources of Hessian fly resistance and make those sources available to the WIT.

During the 2007-2008 growing season, we collected Hessian fly pupae from all of the major wheat growing areas in Oklahoma. As in previous years, populations in most locations were sporadic. However, a few fields near Apache and Blackwell had extremely high densities on susceptible wheat plants. As observed in previous years, higher densities were most common in or near continuous no-till wheat fields. Pupae were sent to Kansas State University and USDA-ARS in Indiana for biotyping, and we are awaiting final confirmation of biotypes. Initial data indicate biotype GP continues to be common in Oklahoma.

In two replicated studies, we evaluated the reaction of advanced breeding lines and selected check varieties to heavy infestations of natural fly populations near Blackwell and Apache. Heavy volunteer wheat levels prevented data collection in Blackwell, but the Apache site provided the highest natural infestations we have evaluated to date and resulted in excellent insect counts and yield data. In a few varieties at Apache, the cumulative average infestation was close to 10 flies per tiller. The number of Hessian fly larvae-plus-pupae varied among generations and entries. Several experimental lines had relatively low numbers of flies that survived, which indicates relative resistance to flies in Oklahoma (Table 1). Many of these lines will continue in the breeding program.

As expected under high fly pressure, the resistant cultivar Duster had the lowest fly infestations and highest yields (Table 1). Interestingly, OK Bullet has no known resistance genes for Hessian fly, yet its grain yield at Apache in the presence of Hessian fly infestation was not statistically different from Duster. Partially-resistant cultivars such as Centerfield and Chisholm had lower fly numbers than highly susceptible cultivars such as Overley. Currently, Oklahoma producers have resistance options for Hessian fly and future breeding efforts do look promising.

Table 1. Hessian fly larvae plus pupae per tiller, and wheat yields, for entries tested in the 2008 Oklahoma Elite Trial (OET2), near Apache, Okla.

	HF larvae + pupae / tiller		*Yield[*]*
Entry	*1st gen*	*2nd gen*	*lbs/ plot*
Duster	0.01	0.01	4.39
OK Bullet	1.27	2.70	4.33
OK04111	0.33	0.35	3.81
Fuller	1.05	1.79	3.76
OK04315	0.27	2.45	3.70
OK00514-05804	1.51	2.33	3.69
OK05903C	0.08	2.18	3.59
OK03716W	0.58	1.44	3.56
Chisholm	0.75	0.71	3.14
OK05737W	1.14	2.32	3.11
Centerfield	0.28	0.34	3.11
OK Rising	1.20	1.85	3.07
Endurance	1.75	4.50	2.98
Billings	1.04	3.32	2.89
OK05741W	0.78	1.98	2.86
OK00611W	1.55	2.78	2.75
OK04507	1.04	2.88	2.69
OK03825-5403-6	1.35	2.62	2.69
OK05830	1.33	3.33	2.62
Pete	0.60	3.76	2.62
OK03825-5403-5	0.78	3.63	2.55
OK00514-05806	1.13	2.16	2.54
Overley	0.96	4.08	2.32
OK05905C	0.99	3.85	2.28
OK04505	0.57	1.72	2.25
Guymon	0.60	2.16	2.22
Deliver	1.12	4.99	2.02
OK04525	0.79	3.01	2.02
OK02405	1.21	8.35	1.73
OK05711W	1.31	8.42	1.51
****LSD (5%)**	**0.81**	**2.72**	**0.91**

*1.0 lb/plot = 15.5 bu/A.

** LSD = Least Significant Difference.

Stress Physiology

Bjorn Martin
Plant and Soil Sciences

We successfully implemented a new testing protocol to measure coleoptile length of advanced breeding lines obtained from the WIT. An elongated coleoptile is desirable because it allows planting the seed deeper than in the case of a short coleoptile. Producers would benefit from planting deep, as many years the uppermost soil layer is very dry at planting time. However, planting the seed so deep that the coleoptile fails to reach the soil surface before it runs out of stored food results in a poor stand.

Our protocol consisted of two strips of germination paper in between a row of sandwiched seeds. The germination paper strips were rolled into a loose roll that was placed on end (seed at the bottom of the roll) in a tub. The tubs contained either water or 3 mm PEG (artificial drought-stress inducing agent) at the bottom. The tubs were placed in a cold room for a brief period and then moved into a dark growth chamber at 22 C. This allowed the coleoptile to grow upward between the germination paper strips as in nature, being protected from shortening of the coleoptile that would result from exposure to light. The coleoptile length was measured after two weeks in the growth chamber. At the same time we measured germination rate, the proportion of germinated seed with a fully extended coleoptile, maximum root length, and root number.

The maximum coleoptile length varied substantially among lines from about 45 mm to 75 mm. Although the maximum coleoptile length in PEG was not different from that in water, much fewer of the germinated seed in PEG had reached maximum coleoptile length by the end of the test period. Germination rate was similar in water and PEG for some lines, and somewhat lower in PEG for some other lines. The maximum root length varied considerably among the lines, and it was either similar or slightly smaller in water versus PEG. Average root number varied among the lines from about 3 mm to 4.5 mm, but root number did not differ between the water and the PEG treatments.

In conclusion, the magnitude of variation in coleoptile length and other traits we measured was great enough that the WIT should be able to focus on these measurements. For example, we will confirm with repeated testing that the released candidate cultivar, OK03522 (Billings) produces a long coleoptile under both treatments (water versus PEG). The variation in coleoptile length, and the variable response among the lines to PEG, particularly regarding germination frequency and proportion of germinated seed with fully extended coleoptile, should assist us in breeding more drought-tolerant wheat cultivars.

Cereal Chemistry

Patricia Rayas-Duarte
Biochemistry
and Molecular Biology

In last year's P-1018, *Partners in Progress Wheat Report*, we reported on the characteristics of either the gluten proteins alone or bread dough using three new methods that reveal information at the gluten protein molecular level. At the center of those methods was one termed *creep-recovery*, which describes the viscoelastic properties of a dough sample. We continued using analytical methods that describe the extensibility of dough via a dough rheometer, and a third method that measures both gluten quantity and to a lesser extent gluten quality via the glutomatic analysis.

In 2008, we completed the analysis of 45 cultivars and advanced experimental lines from the WIT grown in 2007, representing four environments. We combined the data from the three new methods, which will be referred to collectively as CREG, with mixograph and baking data routinely obtained from the OSU Wheat Quality Laboratory. Using multivariate analysis, the addition of the CREG data allowed a 10% improvement in explanation of the wheat quality data, giving us the needed tools to better differentiate among large numbers of advanced experimental lines and in a friendlier graphic form.

The rheological creep-recovery method consists of applying a force (stress) to the gluten isolated from flour and measuring its flow or viscous (creep) properties, followed by removal of the stress and measuring its elastic properties (recovery). This is a fundamental test used on organic polymers and reveals properties or behavior patterns at the molecular level. The flow and elastic properties reveal the distribution of the molecular weight of the polymers studied. Measured parameters from this test reveal at least three significant correlations with dough mixing properties and dough loaf heights before baking. Benefits derived from using this new methodology may extend well beyond our breeding program into the marketplace, as new quality parameters are desperately needed to accurately predict end-product quality or functionality of a grain sample.

We also have improved the method of analyzing dough extensibility (the functional complement of dough strength) by optimizing the time and force used during manipulation of the dough sample. Our improved method now can reveal smaller differences at the beginning of the test, showing parameters overlooked or not before used.

Wheat Molecular Genetics

Liuling Yan
Plant and Soil Sciences

This report marks the second year of Yan's participation on the WIT, with many exciting research results produced from his wheat molecular genetics laboratory. Yan's laboratory is the first in the world to identify and locate quantitative trait loci, or QTLs, responsible for genetic variation in arrival at the first hollow stem, growth stage. This is a critical growth stage used to determine proper grazing termination dates in local cultivars and to describe reproductive development of wheat worldwide. Genetic manipulation of the first hollow stem stage is particularly important in Oklahoma and the Southern Great Plains, as this selection strategy can be used to extend or modify the length of the vegetative phase, or grazing period, in a dual-purpose (DP) production system. This selection strategy also can be used to avoid the damaging effects of late-winter freeze events associated with precocious stem elongation. Without the aid of these QTLs, selection for the appropriate first hollow stem stage is cumbersome and costly.

We discovered that variation in first hollow stem arrival time in a Jagger x 2174 population was controlled by a major QTL (*QSte.osu-5A)* (including the vernalization gene *VRN-A1* locus) on chromosome 5A, plus three additional minor QTLs on chromosomes 1B (*QSte.osu-1B*), 2D (*QSte.osu-2D*), and 6A (*QSte.osu-6A*). The molecular markers for these QTLs are now being used for line selection in the wheat breeding program. This research work, which features QTL names credited to OSU, has appeared in the international genetics journal *Theoretical and Applied Genetics*.

We found that first hollow stem stage was regulated by other genetic loci when the major *QSte.osu-5A* locus was "fixed" for a given allele. In this case, major QTLs relating to genes in the photoperiod pathway were found to regulate reproductive development of winter wheat, accounting for 43% (in the case of initial stem length) and 68% (heading date) of the overall phenotypic variation in an Intrada x Cimarron population. This finding has enabled us to develop a selection protocol that delays the first hollow stem stage with minimal delay in heading date. This trait combination is a desirable phenotype in our ***Grazen**n**Grain*** breeding system. Findings from this work will soon appear in *Theoretical and Applied Genetics*.

In other molecular genetics research, we found that 2174 has a *Pm3a* allele that confers resistance to powdery mildew, whereas Jagger lacks this gene form, resulting in high susceptibility to powdery mildew. This genetic resistance source in 2174 and three other related cultivars, Okfield, Centerfield, and Ok102, can be directly applied to wheat breeding programs in the Southern Great Plains. These findings will appear soon in *Molecular Breeding*.

Our doctoral student Shuwen Wang was invited to give an oral presentation at the National Wheat Genomics Conference for his research work on heat-sensitive germination, another important trait in a dual-purpose production system. Wang discovered two major QTLs that control germination when seeds are planted in hot soil conditions typically found in the Southern Great Plains in early September.

Our genetic map from the Jagger x 2174 population is being used to map additional traits, such as heading date, physiological maturity, and test weight, all of which segregated in this population. Our genetic map has been extensively recognized and seeds of the population have been requested by collaborators in Washington and China to map stripe rust and other traits. More accomplishments are expected for the next funding cycle of 2008-2009.

Wheat Breeding and Variety Development

Brett Carver
Plant and Soil Sciences

The 2007-2008 crop year provided numerous opportunities to achieve significant genetic advances by removing unfit materials from the breeding program. Notable examples include a moderate infection by leaf rust and sufficient infection by powdery mildew or stripe rust to identify resistant progenies in various generations of the 10-year breeding cycle. Also, an acute level of both *High plains virus* in the Panhandle and *Barley yellow dwarf virus* elsewhere. The year would not have been complete without the presence of grain shattering; we certainly took advantage of that nemesis to rid the most dehiscent breeding lines from further consideration.

What stands out most about the past crop year is the superior performance of two advanced lines, OK03305 and OK03522. Both held our attention in past years, but with such unusual environmental conditions in 2006 (severe drought) and 2007 (severe powdery mildew and leaf rust, followed by rain-delayed harvest), their performance was truly difficult to pinpoint and assess. We now have sufficient data, both for agronomic traits and quality, to recommend their consideration for release by the OAES in 2009. While that decision is pending, the remainder of this report will be devoted to their history and description.

A coincidental common link lies in the single-cross parentage of both lines. One-half of the parentage of OK03522 and OK03305 can be credited to germplasm introduced from the Institute of Plant Breeding in Odessa, Ukraine, in 1994. Thus, the pedigree of OK03522 is N566/OK94P597, in which N566 was bred at Odessa and OK94P597 originated in the Pioneer hard wheat program as HBY359A/Fundulea 133//TAM 200. With Fundulea 133 from Romania as a parent of OK94P597, Eastern European germplasm is prominent on both sides of the parentage of OK03522.

The pedigree of OK03305 is N40/OK94P455, which N40 also came from Odessa and OK94P455 was derived from a double-cross of Pioneer and Kansas State University experimental lines (W0405D/KS831957//W3416/KS831957). Obvious from these pedigrees is the absence of any variety currently in production, such as Jagger or 2174. Their unique breeding history serves as a reminder of how well germplasm from Eastern Europe can serve wheat breeding programs in the Great Plains.

What does the WIT wish to accomplish with the release of these two candidates? The answers lie in three HRW wheat varieties currently in production: OK Bullet, Overley, and Deliver. Let's consider the first two in the following discussion adapted from the release proposal for OK03522 and OK03305.

OK Bullet (OAES) and Overley (Kansas Agricultural Experiment Station, or KAES), which were released by their respective institutions in 2005 and 2003, brought significant improvement in both grain yield and end-use quality to the Southern Great Plains. In the short-term, OK Bullet will continue to command acreage in central, southwest, and northwest portions of Oklahoma, whereas Overley will likely carry significant acreage in north central Oklahoma. Their long-term status, however, is already being questioned. Just as quickly as they captured the attention of wheat growers, they also captured the attention of *Puccinia triticina* Eriks., the causal organism of leaf rust. Races with virulence to the resistance gene featured in these cultivars, *Lr41*, soon began to multiply in the Southern Great Plains. By spring 2007, susceptible reactions were found on OK Bullet and Overley throughout northern Oklahoma and southern Kansas. Resistant alternatives are constantly in demand, without sacrificing gains accrued in grain yield potential and marketing ability.

OK03522 can meet this demand for an alternative source of leaf rust resistance, though only speculation can be used to predict how durable this resistance will be. We simply cannot state which resistance genes are present in OK03522, other than the two that are known to confer seedling resistance in the adult plant. Perhaps of greater importance is the resistance OK03522 offers to stripe rust, which is confirmed to be expressed in the adult plant, and potentially a different source of resistance than derived from Jagger. With additional resistance to the WSBMV/WSSMV complex and to powdery mildew, OK03522 offers a garrison of protection against foliar diseases that will improve upon the capabilities of OK Bullet, Overley, and other OSU releases such as Endurance and Duster. Additional traits that will be attractive to Oklahoma wheat producers are a moderate to high level of tolerance to soil acidity and a high level of shattering tolerance. The cultivar Fuller (KAES) should displace some of the Overley acreage with its greater shattering tolerance, but Fuller may not have sufficient acid-soil tolerance to be used in many areas of north central and central Oklahoma where OK03522 will fit well. Finally, OK03522 will exceed expectations of millers for its superior kernel size, and will meet or exceed expectations of bakers for its reliable dough strength at an intermediate level of protein (Table 2).

Based on multiple-year and statewide field testing, OK03522 is best adapted to north central Oklahoma and to the Panhandle with irrigation (Table 3). The bulls-eye of its primary adaptation area extends from Enid, Okla., to Wichita, Kan. Secondary areas of adaptation may extend in a southwestern direction, but OK03522 will be at risk in extreme southwestern portions of the state if drought stress occurs in the spring. OK03522 is recommended primarily for grain-only (GO) management systems. It may present added risks when adopted in early-planted grazed systems due to its susceptibility to *Barley yellow dwarf virus*, lower propensity for tiller survival following grazing, and untimely winter dormancy release with early planting.

OK03305 should provide an update, if not replacement, to the beardless cultivar Deliver. The experimental line OK02405 previously held this position, but its very poor history of test weight performance delayed our decision to offer a replacement for Deliver in 2007. The emergence of OK03305 provides bona fide improvements over Deliver beyond its superior test weight pattern. Most notable are grain yield superiority (+4 bu/A over 19 site–years; Table 3), greatly improved straw strength, and earlier maturity. Very slight or no further improvements are observed in acid-soil tolerance and overall foliar disease resistance, for which Deliver has remained effective against WSBMV/WSSMV, leaf rust, powdery mildew, and stripe rust. OK03305 is considered inferior to Deliver for stripe rust resistance and protein content but not necessarily for protein quality (Table 2).

OK03305 is best adapted to southwest Oklahoma and the Oklahoma Panhandle (dry land or irrigated). Secondary areas of adaptation may extend south into Texas and north, though its performance in northern Oklahoma may be limited under acid-soil conditions. Chronic infection of stripe rust would present the greatest risk for OK03305, as it appears to offer no more protection than Endurance.

(Since the submission of this report, OK03522 was named 'Billings,' and OK03305 was named 'Pete.')

Table 2. Complete quality profile for composite samples of grain produced in five Oklahoma environments each in 2006 and 2007. Data provided by Richard Chen, Hard Winter Wheat Quality Laboratory, USDA-ARS, Manhattan, Kan.

		2006					2007				
Trait	*Unit*	*OK03522*	*OK03305*	*OK Bullet*	*Endurance*	*Sample mean*	*OK03522*	*OK03305*	*OK Bullet*	*Endurance*	*Sample mean*
						n=13					*n=14*
Test wt.	lbs/bu	62.6	63.3	62.8	61.1	62.5	56.2	58.9	58.7	58.0	57.2
SKCS-TKW	g	35.1	31.2	31.5	29.2	31.5	32.3	30.0	28.7	28.7	27.9
SKCS-TKW SD	g	9.7	7.4	8.3	7.9	7.9	10.2	8.3	8.1	8.5	10.2
SKCS-Diam	mm	2.5	2.3	2.4	2.1	2.4	2.4	2.3	2.3	2.2	2.2
SKCS-Diam SD	mm	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.6	0.5	0.5
SKCS-Hardness		71	66	78	70	74	60	58	69	58	64
SKCS-Hardness SD		15	15	14	16	16	20	20	19	18	18.7
SKCS-Classification		HARD	HARD	HARD	HARD		HARD	MIXED	HARD	HARD	
Flour yield	%	75	76	75	74	75	72	75	73	74	72
Flour ash (14% mb)	%	0.48	0.44	0.52	0.45	0.51	0.44	0.46	0.52	0.50	0.50
Wheat protein (14% mb)	%	13.6	12.5	13.8	13.2	13.3	11.3	11.2	12.0	10.9	12.0
Flour protein (14% mb)	%	12.2	11.4	12.6	11.9	12.2	9.8	10.0	10.9	9.7	10.8
Mixograph mix time	min	4.5	3.4	4.0	3.7	3.8	2.5	2.6	4.1	2.8	3.2
Mixograph mixing tolerance	0-6	4	1	3	1	2.4	2	1	4	2	2.9
Mixograph absorption	%	66	62	66	63	64	59	60	61	57	61
Farinograph absorption	%	63	57	62	60	62	55	53	57	55	56
Farinograph peak time	min	10	8	9	7	9	2	2	4	5	4
Farinograph stability	min	23	11	19	17	16	5	7	11	8	9
Bake mix time	min	5.1	3.9	4.8	4.4	4.4	2.9	3.0	4.2	2.9	3.7
Bake absorption	%	63	61	65	61	63	58	57	61	58	60
Loaf volume	cc	855	875	890	845	864	935	930	945	880	935
Specific loaf volume	cc/g	5.7	5.9	5.9	5.6	5.8	6.4	6.4	6.4	6.1	6.4
Loaf volume regression		60	68	61	61	62	92	89	81	84	81
Crumb grain	0-6	2.5	2.8	3.0	2.8	2.8	1.8	2.5	4.5	4.0	3.7
Crumb color		dull	dull	dull	slightly yellow		yellow	dull	dull	dull	

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Table 3. Grain yield comparisons from the 2006, 2007, and 2008 OET2 in five to eight environments per year.

Year	Entry	Lahoma	Cherokee	Winfield	DP* El Reno	Ft. Cobb	Altus/ Hobart	Sweetwater	Goodwell	DP Coyle	GO* Coyle	Across sites
		bu/ac										
2006	**OK03522**	**59**	Severe drought stress	**52**	**35**	**28**	**42**	Severe drought stress	Hailed out			**43**
	OK Bullet	60		57	38	30	59					49
	Overley	63		60	25	26	57					46
	OK03305	**67**		**49**	**33**	**26**	**54**					**46**
	Deliver	48		51	37	26	57					44
	Endurance	53		58	37	34	57					48
	Trial mean	**58**		**51**	**32**	**29**	**54**					**45**
	LSD (0.05)	10		6	11	5	7					5

Year	Entry	Lahoma	Cherokee	Winfield	DP El Reno	DP Ft. Cobb	Altus/ Hobart	DP Sweetwater	Goodwell	DP Coyle	Coyle	Across sites
		bu/ac										
2007	**OK03522**	Rained out	**32**	Frozen out	**15**	**33**	**43**	**37**	**94**			**42**
	OK Bullet		32		15	37	46	31	91			42
	Overley		37		17	35	43	38	101			45
	OK03305		**33**		**17**	**35**	**49**	**33**	**103**			**45**
	Deliver		37		16	31	41	34	80			40
	Endurance		44		25	49	35	40	103			49
	Trial mean		**32**		**17**	**35**	**41**	**32**	**90**			**41**
	LSD (0.05)		3		5	6	6	7	12			5

Year	Entry	Lahoma	DP Cherokee	Winfield	DP El Reno	Ft. Cobb	Altus/ Hobart	Sweetwater	Goodwell	DP Coyle	Coyle	Across sites
		bu/ac										
2008	**OK03522**	**74**	**49**	**58**	**64**	Excessive volunteer	**46**	Deer grazed	**50**	**40**	**52**	**54**
	OK Bullet	62	54	58	60		54		49	47	38	53
	Overley	59	45	49	48		53		38	42	54	48
	OK03305	**71**	**52**	**58**	**55**		**62**		**43**	**44**	**48**	**54**
	Deliver	67	46	57	50		45		37	47	43	49
	Endurance	62	49	55	69		50		52	50	44	54
	Trial mean	**64**	**49**	**57**	**58**		**53**		**43**	**43**	**45**	**51**
	LSD (0.05)	7	9	6	10		11		6	5	7	4

*DP = dual-purpose; GO = grain-only.
Dual-purpose sites in italics. New releases are in bold.

Wheat Variety Trials

Jeff Edwards
Plant and Soil Sciences

2007 to 2008 progress made possible through OWRF/OWC support

- **Favorable weather and adequate fertility resulted in record wheat yields. Duster and Fuller, for example, averaged more than 90 bu/A at the El Reno no-till site.**
- **Newer varieties outperformed Jagger and Jagalene at most locations, indicating that farmers still producing these two cultivars would be better served by newer genetics.**

2008 Wheat Crop Overview

Planting conditions in fall 2007 were favorable for most of the state. As is usually the case in Oklahoma, some areas lacked moisture. A large area around Frederick, for example, did not receive sufficient rainfall for wheat emergence until late winter. Rains finally came to this part of the state, and most producers were able to salvage a respectable wheat crop.

The Oklahoma Panhandle and parts of northwestern Oklahoma were dry in 2007 as well. Dry land grain yields in this region ranged from the teens in Cimarron County to the mid-twenties in Beaver County. Needless to say, dry land wheat production in the Panhandle and areas west of Buffalo was far from the bumper-crop produced in that region in 2007.

Many farmers in northcentral Oklahoma had to contend with extremely dense stands of volunteer wheat. There was some debate as to how to best handle this issue. Some growers delayed planting, hoping that most of the volunteer had emerged prior to the last tillage operation. Others simply planted and hoped that winterkill would remove most of the volunteer from fields. By the end of the season, the volunteer was still present in many fields but had little effect on final grain yield. Wheat plants compensated for the volunteer by tillering less and producing smaller heads.

Fall forage production in the OSU variety testing program ranged from 1,550 lbs/A to 2,570 lbs/A at Stillwater and 1,180 lbs/A to 3,000 lbs/A at El Reno. Regardless of the location, there were several varieties that produced acceptable forage yield. It also is important to view forage production data in conjunction with yield performance after grazing.

Even though there was adequate fall forage production around the state, many dual-purpose wheat producers reduced stocking rates or chose to forgo grazing altogether. This was a result of the record-high futures prices for wheat grain. Likewise, many producers chose to terminate grazing earlier than normal, and the bulk of cattle were pulled from wheat pasture by March 1. Average occurrence of first hollow stem among varieties in the OSU testing program at Stillwater was March 12.

Conventional till and no-till grazed plots at El Reno yielded 2 bu/A and 9 bu/A more than non-grazed plots. This is in contrast to an average 8 bu/A yield loss associated with grazing at our Marshall location. These contrasting results further demonstrate that a large portion of the yield penalty associated with gazing wheat is due to planting date. Both grazed and non-grazed plots at El Reno were sown Sept. 17. So, plots were sown at an optimal date for dual-purpose wheat production but an earlier-than-optimal date for grain-only production. Grazing likely benefited these early-sown plots through removal of excess fall growth. At the Wheat Pasture Research Unit at Marshall, we compared grazed versus non-grazed plots as management systems. Grazed plots were sown Sept. 18 and non-grazed were sown Oct. 30. Grazed wheat sown at the earlier date yielded 8 bu/A less than late-sown non-grazed plots. This was partly due to the yield penalty from grazing but also was due to the penalty of an earlier-than-optimal sowing date for grain-only production.

High nitrogen prices impacted fertility choices in 2007 and 2008. Most top-dress nitrogen applications to wheat in Oklahoma are made in January and February. The majority of the top wheat producing areas of the state were still very dry at this time and the crop was not well developed. Thus, many producers chose to reduce top-dress nitrogen applications and a few chose not to top-dress at all. Favorable environmental conditions during grain fill and adequate mineralization from soil organic matter compensated to some degree for reduced nitrogen applications.

Grass weeds were plentiful during the 2007-2008 crop year. In fact, feral rye pressure was severe enough that some fields were abandoned and cut for hay. There are several possibilities as to why grass weed pressure was higher this crop year. The inability to harvest several acres last year, however, is probably the leading culprit. Since these acres were not harvested for grain, the grass weed seed was not removed from the field and the soil seed bank was overflowing with grass weed seed. Whatever the reason, grass weed pressure was high enough that it will take several years of crop rotation and sound weed management strategies to reduce weed numbers to acceptable levels.

Insect pests frequently observed this year included Hessian flies, greenbugs, bird cherry oat aphids, and wheat stem maggots. Some of these pests reached economic thresholds in localized areas and insecticides were used.

Even though aphid numbers were low during most of the production year, barley yellow dwarf, or BYD, was a common problem during 2008. Most of the BYD observed was the result of late-winter or early-spring aphid infestations because leaf discoloration (yellowing from the leaf tip down the leaf) and only slight to moderate stunting were observed.

Symptoms indicative of *High plains virus* and *Wheat streak mosaic virus*, or WSMV, were evident in isolated fields in 2007-2008. The large amount of volunteer wheat present most likely was a big factor in the occurrence of these two diseases, as the wheat curl mite (vector for these diseases) needs a green bridge to survive the summer.

Some fields showing yellowing and stunting were incorrectly diagnosed as having WSMV. While field symptoms closely resembled WSMV, repeated lab tests showed that no WSMV was present in these fields. It was determined the culprit was likely either chloride deficiency or due to rapid changes in temperature.

Another disease that was commonly

misdiagnosed on varieties such as Doans and Duster was tan spot. Growers reported seeing yellow and brown necrotic lesions on these varieties. Tan spot was first tentatively identified as the probable cause, but repeated lab tests showed no tan spot to be present. It was determined that the yellowing and necrosis on these varieties was due to a physiological speckling that can sometimes be induced by prolonged cool conditions followed by hot conditions or by chloride deficiency. Similar observations were reported from many states north and east of Oklahoma as the season progressed.

Powdery mildew, leaf rust, stripe rust, and even stem rust were all present during 2008. Only leaf rust, however, approached levels that warranted fungicide application. Many fields were treated with a fungicide, but it is likely the high grain prices had just as much influence on these decisions as wheat foliar disease reports.

There was one confirmed case of fusarium head blight, or head scab, in 2008. This was in a field near Billings where wheat had been no-tilled into corn residue. The field was not a complete loss, but it is likely that losses were in the 30% to 40% range.

Foliar fungicide application had no effect on grain yield at Apache in 2008, but increased grain yields by an average of 13 bu/A at Lahoma. This difference, in response to foliar fungicides, was not a result of products applied or timing of application; rather, it is a reflection of the incidence and severity of disease at each location.

Average air temperatures during grain fill were cooler than normal, which provided ample opportunity for some of the late-emerging wheat to catch up. Summer-like conditions, however, prevailed in late May and temperatures soared to above 100 F. Wheat ripened quickly and harvest crews began rolling throughout the southwest during the last week of May.

Grain yields were much better than expected. Reports of grain yields in the 70 bu/A to 80 bu/A range were not uncommon, and there were a few reports of yields in excess of 100 bu/A. Harvest came to a halt by rains the first week of June and then continued in an intermittent fashion the remainder of the season. Late-season rains reduced test weights and 90 mph straight-line winds resulted in severe shatter losses.

Methods

Cultural practices

Conventional plots were eight rows wide with six-inch row spacing. No-till plots were seven rows wide with 7.5-inch row spacing. Plots were either 20 feet or 40 feet long depending on location. Conventional till plots received 50 lbs/A of 18-46-0 in-furrow at planting. No-till plots received 5 gal/A of 10-34-0 at planting. The El Reno, Marshall dual-purpose, or DP, and Cherokee locations were sown at 120 lbs/A. Marshall grain-only, or GO, and Homestead sites were sown at 90 lbs/A to compensate for late sowing. All other locations were sown at 60 lbs/A. Grazing pressure, nitrogen fertilization, and insect and weed control decisions were all made on a location-by-location basis and reflect standard management practices for the area.

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:

www.wheat.okstate.edu

2008 Oklahoma Wheat Variety Trial Summary.

	Alva	Apache	Apache fungicide	Cherokee	Elk City	El Reno Conv Till DP	El Reno Conv Till GO	El Reno No-Till DP	El Reno No-Till GO	Gage	Haskell
Variety					bu/ac						
Centerfield	59	54	53	47	26	57	52	81	65	36	50
Danby (W)	-	-	-	-	-	-	-	-	-	-	
Deliver	61	47	53	48	21	66	53	83	72	34	55
Doans	63	61	55	50	26	64	51	71	66	39	52
Duster	65	71	67	55	28	87	85	94	87	41	62
Endurance	60	55	53	55	30	74	74	82	78	41	66
Fannin	54	50	49	37	27	45	57	58	58	30	61
Fuller	69	68	67	47	29	69	69	95	78	40	59
Guymon (W)	-	-	-	-	-	-	-	-	-	-	-
Jackpot	66	61	53	49	25	64	55	86	70	41	52
Jagalene	58	64	60	52	24	57	55	79	70	40	43
Jagger	59	60	63	51	25	61	59	84	65	35	47
Mace	-	-	-	-	-	-	-	-	-	-	
OK Bullet	60	63	54	50	30	59	65	81	78	38	50
OK Rising (W)	63	59	56	-	23	-	-	-	-	37	-
Okfield	58	58	62	42	26	68	62	76	65	36	54
Overley	55	57	57	39	18	49	45	55	53	36	46
Santa Fe	60	59	60	51	25	65	69	84	82	36	53
Shocker	58	61	67	48	21	57	55	78	69	33	47
TAM 111	62	-	-	-	27	-	-	-	-	40	-
TAM 112	-	-	-	-	-	-	-	-	-	-	-
TAM 203		58	61	-	-	-	-	-	-	-	-
TAM 304	-	-	-	-	-	-	-	-	-	-	58
OK00514-05806	-	52	58	-	31	-	-	-	-	-	-
OK00611W	56	-	-	-	-	-	-	-	-	-	
OK02405	-	-	-	-	26	-	-	-	-	-	-
OK03305	60	66	61	-	26	-	-	-	-	-	-
OK03522	60	60	61	-	29	-	-	-	-	-	-
OK04505	62	63	55	-	-	-	-	-	-	-	-
OK05737W	64	-	-	-	-	-	-	-	-	34	-
OK05903C	-	-	-	-	-	-	-	-	-	-	-
OK07S110	-	-	-	-	-	-	-	-	-	-	-
STARS 0601W	-	-	-	-	-	-	-	-	-	-	-
Eve Barley	-	-	-	-	-	-	-	-	-	-	-
Va 125 Barley	-	-	-	-	-	-	-	-	-	-	-
Mean	61	59	58	48	26	63	61	79	70	37	53
LSD (0.05)	5	8	9	8	2	11	10	7	11	4	5

2008 Oklahoma Wheat Variety Trial Summary.

Variety	Homestead Conv Till	Homestead No-Till	Hooker	Keyes	Kildare	Kingfisher	Lamont	Lahoma	Lahoma fungicide	Marshall grazed	Marshall non-grazed	Olustee
	bu/ac											
Centerfield	33	41	-	-	43	56	46	60	69	52	59	51
Danby (W)	-	-	25	22	-	-	-	-	-	-	-	-
Deliver	31	40	25	23	50	47	48	68	75	54	62	53
Doans	32	40	-	48	57	65	71	75	52	64	51	
Duster	32	46	24	25	53	65	67	65	79	60	71	50
Endurance	34	42	26	25	54	62	51	66	74	60	67	53
Fannin	34	30	-	-	44	51	57	68	80	52	62	49
Fuller	36	49	27	18	60	61	69	73	80	59	73	59
Guymon (W)	-	-	25	28	-	-	-	-	-	-	-	-
Jackpot	42	47	-	-	51	60	71	80	96	61	76	56
Jagalene	28	34	28	25	45	55	44	43	71	46	41	56
Jagger	34	39	24	14	44	56	46	47	74	57	49	56
Mace	-	-	24	23	-	-	-	-	-	-	-	-
OK Bullet	34	39	26	24	41	58	51	52	73	55	60	55
OK Rising (W)	-	-	-	19	39	55	51	59	76	49	62	-
Okfield	33	43	-	-	44	53	44	52	72	51	56	49
Overley	27	33	-	-	43	54	58	66	75	59	69	55
Santa Fe	38	41	-	-	60	54	62	72	77	54	64	57
Shocker	32	38	-	-	56	49	55	81	84	54	65	53
TAM 111	-	-	27	30	-	-	-	-	-	-	-	-
TAM 112	-	-	27	30	-	-	-	-	-	-	-	-
TAM 203	-	-	-	-	-	61	-	78	84	62	72	59
TAM 304	-	-	-	-	56	-	69	-	-	-	-	-
OK00514-05806	-	-	-	-	41	-	48	50	74	-	-	-
OK00611W	-	-	-	-	44	56	50	61	74	-	62	-
OK02405	-	-	-	-	-	-	-	-	-	-	-	50
OK03305	-	-	-	-	-	58	-	-	-	-	-	52
OK03522	-	-	-	-	45	54	63	77	79	57	67	-
OK04505	-	-	-	-	56	-	59	69	78	58	65	52
OK05737W	-	-	-	-	39	61	-	55	77	-	-	-
OK05903C	-	-	-	-	-	-	-	-	-	54	-	47
OK07S110	-	-	-	-	-	-	-	59	65	-	-	-
STARS 0601W	-	-	22	12	-	-	-	-	-	-	-	-
Eve Barley	-	-	-	-	-	-	-	-	-	25	57	-
Va 125 Barley	-	-	-	-	-	-	-	-	-	39	55	-
Mean	33	40	25	23	48	56	56	64	77	55	63	53
LSD (0.05)	8	8	3	5	9	5	8	6	7	8	7	6

OKLAHOMA STATE UNIVERSITY

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