Partners in Progress
WHEAT

Wheat Research at OSU 2010

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 help 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 2009-2010. 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.

Goals to Give Us a Sense of Direction

On the best sunny day, the most powerful magnifying glass will not light paper if you keep moving the glass. But if you focus and hold it steady, the paper will light up. That is the power of concentration.

A man was traveling and stopped at an intersection. He asked an elderly man, "Where does this road take me?" The elderly person asked, "Where do you want to go?" The man replied, "I don't know." The elderly person said, "Then take any road. What difference does it make?" How true. When we don't know where we are going, any road will take us there.

Enthusiasm without direction is like wildfire and leads to frustration. Goals give us a sense of direction. The current goals that are being set by the Oklahoma Wheat Commission and Oklahoma Wheat Research Foundation are not only becoming reality, but also are increasing the enthusiasm of the Oklahoma State University Wheat Improvement Team with a direction that is helping us reach new horizons every day.

While we have items that we are constantly working on for better quality wheat production, we keep making new advances each day with research on new wheat varieties that will benefit Oklahoma wheat producers. We continue promoting crop rotations for clean wheat along with the planting of new registered and certified seeds. This year, we are proud to say that 34 percent of Oklahoma's wheat acreage was planted with releases from OSU.

We are fortunate to have great leadership on the Wheat Improvement Team at OSU's Division of Agricultural Sciences and Natural Resources. It looks like the potential for new releases this coming year will only help lead us to greater possibilities for producers in the future.

We continue to move forward with great strides of looking at new ways to accomplish the goals that we have set forth. New varieties released from OSU have had focus on drought tolerance and greater nitrogen efficiency usage. Focusing on these traits give Oklahoma producers benefits for 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. We have had some protein concerns in our state this past year. As with anything, in order to have a good product at the end, we must remember it is important to start with good quality at the beginning. We encourage soil testing that is made 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 for high quality wheat to be delivered.

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, some flour types absorb faster than others. A higher protein flour absorbs more moisture than a lower protein flour. Baker's have blamed the difference in absorption on humidity, which only makes a minute difference; however, it is a flour's protein level that directly affects the ratio of wet ingredients to dry. Higher protein flours also create stronger products that have firmer rising characteristics, which allow for better consistencies on bakery floors.

The Oklahoma Wheat Commission along with the OSU Wheat Improvement Team 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 move forward in the right direction because of the goals we place in front of us as an industry working together by being Partners in Progress.

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Genetic Improvement and Varietal Release of Hard Winter Wheat

Wheat Improvement Team

2009-2010 progress made possible through OWRF/OWC support

- **Put science into action through timely delivery of variety performance data and wheat management tactics that optimize the adoption of improved genetics.**
- **Provided 21 wheat disease updates to wheat growers, consultants, Extension educators and researchers via an electronic format.**
- **Provided decisive and vital data on nearly 1,500 experimental lines for their reaction to the wheat soilborne mosaic virus (WSBMV)/wheat spindle streak mosaic virus (WSSMV) complex. A subset of 488 advanced lines from Oklahoma also was tested in the lab using ELISA (enzyme-linked immunosorbent assay) to specifically test for resistance to WSBMV, WSSMV or both by detecting virus presence. This ongoing screening process ensures frequencies of resistance in OSU varieties exceeding 95 percent for WSBMV and 90 percent for WSSMV.**
- **Expanded efforts to more accurately determine seedling reaction in the greenhouse to leaf rust, powdery mildew, tan spot and septoria.**
- **Discovered a critical point mutation of the *Lr34* gene that, together with other gene markers further refined by the Wheat Improvement Team (WIT), can distinguish between the resistant and susceptible alleles of contemporary cultivars and OSU experimental lines.**
- **Determined genotypes of key experimental lines in the OSU wheat improvement program using seven perfect gene markers for wheat development and resistance to leaf rust, stripe rust and powdery mildew.**
- **Further developed winter wheat materials with probable adult-plant resistance to leaf rust and stripe rust.**
- **Demonstrated that developmental variation in key growth stages is mainly controlled by three loci, *VRN-A1*, *PPD-D1* and *VRN-D3*, which act in vernalization and photoperiod pathways. Their corresponding gene markers (developed by the WIT) revealed distinct allelic patterns at these loci in OSU materials to suggest a marker-based selection approach in future breeding generations for optimized dual-purpose adaptation.**
- **Documented reduced populations of Hessian flies in the major wheat growing regions of Oklahoma in 2010.**
- **Demonstrated reduced fly infestations on certain OSU experimental lines and available cultivars that have resistance to natural fly populations.**
- **Used an additional set of 201 grain samples from the OSU wheat improvement program to expand our long-term database for associating the presence of specific glutenin subunits (low molecular weight and high molecular weight) with end-use traits of interest to the baking industry.**
- **Provided novel analysis of extensibility, viscous (flowability), elastic (stiffness) properties and gluten content of elite experimental lines.**
- **Concentrated crossing efforts on a new group of winter synthetic materials.**

- **Initiated a historical yield trial to determine yield advances made during the semidwarf era.**
- **Certified to the USDA-APHIS-PPQ that no Karnal bunt was detected in wheat produced in Oklahoma, based on 45 wheat grain samples from 13 counties. This data was used to obtain a phytosanitary certificate allowing Oklahoma wheat to move without restriction into the export market.**
- **Identified two candidate cultivars worthy of continued foundation seed production and potential release in 2011, pending final data analysis and quality testing:**

  OK05526-RHf, *KS94U275/Endurance*

  OK05212, *OK95616/Hickok//Betty*
- **Identified four additional candidate cultivars worthy of initiating foundation seed production in 2010, with final release decision pending in 2011 (OK07S117, OK07209, OK07214 and OK07231).**
- **Since 1998, the approximate rate of annual genetic gain accrued in the OSU wheat improvement program for grain yield was 1.5 percent.**

Oklahoma's WIT is committed to discovering genetic solutions and creating greater economic opportunities for Oklahoma's wheat producers. Lost to retirement in 2010 was one of its charter members, Bjorn Martin, specializing in drought resistance and wheat physiology. Eight OSU faculty remained to form an integrated team that combines fundamental and applied components of wheat research to achieve a common goal—to move the entire chain of Oklahoma's wheat industry forward with the infusion of new, improved cultivars.

Scientists on the WIT are **Jeff Edwards**, information exchange and systems research; **Bob Hunger** and **Art Klatt**, wheat pathology research and development of disease-resistant germplasm; **Kris Giles** and **Tom Royer**, characterization of Hessian fly diversity and resistance; **Patricia Rayas-Duarte**, cereal chemistry; **Liuling Yan**, Quantitative Trait Loci (QTL) discovery and genomic technology; and **Brett Carver**, wheat breeding and genetics.

The 2009-2010 season produced yet another bumper crop of research information and technology, and a diverse panel of candidates from which to choose OSU's next wheat cultivar ... or two. In this report, you can read more about these and other significant highlights, such as the value ($21.46 per acre) field day attendees placed on the information they received in 2010 from the small grains Extension program; expanded research to more accurately determine wheat disease reactions, including tan spot and septoria; the first widescale application of gene markers discovered with Oklahoma Wheat Reasearch Foundation (OWRF) and Oklahoma Wheat Commission (OWC) funding to more precisely select purelines for further field testing, including a new and unique marker for powdery mildew resistance; the rolling out of synthetic derivatives with improved adaptation to winter wheat production areas; and the assimilation of multiple-year data on Hessian fly resistance, a trait that promises not to be lacking in future breeding generations thanks to this new area of OWRF- and OWC-funded research initiated in 2006.

Information Exchange and Systems Research

Jeff Edwards
Plant and Soil Sciences

The information exchange portion of the WIT team continued to focus on timely delivery of relevant information to the Oklahoma wheat farmer. Timely information was delivered to Oklahoma wheat farmers through 15 issues of the *Plant and Soil Sciences Extension Newsletter* in 2010, and the e-mail distribution list for this publication continues to grow. The small grains Extension program joined the latest technological revolution in late 2010 and opened a Twitter account (@ OSU_smallgrains) that is used to keep followers aware of recent developments in the field.

Data were collected at the 2010 wheat field days to determine financial impact of the OSU small grains variety testing program. Field day attendees represented more than 1.7 million acres and placed an average value of $21.46 per acre on the information they received. This equates to $37 million in perceived value by producers from a $25,000 annual investment in the small grains variety testing program by the OWC and OWRF. This and other impact statistics were published in two tri-fold leaflets: L-342, *Impact of the OSU Wheat Variety Testing Program* and L-343, *Impact of the OSU Small Grains Extension Program*.

Wheat variety trial results were posted on the small grains Extension website (www.wheat.okstate.edu) within a few days of harvest at each site, which allowed local producers to access data much more quickly than in previous years. Variety trial data were accessed from the website more than 50 times per day during wheat harvest. 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.

In addition to data on released cultivars, the WIT provided phenological, morphological and yield performance data on experimental cultivars that are candidates for release. Experimental lines OK05526 and OK05212 were tested at 11 small grains variety performance sites in 2009-2010. As shown in Table 1, these candidate cultivars offer considerable yield improvement over Fuller and Jagger. Duster had an outstanding year and no cultivar, released or experimental,

Table 1. Performance of two candidate cultivars in the 2009-2010 wheat variety trials.

Variety	*Forage Yield*	*Grain Yield*	*Test Weight*
	-----lbs/A-----	-----bu/A-----	-----lbs/bu-----
OK05526	2,520	45	57.5
OK05212	1,840	44	56.5
Duster	2,810	49	57.6
Endurance	2,450	44	55.6
Fuller	2,430	41	56.9
Jagger	2,320	37	56.0

was close competition for Duster when averaged across numerous locations. As demonstrated this past year, however, disease races can shift and cultivars can quickly become obsolete. Data from 2010 indicate that OK05526 and OK05212 offer promise as high-yielding cultivars with improved disease resistance (Table 1).

Wheat Pathology Research and Development of Disease-Resistant Germplasm

Bob Hunger
Entomology and Plant Pathology

Evaluation of experimental lines in the OSU wheat improvement program for reaction to diseases including leaf rust, the WSBMV/WSSMV complex, powdery mildew, tan spot and septoria is critical to developing improved wheat cultivars. This testing is conducted in the greenhouse, the field or both.

During 2009-2010, our efforts were expanded to more accurately determine the reaction of wheat seedlings tested in the greenhouse. Many factors can impact or even devalue seedling ratings — most notably adult plant resistance, which is only expressed as plants approach maturity. Although field ratings are the most reliable ratings for disease reaction (reaction to barley yellow dwarf virus [BYDV] for example, Table 2), greenhouse testing is useful in identifying highly resistant and highly susceptible lines. This appears to be the case with powdery mildew. In Table 3, Century and Armour, which are highly resistant to powdery mildew in the field, also are identified as highly

Table 2. Reaction of winter wheat varieties and advanced experimental lines to barley yellow dwarf virus (BYDV) at Lahoma, 2010. Reaction was determined by estimating the percentage of each plot showing BYDV symptoms on May 14, 2010.

Variety/Breeding Line	Origin	BYDV Incidence (%) (Average of 8 Replications)
Resistant (0-16% incidence)		
Centerfield	**OSU**	**9.4**
OK05511	**OSU**	**10.0**
Endurance	**OSU**	**11.3**
Everest	KSU	11.9
Duster	**OSU**	**15.6**
Moderately Resistant (17%-45% incidence)		
OK05526	**OSU**	**28.1**
OK07231	**OSU**	**23.1**
OK05212	**OSU**	**33.1**
Jackpot	AgriPro	37.5
Billings	**OSU**	**44.4**
Armour	WestBred/Monsanto	48.8
Moderately Susceptible (46%-76% incidence)		
Greer	AgriPro	54.4
Overley	KSU	59.4
OK Bullet	**OSU**	**63.8**
Santa Fe	WestBred/Monsanto	64.4
Pete	**OSU**	**66.9**
Doans	AgriPro	69.9
Fuller	KSU	72.5
Shocker	WestBred/Monsanto	75.6
Susceptible (>76% incidence)		
Jagalene	AgriPro	82.3
Deliver	**OSU**	**85.0**
Jagger	KSU	85.0
TAM 401	TAMU	92.3
TAM 203	TAMU	93.3
Art	AgriPro	94.5

Boldface is used to indicate OSU wheat varieties.

Table 3. Examples of reactions of winter wheat varieties to various wheat diseases in greenhouse testing compared to field ratings.

POWDERY MILDEW

Variety/Breeding Line	*Origin*	*No. Seedlings Tested*	*Reaction (1-4)*	*Greenhouse Reaction*	*Field Reaction*
Jagger (susceptible check)	KSU	263	4.0	S	S
Century (resistant check)	OSU	141	0.7	R	R
Armour	Westbred/Monsanto	9	0.0	R	R
Billings	OSU	36	4.0	S	MR
Endurance	OSU	36	3.7	S	MR
Duster	OSU	61	4.0	S	MR
Fuller	KSU	16	4.0	S	MS
TAM 203	TX A&M	9	4.0	S	MS

TAN SPOT

Variety/Breeding Line	*Origin*	*No. Seedlings Tested*	*Leaf Reaction*		*Rating*	
			1st	*2nd*	*Grnhse*	*Field*
TAM 105 (susceptible check)	TX A&M	278	29	7	S	S
Red Chief (resistant check)	Cornell Univ.	190	1	<1	R	R
Armour	Westbred/Monsanto	9	1	<1	R	MR
Billings	OSU	32	34	7	S	MS
Endurance	OSU	32	50	24	S	MS
Duster	OSU	60	12	6	MR	MS
Fuller	KSU	18	19	5	MS	MS
TAM 203	TX A&M	9	8	1	MR	MS

SEPTORIA

Variety/Breeding Line	*Origin*	*No. Seedlings Tested*	*Leaf Reaction 2nd*	*Rating*	
				Grnhse	*Field*
Newton (susceptible check)	KSU	129	28	S	S
2137 (resistant check)	KSU	100	16	MR	MR
Armour	Westbred/Monsanto	9	<1	R	MS
Billings	OSU	17	23	MS	MR
Endurance	OSU	26	16	MR	MR
Duster	OSU	27	22	MS	MS
Fuller	KSU	17	28	S	MS
TAM 203	TX A&M	8	50	S	MR

resistant in seedling assays. However, many cultivars identified as susceptible in the seedling assay actually give a moderately resistant or moderately susceptible reaction in the field. Thus, it is known that lines identified as resistant in the seedling test will be resistant in the field, but lines identified as susceptible to powdery mildew in the seedling assay will not necessarily score susceptible to powdery mildew in the field.

Two diseases, tan spot and septoria, are important in no-till systems, but ratings in the field are difficult to obtain in Oklahoma on a consistent basis. Thus, a greenhouse seedling trial offers an alternative to evaluating the reaction of a line/cultivar to these diseases. Attempts this past year provided information, but agreement with known reactions of cultivars was not as strongly correlated as desired (Table 3). Achieving consistent reactions to tan spot and septoria is challenged by the fact that pathogens that cause these diseases do so primarily by the production of toxins that kill leaf tissue (Figure 1). Toxin production is not

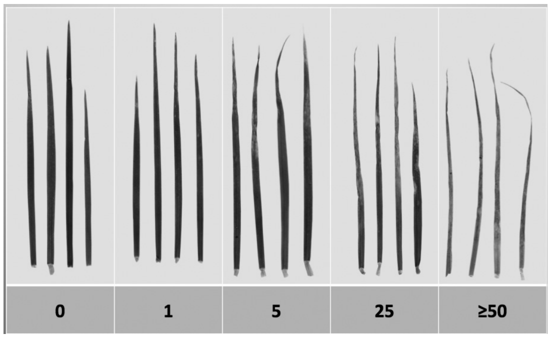
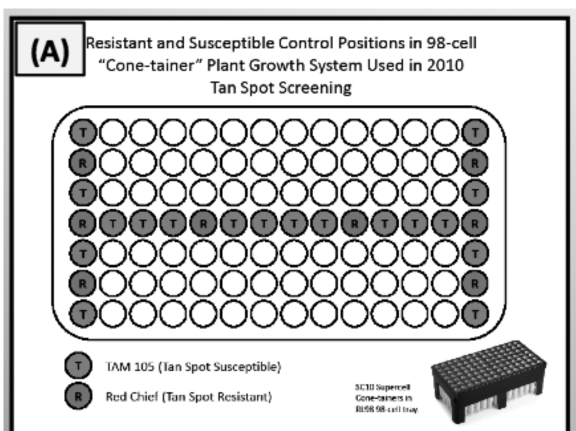


Figure 1. Rating of wheat seedling leaves for reaction to tan spot or septoria . Numbers from 0-50 indicate the percentage of the leaf showing symptoms. Based on the system developed by W.C. James, 1971. Canadian Plant Disease Survey, 51: 39-65.



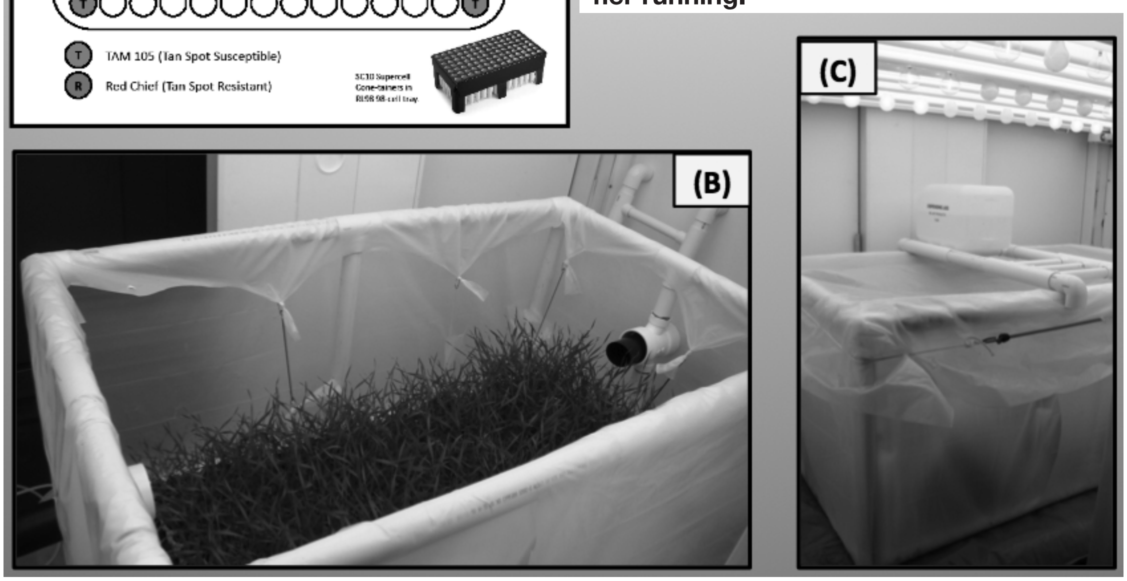


Figure 2. Schematic showing increased replication and inoculation of wheat seedlings for tan spot and septoria testing. (A) Conetainers in racks are used to rate multiple leaves of breeder lines with two seedlings per cone. (B) Inoculation chamber inside a growth chamber holding four racks of conetainers. (C) Inoculation chamber covered with plastic with humidifier running.

always consistent, different seedling leaves give different reactions, and leaf aging/senescence can be confused with the toxin symptoms. As a result, greater variability in reaction is expected. To some extent, this can be overcome by increasing the number of seedlings tested, which is being pursued in 2010-2011 trials by rating multiple leaves of individual seedlings (usually two) growing in "conetainers" as depicted in Figure 2. Although such testing requires significantly more time and effort to conduct, results facilitate selection of lines with improved resistance to leaf rust, powdery mildew, tan spot and septoria.

Finally, funds provided by the OWC supported the testing of the 2010 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

Germplasm development in the OSU wheat improvement program has two recurrent areas of focus described here: i) incorporate stable and durable leaf and stripe rust resistance into adapted winter wheat backgrounds for Oklahoma, and ii) transfer useful genes — especially genes for improved drought and heat tolerance and improved resistance to tan spot — from synthetic wheat into adapted winter wheat. The spring wheat breeding program at CIMMYT has generously provided primary synthetic hexaploid (cultivated durum x *Ae. tauschii* [goatgrass]) wheat lines and advanced breeding lines with nonrace specific/adult-plant resistance (APR) to leaf rust and stripe rust. Crosses between local winter wheat materials and these introduced materials have been made for the last 10 years, and materials derived from these crosses are in the final stages of evaluation.

During the 2009-2010 crop cycle, a new race of stripe rust became evident throughout the Great Plains region. This new race caused Jagger to become susceptible to stripe rust, and in addition, several cultivars whose resistance was based on the Jagger genes also became susceptible to stripe rust. It is also quite likely that a new race of leaf rust was present in certain locations last year, which caused previously resistant advanced materials to become susceptible. Even with these race changes, many of the advanced lines derived from APR materials had good resistance to both leaf rust and stripe rust. It is believed the majority of these materials contain the APR genes *Lr34* and *Lr46*, plus at least one, and in most cases two, additional APR genes of unnamed designation. Many of these materials are currently in second-year yield trials. If they continue to show high yield potential and acceptable quality, they could lead to cultivars with a more durable type of rust resistance, which would be highly beneficial for the wheat producers of Oklahoma.

Many new crosses were made to the spring type and winter type synthetics during the 2009-2010 crop season. In addition, more crosses were made to promising winter type synthetic derivatives selected from previous crosses. It is quite likely that more promising selections will be obtained from this second round of crossing. In addition, 30 synthetics were identified by Cheryl Baker at USDA-ARS (Stillwater) as having excellent greenbug resistance. Baker's results have shown that none of the current synthetics have acceptable levels of resistance to Russian Wheat Aphid.

In 2010, a yield trial was initiated to determine the rate of realized genetic gain in grain yield on a regional basis during the semidwarf era (early 1970s to present day). Twenty-eight cultivars were tested at 11 sites in Oklahoma, Kansas and Texas, and the trial will be repeated at 11 sites in 2011. The trial includes fungicide treatments to determine the effect on yield gains under reduced disease pressure.

The regional cooperative nursery near San Antonio, Texas, continues to serve as a hotspot 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 evaluated under severe rust pressure at this site. In 2010, this site provided good differentiation for stripe rust reaction. Significant benefits continue to be derived from the cooperative program with CIMMYT.

Characterization of Hessian Fly Diversity and Resistance

Kris Giles and Tom Royer
Entomology and Plant Pathology

The WIT continued to survey natural Hessian fly populations in Oklahoma and assess the ability to provide a genetic line of defense to those populations. The overall objective was to identify sources of Hessian fly resistance with specific value to the OSU wheat improvement program. Auxillary objectives included the deployment of pheromone traps to characterize Hessian fly flight activity and subsequent inclusion of this information into management guidelines. Further, the WIT is evaluating effectiveness of seed treatments as one component of a comprehensive Hessian fly management plan.

During the growing season, Hessian fly pupae was collected from all of the major wheat growing areas in Oklahoma. Contrary to previous years, populations were quite low in most locations, including fields near Apache, which traditionally have extremely high densities. It is possible that more widespread use of Duster and Centerfield, which are resistant to Oklahoma Hessian fly populations, have reduced regional infestation levels, especially in early-planted and/or no-till fields where flies have been a significant problem. Pupae were sent to Kansas State University for biotype assessment, and the WIT is awaiting confirmation on biotypes. Data continues to indicate that biotype GP is common in Oklahoma.

In replicated field studies, the reaction of wheat lines was evaluated in the OSU wheat improvement program (and selected check cultivars) to natural fly populations near Apache. Northern plots near Braman were planted late and did not survive winter growing conditions. Again, the natural fly infestations near Apache were abnormally low (Table 4). Fly intensities exceeded the Economic Injury Level of one per tiller in only a few entries. Because of low population density, it was difficult to separate the impact of resistance and fly infestations on grain yield.

Table 4. Hessian fly infestations in the 2009-2010 Oklahoma Elite Trial at Apache with entries arranged in decreasing yield order. Duster is not shown due to incorrect seed source.

Entry	*Flies/Tiller*	*bu/A*
OK06822W	0.01	64.91
TAM 203	0.52	52.79
OK05511	0.23	45.64
Pete	0.14	45.00
OK Bullet	0.05	44.19
OK07919C	0.26	43.18
OK06127	0.03	42.76
OK06029C	0.27	41.24
Jackpot	0.59	40.86
Centerfield	0.10	40.73
OK06528	0.49	40.56
OK05312	0.05	40.12
OK06609	0.01	39.09
OK07209	0.01	38.63
Chisholm	1.23	37.23
OK06336	0.06	37.13
OK07231	0.48	37.04
OK05526	1.53	36.85
OK07214	0.04	36.63
OK05212	0.56	36.31
Fuller	0.39	35.50
OK06332	0.64	32.51
OK05711W	0.78	32.22
OK03825-5403-6	0.53	31.81
OK06617	0.75	30.20
OK06618	0.56	28.82
Billings	0.29	28.52
Endurance	0.50	27.87
OK05204	1.20	25.72

To demonstrate the value of the Hessian fly resistance program, multiple years of data were summarized (Table 5) for resistant and susceptible entries (cultivars and candidates for release). As expected, Duster is clearly a durable option for Hessian fly management and also superior in overall yield (Table 5). The partially-resistant cultivar Centerfield continues to perform well in our trials. The value of resistance is quite clear; Hessian fly numbers are lower and yields are preserved on entries that have some resistance. Infestations above three per tiller appeared quite damaging.

Currently, Oklahoma wheat producers have resistance options for Hessian fly, and future breeding efforts look promising. The WIT is particularly interested in monitoring future Hessian fly infestations on promising candidate lines that are either susceptible or demonstrate some level of resistance.

Table 5. Multi-year responses for common entries in Hessian fly infested sites of the Oklahoma Elite Trial during the period 2006-2010.

Entry	*Resistance*	*Years of Data*	*Average Flies/Tiller*	*Average Yield Rank (Out of 30)*
Duster	Resistant	3	0.31	1
Centerfield	Partial	4	0.33	10
Chisholm	Partial	4	1.52	13
OK Bullet	Susceptible	3	2.58	9
Deliver	Susceptible	3	3.29	17
Endurance	Susceptible	4	3.56	22
OK06618	Resistant?*	2	0.53	.
OK05204	Resistant?*	2	0.70	.
OK05526	Resistant?*	2	1.17	.
OK06029C	Susceptible	2	1.79	.
OK03825-5403-6	Susceptible	3	3.27	21
OK05312	Susceptible	2	3.85	.
OK05212	Susceptible	2	4.18	.
OK05711W	Susceptible	3	6.14	27

* Inconsistent reaction or lack of confidence in data.

Cereal Chemistry

Patricia Rayas-Duarte
Biochemistry and Molecular Biology

An important component of OSU's wheat improvement research is the selection of quality traits that offer better performance to the end user than those present in currently grown cultivars. Among the important traits of end-use quality are viscoelastic parameters of the dough or of the gluten matrix formed when the flour is mixed with water. A hallmark of functional wheat quality that breeders around the world use as benchmarks is the composition of proteins that form gluten, known as glutenins. Two types are recognized as high molecular weight (HMW) and low molecular weight (LMW) glutenins. There is a growing realization that both types are important contributors to end-use quality.

In 2009-2010, viscoelastic and elastic properties were analyzed, as well as the gluten content, of 50 elite OSU experimental lines and cultivars. The gluten was subjected to stresses meant to simulate the dough mixing and formation process; the compliance reaction (flowability or viscous behavior) derived from the protein molecules was recorded. When stress placed upon the gluten is released, the elastic (stiffness) properties can be measured. With this test we were able to separate flowability versus stiffness properties, which are physical properties universally evaluated in polymers and are directly related to their composition, specifically the size of the molecules formed. The extensibility properties of gluten are obtained by stretching it at a particular rate and determining the force needed to stretch it as well as the work needed to accomplish the task. The amount of wet gluten, an index obtained from the ratio of the gluten components that form a large agglomerate and do not pass a particular sieve (indicating large molecular size particles formed) relative to the total gluten, also was evaluated in the 50 wheat samples.

Efforts were extended to identify and correlate the presence of HMW and LMW glutenins present in 201 selected samples. In 2009, the WIT paid particular attention to the LMW glutenin composition since this group of proteins is believed to contribute uniquely to the quality of gluten formed. If this group is not present, the gluten will be too stiff. These LMW glutenins are difficult to analyze and the scientific community is slowly making progress in understanding their role in different aspects of end-use quality traits. The difficulty in studying these proteins comes in part from their diversity and in their difficult physical separation for analysis. Efforts focused on documenting which proteins dominate in the OSU wheat improvement program in response to continued selection pressure over several years for certain end-use quality traits. The WIT intends to continue expanding its knowledge of these LMW glutenins with materials from the OSU wheat improvement program, as well as interacting with researchers of other programs around the world to confirm their consistency.

Finally, the variation observed in the 50 samples from 2009 was largely explained by viscoelasticity and extensibility properties. In contrast, the loaf volume (a very important baking characteristic), flour protein and mixing properties were minor contributors to the variation observed. Principal Component Analysis was performed to determine the explained variance. When the baking, flour protein and mixing properties were included with the viscoelastic and extensibility properties and with the wet gluten plus gluten index, the total explained variance was 45 percent. When the analysis was performed including only the major contributors to the variance (that is, the viscoelastic and extensibility properties), the explained variance was 51 percent. This means that by using the viscoelastic and extensibility properties, a slightly improved statistical model was obtained, and the variation due to other properties did not contribute significantly to the variance. In other words, the WIT was able to identify differences that otherwise may have gone undetected using traditional tests in wheat quality laboratories.

QTL Discovery and Genomic Technology

Liuling Yan
Plant and Soil Sciences

Leaf rust is one of the most significant inhibitors of wheat production in the southern Great Plains. Jagger and 2174 adult plants show divergent reactions to leaf rust, and the QTL responsible for leaf rust variation found in a random set of progeny derived from the cross, Jagger x 2174, was found to be associated with the *Lr34* locus located on chromosome 7DS. This gene explained up to one-third of the variation in leaf rust reaction observed in the field. However, the two cultivars have exactly the same allele for previous molecular markers such as *csLV34*, and for two polymorphic sites in exon 11 (E11) and exon 12 (E12) of the *Lr34* gene that was recently cloned.

Complete sequences of the *Lr34* gene were determined for both Jagger and 2174 alleles, each containing approximately 16,000 pairs of nucleotides. A single-nucleotide polymorphism (SNP), or point mutation, was found in exon 22 (E22) of *Lr34* in the Jagger allele that results in a premature stop codon and thus a nonfunctional form of *Lr34* (Figure 3). The *Lr34*-E22 marker, which detects the critical SNP in E22, provided a molecular basis for differentiation between the resistant 2174 allele and the susceptible Jagger allele, and platform by which to discriminate among experimental lines in the OSU wheat improvement program.

The WIT has genotyped contemporary cultivars and advanced lines using gene markers for the three polymorphic sites at E11, E12 and E22 of the *Lr34* gene. Genotypes of locally adapted cultivars according to the *Lr34* gene markers are listed in Table 6. This type of information is precisely what is being used in the OSU wheat improvement program to select for leaf rust resistance. The strategy is to use gene *Lr34* as a ground floor for resistance, to which additional floors or genes are added that confer effective race-specific or nonrace specific resistance. Combining genes in this fashion critically depends on our ability to identify *Lr34* at the genotypic, or DNA, level.

Note in Table 6 that the recently released cultivar Duster has been confirmed to carry an effective *Lr34* gene, both in genotype and phenotype. Also, the resistance observed in Fuller is conferred not by *Lr34* but by other resistance gene(s), which might be explored. Finally, many Great Plains cultivars show heterogeneity for *Lr34*-E11 and *Lr34*-E12 markers (designated as 'H' in Table 6), possibly indicative of nonspecificity of the published markers for genome D or the occurrence of two or more copies of *Lr34*. A resistant allele at all three polymorphic sites provides unambiguous identification of the functional *Lr34* allele in wheat. In Table 6, the resistant allele is designated 'B' (*Lr34*-E22) and 'A' (*Lr34*-E11, *Lr34*-E12).

Figure 3. Allelic variation at the *Lr34* gene between susceptible Jagger and resistant 2174.

Table 6. Allelic identification at *Lr34*.

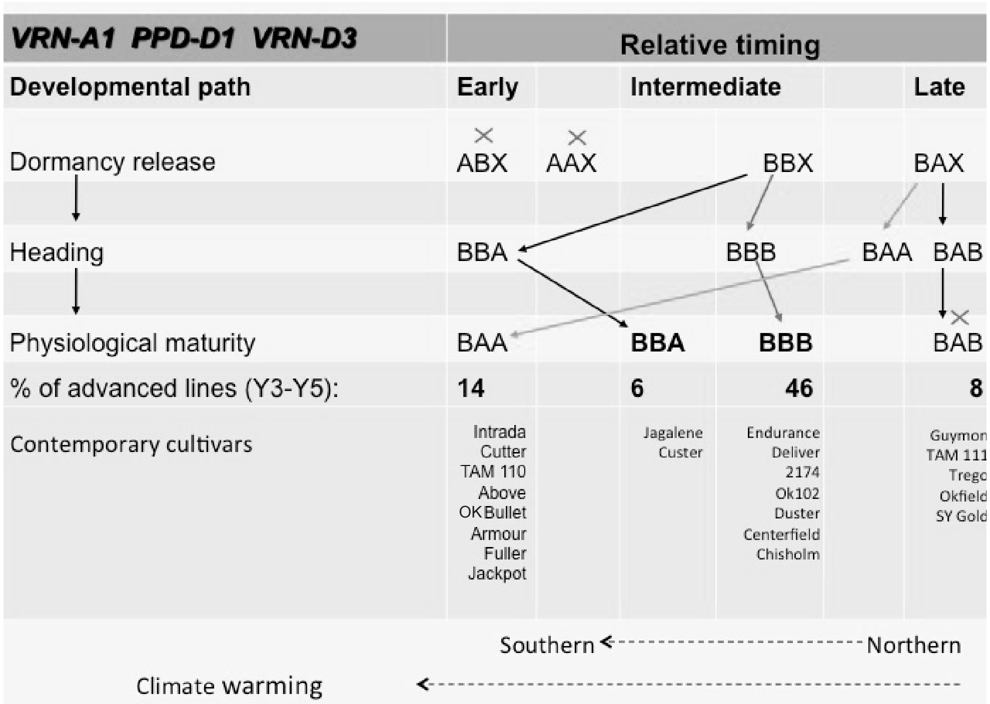
Variety	*Lr34*-E22	*Lr34*-E11	*Lr34*-E12	Effective *Lr34*	Field Reaction
2174	B	A	H	Yes	I
Armour	B	B	B	No	R
Billings	B	B	B	No	R
Duster	B	H	H	Yes	R
Endurance	B	B	B	No	MR
Fuller	A	A	H	No	R
Jackpot	B	B	B	No	MR
Jagger	A	A	H	No	VS
OK Bullet	A	A	H	No	MS
Pete	B	H	B	No	MR

Gene markers were used for *VRN-A1* on chromosome 5A, *PPD-D1* on chromosome 2D, and *VRN-D3* on chromosome 7D to classify OSU experimental lines on the basis of their maturity patterns. Each gene has two alleles, 'A' for Jagger and 'B' for 2174, and the three genes make eight genotypes (Figure 4). Jagger has an 'early' allele at each of *VRN-A1* and *VRN-D3*, whereas 2174 has an 'early' allele at *PPD-D1* due to its insensitivity to photoperiod. *VRN-A1*, *PPD-D1* and *VRN-D3* exert primary effects on stem elongation, heading date and physiological maturity, respectively, but it is the integration of different genes, their alleles and duration of their effects altogether that determine variation in arrival at each stage, and thus the length of the phase among successive stages. Additional genes yet accounted for likely influence maturity and should add precision to the genetic model.

It was found that the majority of advanced experimental lines tested in 2010 (46 of 74 lines) had genotype BBB—the specific combination of the 2174 allele at all three loci. This genotype appears to provide an ideal fit for a dual-purpose environment, in which delayed stem elongation, but not late heading date or physiological maturity, are desired (Figure 4). Genotypes AXX (X = A or B) are associated with earlier development by allele *VRN-A1a*, regardless of other loci, and may lead to precocious first hollow stem arrival and could result in greater risk to late-season freeze events. Only 1 percent of the lines tested in 2010 from OSU belonged to this genotypic class. On the other hand, genotype BAB is associated with later development at each of the three loci and may lead to undesirable late maturity. The genetic models will be further developed to breed cultivars adapted to different management schemes, to different geographical environments and to changing climates.

Gene markers were used to determine genotypes of breeding materials used as primary parental stocks for future OSU wheat cultivar development. The targeted genes included *Yr17* for stripe rust and *Pm3* for powdery mildew, in addition to the genes mentioned above for leaf rust reaction and development. Extensive application of perfect gene markers

Figure 4. Immediate applications of developmental genes in wheat breeding.



has increased selection efficiency and selection confidence, and will ensure greater efficiency in breeding more and better winter wheat cultivars for Oklahoma.

Wheat Breeding and Genetics

Brett Carver
Plant and Soil Sciences

Year in review. Diseases once again played an essential role in forming selection decisions throughout all phases of the OSU wheat improvement program in 2009-2010. At the top of the list was stripe rust, a disease that, with exception of a couple of cameo appearances in recent years, has had limited impact on selection in Oklahoma since 2005. The stripe rust pathogen is highly variable for virulence to resistance genes currently deployed in hard winter wheat. Such variability played out in April 2010, when resistance genes derived from Jagger no longer provided the expected level of protection in experimental populations and breeding lines. What made the 2010 stripe rust event so noteworthy was that Jagger is known to have at least two genes for adult-plant resistance to stripe rust (see report by Liuling Yan) and possibly more. The potential downfall of these genes was likely their race specificity, though the relevant race(s) were previously not in sufficient frequency to cause adverse reaction in Oklahoma wheat fields. A race-specific resistance gene may provide effective resistance to stripe rust for an average of about three years to four years, so Jagger certainly beat the odds.

Normally about 15 percent to 20 percent of OSU breeding materials are removed from further evaluation in any phase of the breeding cycle, based off a wide range of target traits. In 2010, this cull rate varied from 20 percent to 35 percent, with stripe rust reaction accounting for most of the spike in selection intensity. The spike could have been even higher if not for decisions made several years ago to reduce dependency on Jagger as a foundation genotype in the OSU wheat improvement program. This decision was in fact made for reasons other than potential vulnerability to stripe rust, including acute susceptibility to leaf rust, powdery mildew and BYDV, and unstable and precocious dormancy release patterns unbefitting to dual-purpose systems. What remains in the breeding program, moving forward to the 2010-2011 selection season, are materials featuring effective resistance to races either prevalent in Oklahoma before 2010 (e.g., PST100) or during the 2010 season. Table 7 summarizes the reactions of experimental lines chosen for testing in the 2011 Oklahoma Elite Trial (OET) 3. Note that only one experimental line, a high yielding white wheat named OK08707W, produced a susceptible reaction to stripe rust race(s) prevalent in 2010.

Any discussion of disease pressure in 2010 would be incomplete without reference to BYDV, a disease found in nearly all breeding nurseries. Though its presence was widely felt, its impact was not as severe or yield-limiting as stripe rust. Nevertheless, BYDV tolerance is becoming a greater focal point in the OSU wheat improvement program as efforts intensify to produce cultivars with improved early-planted, dual-purpose adaptation. These cultivars are branded with the ***Grazen*****Grain** trademark. Four cultivars already released from OSU — 2174, Endurance, Duster and Centerfield — offer relatively good BYDV tolerance and have provided a solid foundation from which to develop improved cultivars with a comparable level of tolerance. Advanced experimental lines from Table 7 that might carry this reputation are **OK05212**, **OK05526-RHf** (50 percent

Table 7. Reactions to stripe rust for 25 elite experimental lines advanced to the 2011 Oklahoma Elite Trial 3 nursery, based on artificial inoculation with race PST100 in the field at Rossville, Kan., (data provided by USDA-ARS) and natural infection in breeding nurseries statewide in 2010.

Experimental	Source Nursery in 2010	Race PST100 Rossville	2010 Oklahoma Statewide
OK05212	OET3	R	R
OK05312	OET3	MS	MR
OK05526-RHf	OET3	I	I
OK05511-RHf2	OET3	R	R
OK07209	OET3	R	MR
OK07214	OET3	R	R
OK07231	OET3	MR	MR
OK06336	OET3	R	R
OK06617-RHf	OET3	I	I
OK07216	OET2	I	R
OK07218	OET2	S	MR
OK07226	OET2	I	I
OK07S117	OET2	MR	R
OK07418	OET2	S	I
OK08214	OET1	I	R
OK08127	OET1	I	I
OK08306	OET1	I	R
OK08328	OET1	MR	MR
OK08413	OET1	S	MR
OK08539	OET1	R	R
OCW00S063S-1B	OET1	S	I
OK08229	OET1	S	I
OK07820W	OET2	R	R
OK08707W	OET1	MR	MS
OK08826W	OET1	R	R

S=Susceptible, MS=moderately susceptible, I=intermediate, MR=moderately resistant and R=resistant

Table 8. Grain yield and visual tolerance ratings collected from the 2010 Oklahoma Elite Trial 3 at Enid (pH~4.0). Yield data were potentially biased by variable reactions to stripe rust.

Entry	*Grain Yield bu/A*	*Visual Rating 1-5*
Duster	56	1.0
Jackpot	55	1.6
OK05212	55	0.9
OK07214	53	1.9
OK06618	52	1.7
OK07231	51	1.8
OK06029C	49	1.2
OK06127	48	1.4
OK06609	48	1.2
Endurance	47	1.1
OK06822W	47	2.7
OK06617	46	1.1
OK05204	46	2.7
Billings	44	1.7
OK06332	44	3.0
OK06336	43	1.9
Chisholm	43	2.0
Centerfield	40	2.0
Pete	40	2.3
OK05511	38	3.0
OK Bullet	37	2.4
OK03825-5403-6	37	2.0
OK05526	34	3.7
OK05711W	31	4.1
Fuller	29	4.0
OK07209	27	4.9
OK06528	26	1.3
OK07919C	22	4.7
TAM 203	20	4.9
OK05312	18	5.0
Mean	41	2.4
C.V.	12	27.1
LSD (0.05)	8	1.0

Top LSD group of entries enclosed in dashed box. Most susceptible group of entries are shaded.

Endurance), OK05511-RHf2 (50 percent 2174), OK06617 and **OK07209** (50 percent Duster). See Bob Hunger's report for more discussion of cultivar reactions to this disease.

Selection continued under low pH soil conditions near Enid. This site has long provided reliable visual ratings of experimental lines committed to statewide yield testing, but seldom have conditions allowed timely and unhindered harvest from severe weed

pressure. Yield estimates were indeed obtained in 2010 on experimental lines tested in the OET3 (most advanced materials), and the data are reported in Table 8, along with visual readings averaged throughout the season (1-to-5 scale, in which 5 was most susceptible). The yield results may not directly associate with the visual ratings because the former were biased by varying sensitivities to stripe rust. This bias would not have been manifested until well after the last visual rating for acid soil tolerance. For example, the experimental line OK06528 appeared to have superior acid soil tolerance, but its subsequent yielding ability was compromised by severe susceptibility to stripe rust.

The yield data at Enid confirmed the superior tolerance (and adequate protection from stripe rust) for the experimental lines **OK05212**, **OK07214** and **OK07231**. The latter two lines each contain Duster as 50 percent of their parentage. Note that the single effect of acid-soil stress (OK07209) or the compounded effect of susceptibility to stripe rust (OK05312) caused lower yield performance of some experimental lines and contemporary check cultivars (Fuller and TAM 203) than the long-term check cultivar, Chisholm, with adequate protection to both stress factors but released almost 20 years ago. In effect, sensitivity to low soil pH can wipe out 20 or more years of genetic gains for grain yield in the absence of soil acidity. The WIT maintains its position to produce cultivars in the future that carry forward the acid-soil tolerance of those before, such as Duster, Endurance and Billings.

The numbers. Field evaluation, relevant molecular and greenhouse assays, and extensive end-use quality testing were conducted on more than 2,700 breeding lines in the preliminary (F_6), intermediate (F_7) and advanced stages (F_8 and beyond). Of those, 535 breeding lines (20 percent) belonged to the hard white class, with the balance being hard red winter or, in rare cases, soft red winter (<1 percent). With exception of populations enriched by marker-assisted selection (about 5 percent of the experimental line output), a modified bulk population selection method was invoked in the early inbreeding generations, using a dual-purpose grazing management system. More than 1,000 unique hybridizations were performed in 2010, and about 15 percent of those will potentially lead to breeding populations that contain genes fixed for white kernel color or otherwise segregate for kernel color. Only about 18 percent of all hybridizations were strictly limited to elite local parentage, underscoring the emphasis placed on germplasm introgression from foreign sources. Ten advanced experimental lines were entered in the OSU wheat variety trials in fall 2010. Seven of these were forwarded for preliminary or advanced stages of foundation seed production to actuate cultivar release.

The genetic pipeline. Two experimental lines were selected as candidates for potential release in February 2011. One is **OK05526-RHf**, a Hessian fly resistant reselection of the original line, OK05526, with the pedigree KS94U275/Endurance. Part of the yield advantage over the parent Endurance may be lost under conditions of an early spring freeze event given the early maturity of OK05526-RHf (similar to Jagger), or in acidic soil environments (see Table 8). Yield performance of OK05526 in the 2010 OSU wheat variety trials, and in specific locations of the OET3 that were yield-limited by stripe rust infection, are summarized in Table 9. Even with its intermediate level of stripe rust resistance, yields of OK05526 were considered upper echelon.

In the foundation seed production field located near McCloud, the original line, which segregated for chaff color and Hessian fly resistance, averaged 112 bu/A. Other experimental lines grown for foundation seed production

Table 9. Grain yield performance of OK05526 in the 2010 OSU wheat variety trials (data provided by Jeff Edwards) and stripe rust affected sites of the Oklahoma Elite Trial 3.

Entry	WVT *(n=16)*	OET3 Granite	Kingfisher	Winfield, Kan.
	bu/A			
Duster	51	56	60	42
Endurance	47	47	51	45
Fuller	42	43	52	39
OK05526	48	57	54	54
LSD (0.05)	2	7	5	3
		← significant stripe rust presence →		

averaged <90 bu/A. Throughout the primary testing region (Texas, Oklahoma, Colorado, Kansas and Nebraska) of the 2010 Southern Regional Performance Nursery, OK05526 ranked fifth out of 48 entries, placing first at Bushland, Texas, (irrigated); Chillicothe, Texas; and Winfield, Kan. OK05526-RHf also shows very good adaptation to dual-purpose management, combining grazing tolerance with early maturity, a trait combination often difficult to achieve. Notwithstanding its grazing adaptation, OK05526-RHf will be positioned for intensively managed operations and environments, where its genetic yield potential and outstanding end-use quality will more likely be realized.

The second candidate cultivar, OK05212 (OK05616-1/Hickok//Betty), falls in the same maturity class as Endurance and can be justified as a replacement to Endurance based on 1) superior resistance to stripe rust, spindle-streak mosaic virus, tan spot and septoria leaf blotch; 2) even better yielding ability in low pH soils (Endurance is considered tolerant); and 3) improved test weight stability. OK05212 extends very well both geographically and edaphically in dryland as well as water-logged soil environments. However, what makes OK05212 stand out beyond all of these attributes is its yield consistency across the past four years of extremely diverse climatic and production conditions (Table 10). Grazing tolerance needs to be further documented as being equivalent to Duster and Endurance, and though that appears to be defendable (Table 11), OK05212 did show unusually poor dual-purpose performance at Marshall in the 2010 wheat variety trials and OET (Table 11).

The genetic pipeline for candidate cultivars runs deeper into the OSU improvement program. Ten other advanced lines were identified in 2010 with outstanding performance records and utility to Oklahoma's wheat producers, and are at various stages of seed increase (Table 12). Two that warrant close watch for grazing, especially in a dual-purpose setting, are **OK07S117** a synthetic derivative with extremely late dormancy release to promote extended grazing, and OK07231, a Duster derivative with good

Table 10. Rank values (lowest value, 1 = highest rank) of OK05212 and relevant check cultivars based on grain yield performance in breeding nurseries conducted statewide from 2007 to 2010. Each nursery contained 30 or more entries in a given year.

Entry	*2010*	*2009*	*2008*	*2007*	*Rank Sum All Years*
OK05212	5	1	4	4	14
Duster	3	3	1	28	35
Endurance	18	6	8	1	33
Billings	4	28	5	18	55

Table 11. Grain yield in a dual-purpose system for OK05212 and relevant checks in Oklahoma Elite Trial nurseries and in the 2010 wheat variety trials (data provided by Jeff Edwards).

	2008		*2009*		*2010*		
Entry	*Coyle OET*	*Sweetwater OET*	*Coyle OET*	*Sweetwater OET*	*Marshall WVT*	*Marshall OET*	*Sweetwater OET*
	- bu/A -						
OK05212	50	32	30	37	34	40	47
Duster	51	32	28	39	58	52	35
Endurance	50	29	24	36	49	40	37
Nursery mean	44	28	22	29	45	39	39
LSD (0.05)	5	6	4	6	6	7	7

Accompanying photograph below shows OK05212 in a simulated dual-purpose system two weeks after grazing termination on March 18, 2010, Stillwater. Neighboring plots show reduced tillering and off-color due to poor recovery thoughout the forage removal period.

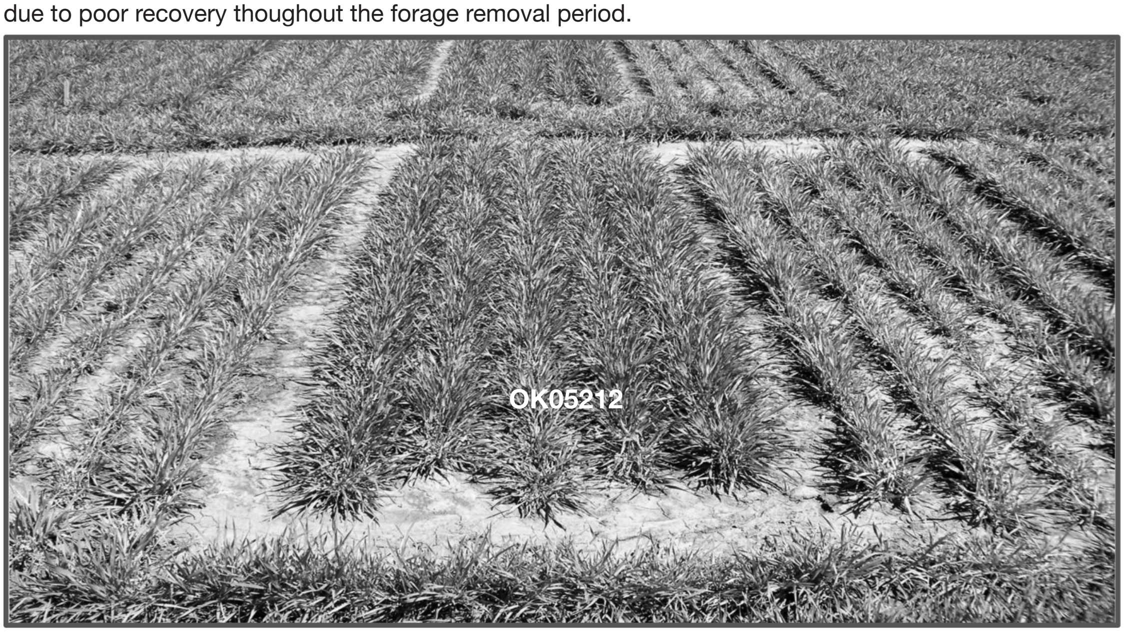


Table 12. Forecasted listing of experimental lines that warrant further evaluation as candidate cultivars following the 2009-2010 breeding cycle.

Years to Proposed Release	*Experimental*	*Maturity*	*Target*	*Impediments*	*Seed Status, 2010-2011* [a]
0	OK05212	L	Okla., Texas, Kan.; low pH	Leaf rust (late)	Year 2 of FS production
	OK05526-RHf	E	Intensive management	Low pH, stripe rust	Limited FS production
0 to 1	OK05511-RHf2	L	SW OK, W and NW Texas	Yield inconsistency	Limited FS production
	OK07209	L	Southern/Central Plains	Protein content	Year 1 FS production
1 to 2	OK05312	L	WSSMV-prone areas in NW Okla.	Quality; chaff variants	BS reconstitution
	OK07214	E	Southern/Central Plains	Chaff variants	BS reconstitution
	OK07231	L	Southern/Central Plains	Stripe rust	Year 1 FS production
	OK07S117	VL	Extended grazing	Powdery mildew	Year 1 FS production (limited)
	OK06336		Quality-contracted acreage	Limited to NC OK	On hold
1 to 3	OK08328	L	Statewide	WSBMV	Year 1 FS production
	OK09634	E	Dryland anywhere; drought tolerance		BS multiplication - accelerated
2 to 3	OK08229		Panhandle	None in High Plains	BS multiplication
	OK08707W		Panhandle - white wheat	Limited interest in HW wheat	BS multiplication
	OK09915C		Statewide (CLEARFIELD®)		BS multiplication - accelerated

[a] FS=foundation seed; BS=breeder seed

fall forage characteristics and grazing tolerance. Two additional experimental lines with Duster lineage, OK07209 and OK07214, have shown exceptional grain yield records in Oklahoma and beyond. Choosing which to advance as a candidate cultivar will be complicated by their divergent maturity, adaptation and disease response patterns.

The WIT's "report card." To get a good idea of where you are headed, it is helpful sometimes to look back and see where you have been. Now that the WIT is in its second decade of research and service to Oklahoma's wheat industry, the time is right to take that look back. Fortunately, the signature trial of the WIT, the OET, is designed to allow such an evaluation. One of the 30 or more entries in the most advanced OET, the OET3, does not change with increasing generations. We use the 1983 release, Chisholm, as a long-term check entry to provide a baseline by which to gauge genetic progress. This cultivar peaked in Oklahoma acreage in the early 1990s and has appeared in the OET3, or nursery equivalent, dating back to the early 1980s.

Chisholm provides the ideal, contemporary baseline because it has relatively high yield potential and yield stability, with the desirable developmental pattern of moderately late first hollow stem stage and early harvest maturity. Chisholm holds winter dormancy very well, and its later first hollow stem pattern lends dexterity in years with early-spring freeze events. Chisholm's yield stability is due to a generalized stress tolerance that allows completion of grain filling when the flag leaf prematurely senesces.

Our expectation is that successive breeding cycles produce experimental lines in the OET3 that yield increasingly better than Chisholm (>100 percent of Chisholm yield). If the WIT were to select only the highest yielding experimental line for advancement, genetic gain (maximal) would be about 2 percent per year based on the linear trendline shown in Figure 5. However, this scenario is not entirely realistic for the obvious reason that grain yield is not the only criterion for advancement and eventual cultivar release. Truly, in only three of the 13 years was the highest yielding line released as a cultivar, that being Endurance, OK Bullet and Duster. If the WIT were to select at the level of the average of all experimental lines tested in a given OET nursery, then genetic gain would be less than 1.5 percent (Figure 5). We typically advance only those lines that exceed, not meet, the mean of the entire nursery, but not necessarily by design. Note that this analysis represents genetic progress in only one phase of the 10-year to 12-year breeding cycle, albeit a very strategic one. Additionally, any estimate of genetic progress based on the OET nursery will be biased downward due to incomplete turnover of experimental lines between successive years. Some lines are tested in two, or sometimes three, successive years. New progress requires new lines.

Temporal changes in actual gains might be more truly assessed not from the linear trendline but on a moving-average basis (not shown). In that case, genetic gains have not been constant over the 13-year period; a period of low gains prior to 2005 was followed by a period of rapid gains. What can be easily observed in Figure 5 is that genetic progress is a two steps forward and a one step back process. Reasons are not clear for more steps taken back during years 1999 to 2004, but this

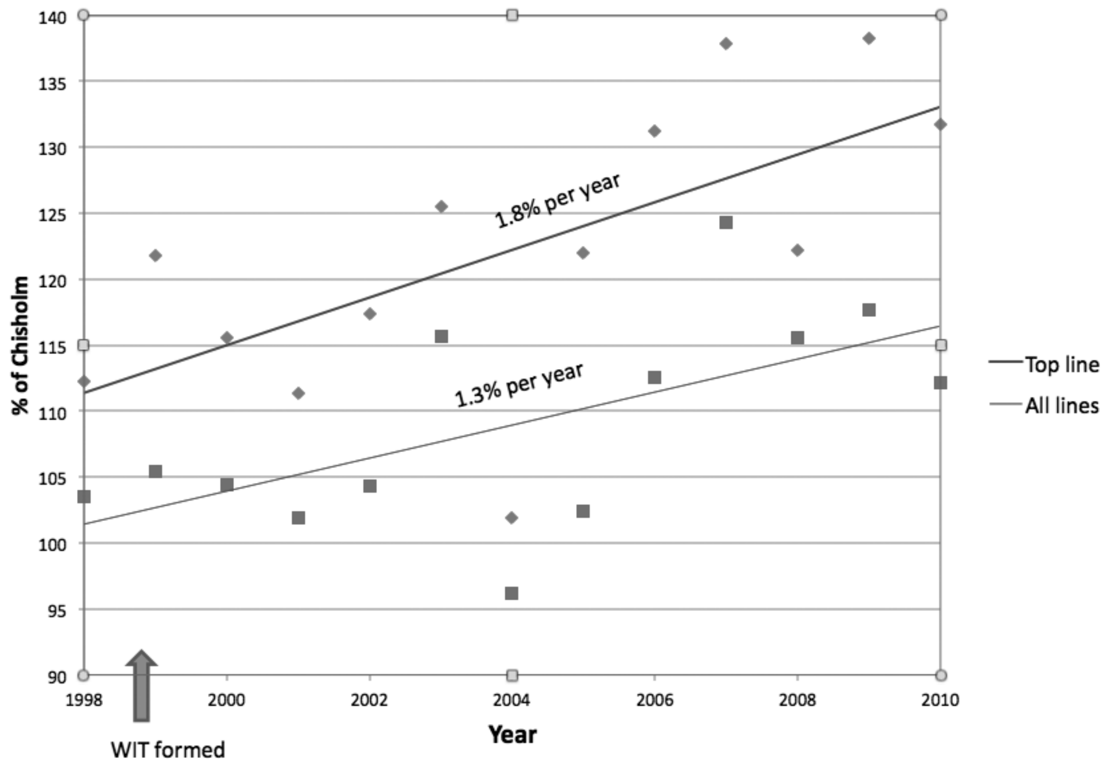


Figure 5. Genetic gain for grain yield in the OSU wheat improvement program from 1998 to 2010, based on relative performance (% of Chisholm) of the top-yielding line or the mean of all experimental lines in the Oklahoma Elite Trial 3.

slow-growth period was followed by an inordinately high rate of gain from 2004 to 2007. The recent upsurge in yield gains can be explained in part by a gradual and substantive increase in overall size of the OSU improvement program from 1999 to 2005. The number of crosses and derived populations cycled through the program each year has more than doubled since 1999. Returns on this increased investment, while already evident, will continue to be cashed by the Oklahoma wheat producer for several years to come.

2010 Small Grains Variety Performance Tests

Jeff Edwards, Rick Kochenower, Richard Austin, Jay Ladd,
Brett Carver, Bob Hunger, Dillon Butchee and Casey Andrews

2009 to 2010 progress made possible through OWRF/OWC support

- **$37 million — the total value placed on information received in 2010 from the small grains Extension program, according to producers attending the 2010 field days.**
- **Delivered wheat yield and phenology data to more than 8,000 Oklahomans through the 2010 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.**
- **Variety trial data published to the Web within a few days of harvest of each location, then accessed more than 1,800 times during harvest.**
- **OSU-released wheat variety Duster topped most grain yield trials and was second in forage trials.**
- **Variety selection made at least 9 bu/A and as much as 29 bu/A difference in grain yield equating to $45 to $145 per acre difference in potential returns associated with choosing the correct variety.**

From an agronomic perspective, the 2009-2010 Oklahoma wheat crop was a huge improvement over the previous year. While final production numbers are not available at the time of this report, it is likely that Oklahoma wheat production will exceed 140 million bushels in 2010, which is roughly double the amount produced in 2009. Unfortunately, excess world ending stocks, a depressed world economy and lower-than-optimal protein resulted in at-harvest cash prices under $3 in many areas of the state.

Planting was in full swing in southwest Oklahoma shortly after Labor Day, and most fields in this region had adequate moisture for emergence and fall forage growth. However, timely planting was much more of a challenge in northcentral Oklahoma, due to wet soil conditions throughout much of October. Challenges presented by wet soil conditions in the region were compounded by rotational crops planted after failed wheat in the spring of 2009. Yields and prices for these rotational and double-crops were generally good, but the later maturity of these crops prevented wheat sowing in many cases. Similarly, very little wheat was sown in northeastern Oklahoma because of wet conditions and rotational crops that were not harvested in time to sow wheat. Conditions in northwestern Oklahoma and the panhandle were mostly favorable for wheat sowing in 2009, but dry conditions in the region restricted fall forage growth. Hardest hit by dry conditions were parts of Beaver, Harper and Woods counties, which experienced moderate to severe drought conditions throughout the growing season.

With the exception of northwestern Oklahoma and the panhandle, the wet conditions last fall persisted through the winter with significant amounts of ice and/or snow. Bitter cold temperatures resulted in winter kill of early-sown wheat that had outpaced cattle stocking density and late-sown wheat that had not established an adequate root system. Cool temperatures prevailed during the spring of 2010, which slowed crop development somewhat but also increased grain yield potential. A brief cold snap during April resulted in some slight freeze injury, but there were no reports of widespread losses from freeze in Oklahoma. May was marked by severe hail storms that were devastating in localized areas. By the first of June, heat had returned and harvest was in full swing. Most of southwest Oklahoma was harvested by June 8, but lingering rain showers and high humidity brought harvest to a crawl during mid June. Heat and dry air returned by June 18 and harvest quickly resumed at full pace. Most of the state was harvested by June 30.

A large portion of the Oklahoma wheat crop was nitrogen deficient in 2009-2010. There are several reasons for this. First, many producers were coming off of several years of poor production and/or crop failures and were simply not in a sound enough cash flow situation to purchase nitrogen in the quantities the crop needed. Second, the wet soil conditions during fall and winter resulted in nitrogen leaching in some areas and inadequate root growth to access nitrogen that had been moved lower in the profile. The wet soil conditions also prevented topdress application of nitrogen fertilizer, especially in southwestern Oklahoma. Some producers attempted to address the issue by aerially applying 25 pounds to 30 pounds of nitrogen per acre, which probably helped. Still others applied nitrogen in quantities under 10 pounds per acre, which probably did not help grain yield much. Finally, the cold winter and cool spring did not provide much opportunity for nitrogen mineralization from previous crop residue. Research has shown that this can be a significant source of nitrogen for wheat, but favorable soil conditions for microbial activity are required for that to happen.

Weeds were a major wheat production factor in 2010, just as they have been for more than 20 years; however, a few changes occurred during the 2009-2010 crop year. The presence of ALS-resistant ryegrass and cheat were confirmed in the state of Oklahoma, with some ryegrass samples showing signs of resistance to ACCase inhibitors, as well. The other big change in the wheat industry is the strict enforcement of stringent dockage discount schedules at the elevator. Once word of the dockage schedules was released, some producers with extremely weedy fields chose to cut them for hay even though the wheat was past the optimal growth for doing so. One promising development during the crop year, however, was an increase in acreage sown to winter canola and other rotational crops. Crop rotation is the best long-term, weed-control strategy available to producers, and it is reassuring to see more acres being rotated.

The fall of 2009 was relatively quiet in terms of insect activity. There were isolated reports of winter grain mite and brown wheat mite activity and a few fields were sprayed for aphids. There were several reports of spraying for greenbugs and bird cherry oat aphids in February, March and April of 2010. The amount of BYDV that became evident in April and May of 2010, indicated that most of these applications were well-justified. BYDV symptoms such as yellowing and purpling of leaves were not hard to find. There was not much stunting of plants, however, indicating that most of the infections occurred after the first of the year. Hessian fly was a factor in 2009-2010, but there were not as many reports of crops being completely devastated by Hessian fly as was the case in 2008-2009. Some of this can likely be attributed to farmers being more aware of Hessian fly and using seed treatments and / or resistant varieties in fields likely to be affected by Hessian fly.

The cold winter prevented fall leaf rust infestations from overwintering, and for a while, it seemed that foliar disease pressure in Oklahoma could be fairly light. Reports from Texas early in the season clearly indicated that something was different this year. Varieties such as Jagger and Jagalene that had been very resistant to stripe rust in the past were being hammered by stripe rust. By late March, it was clear the predominant stripe rust race had shifted and the resistance gene(s) in Jagger that had held out so long could no longer be relied upon for protection. By mid April, Jagger and Jagalene plots were completely devastated by stripe rust and could be picked out from a distance at Frederick and Olustee variety trials. Warmer temperatures and drier plant canopies prevailed by late April and much of the concern shifted to leaf rust. Powdery mildew was present as well in susceptible varieties. Consequently, significant application of foliar fungicides occurred in Oklahoma to help limit losses from foliar disease in 2010.

Wheat quality was a concern in 2010. Dockage schedules were strictly enforced by elevators and made clear to producers that weed-infested wheat fields were costing them more than just grain yield. A surplus of wheat on the world market meant that buyers could pick and choose, and many buyers chose not to purchase wheat that was less than 12 percent protein. Much of the Oklahoma crop fell below this benchmark and left elevator managers and producers scrambling to market the 2010 crop.

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. Conventional till plots received 50 pounds per acre of 18-46-0 in-furrow at planting. No-till plots received 5 gallons per acre of 10-34-0 at planting. The El Reno and Marshall dual-purpose trials were sown at 120 pounds per acre. All other locations were sown at 60 pounds per acre. Grazing pressure, nitrogen fertilization, and insect and weed control decisions were made on a location-by-location basis and reflect standard management practices for the area.

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.

Marketing rights

Breeding programs responsible for varietal release are indicated as the source in results tables. In many cases, however, a separate entity has the marketing rights for these varieties. For this reason, a list of wheat seed companies and the varieties they market is provided below.

AgriPro

Art
Doans
Greer
Fannin
Jackpot
Jagalene
TAM 111
TAM 203
TAM 401
OK Rising (W)

Husker Genetics
Mace

Kansas Wheat Alliance
Everest
Fuller
Jagger
Overley

OK Foundation Seed
Deliver
Endurance

Oklahoma Genetics, Inc.
Billings
Centerfield
Duster
Guymon (W)
OK Bullet
Pete

WestBred
Armour
Aspen (W)
Keota
Santa Fe
Shocker
Winterhawk

Whatley Seed
TAM 112

2010 Oklahoma Wheat Variety Trial Summary

Variety	Altus	Alva	Apache	Apache Fung.	Balko	Buffalo	Cherokee	El Reno	Frederick	Gage	Goodwell Irr.	Goodwell Nonirr.
Armour	56	-	-	-	-	-	-	-	-	-	-	-
Art	46	32	-	-	-	-	19	-	-	-	-	-
Aspen (W)	-	-	-	-	-	-	-	-	-	-	**67**	**58**
Billings	**54**	**34**	-	-	**75**	**23**	**24**	**61**	-	**22**	**67**	**62**
Centerfield	44	33	47	54	68	27	22	49	44	23	58	56
Deliver	43	32	51	49	70	26	23	49	30	21	54	52
Doans	-	**30**	**60**	**54**	**71**	**27**	**19**	**54**	**47**	**23**	**58**	**55**
Duster	**47**	**45**	**68**	**68**	**74**	**30**	**33**	**61**	**53**	**24**	**68**	**69**
Endurance	57	37	57	59	65	31	29	60	35	19	57	60
Everest	59	-	-	-	-	-	31	-	-	-	-	-
Fannin	-	-	**55**	**55**	-	-	-	**57**	**40**	-	-	-
Fuller	**45**	**32**	**53**	**49**	**73**	**24**	**21**	**56**	**41**	**21**	**60**	**57**
Greer	52	40	56	57	-	22	30	49	46	21	64	61
Guymon (W)	-	-	-	-	-	-	-	-	-	-	57	58
Jackpot	**57**	**31**	**57**	**63**	**75**	**26**	**22**	**65**	**47**	**19**	**60**	**61**
Jagalene	**32**	**35**	**44**	**58**	**59**	**28**	**25**	**44**	**36**	**24**	**56**	**62**
Jagger	50	32	48	52	65	24	24	48	30	22	55	65
Keota	-	38	-	-	67	31	25	-	-	25	62	61
Mace	-	-	-	-	**64**	-	-	-	-	-	**61**	**54**
OK Bullet	**45**	**33**	**46**	**53**	**68**	**35**	**23**	**50**	**43**	**24**	**58**	**56**
OK Rising (W)	-	-	-	-	-	-	-	-	-	-	60	59
Overley	49	39	50	59	67	25	28	55	35	21	50	64
Pete	**46**	**31**	**53**	**52**	**68**	**26**	**20**	**58**	**39**	**17**	**57**	**64**
Santa Fe	**48**	**34**	**63**	**52**	**66**	**25**	**23**	**53**	**39**	**21**	**55**	**62**
Shocker	50	32	52	54	65	25	20	51	38	17	55	55
TAM 111	-	46	-	-	79	22	19	-	-	23	73	61
TAM 112	-	**39**	-	-	**74**	**32**	**22**	-	-	**27**	**66**	**71**
TAM 203	**42**	**32**	**52**	**54**	**62**	**34**	**21**	**49**	**36**	**21**	**56**	**51**
TAM 401	52	34	63	56	-	29	22	59	42	20	64	60
Winterhawk	-	43	-	-	74	38	32	-	-	24	66	71
OK[illegible]5312	-	**46**	-	-	**70**	-	**30**	**50**	-	-	**61**	**58**
OK05312	-	**37**	-	-	**73**	**23**	-	-	-	-	**65**	**55**
OK05511	-	-	52	56	70	-	-	53	47	-	-	58
OK05526	61	42	57	56	72	-	25	56	-	-	63	-
OK06618	-	-	-	-	-	-	-	-	-	-	-	-
OK07231	-	**35**	-	-	-	-	-	**51**	-	-	**67**	-
STARS 0601W	-	-	-	-	65	26	-	-	-	-	57	51
Mean	**49**	**36**	**54**	**56**	**69**	**27**	**24**	**54**	**41**	**22**	**61**	**59**
LSD (0.05)	**7**	**5**	**7**	**7**	**5**	**3**	**5**	**11**	**6**	**4**	**7**	**9**

(W) Hard white wheat variety

2010 Oklahoma Wheat Variety Trial Summary

Variety	Haskell	Homestead	Hooker	Keyes	Kingfisher	Lahoma	Lahoma Fung.	Lamont	Marshall DP	Marshall GO	Okarche
Armour	19	-	-	-	-	26	32	51	-	-	-
Art	16	-	-	-	-	18	23	39	-	-	-
Aspen (W)	-	-	-	-	-	-	-	-	-	-	-
Billings	**20**	**43**	**85**	**42**	**54**	**32**	**34**	**50**	**45**	**40**	-
Centerfield	15	42	-	-	48	27	27	41	50	36	41
Deliver	14	41	-	-	48	21	23	41	38	33	36
Doans	-	**37**	**72**	**41**	**56**	**20**	**30**	**47**	**49**	**35**	**48**
Duster	**21**	**49**	**73**	**43**	**61**	**30**	**39**	**45**	**58**	**45**	**49**
Endurance	21	44	66	43	56	30	39	48	49	40	42
Everest	22	-	-	-	-	37	38	56	-	-	-
Fannin	-	-	-	-	-	-	-	-	-	-	**40**
Fuller	**18**	**42**	**77**	**43**	**53**	**23**	**26**	**43**	**48**	**38**	**49**
Greer	16	44	-	-	51	26	34	43	37	35	45
Guymon (W)	-	-	-	-	-	-	-	-	-	-	-
Jackpot	**24**	**44**	**84**	**46**	**56**	**27**	**39**	**51**	**44**	**40**	**43**
Jagalene	**16**	**28**	**72**	**45**	**42**	**16**	**39**	**27**	**30**	**33**	**33**
Jagger	17	31	80	49	45	20	27	38	39	26	39
Keota	-	-	75	38	-	-	-	-	-	-	-
Mace	-	-	**69**	**37**	-	-	-	-	-	-	-
OK Bullet	**17**	**36**	**69**	**41**	**51**	**22**	**39**	**37**	**42**	**32**	**43**
OK Rising (W)	-	-	-	-	-	-	-	-	-	-	-
Overley	15	42	-	-	50	22	26	41	37	32	46
Pete	**13**	**41**	**72**	**41**	**55**	**18**	**31**	**34**	**49**	**36**	**45**
Santa Fe	**18**	**37**	-	-	**52**	**25**	**30**	**36**	**42**	**35**	**43**
Shocker	23	36	-	-	51	20	25	38	49	38	43
TAM 111	-	-	80	41	-	-	-	-	-	-	-
TAM 113	-	-	**82**	**42**	-	-	-	-	-	-	-
TAM 203	**18**	**39**	**74**	**44**	**46**	**18**	**32**	**38**	**41**	**30**	**37**
TAM 401	23	41	-	-	51	18	23	44	38	40	43
Winterhawk	-	-	81	40	-	-	-	-	-	-	-
OK05212	**17**	-	**77**	-	**54**	**33**	**38**	**49**	**34**	**41**	-
OK05312	-	-	**58**	**50**	-	-	-	-	-	-	-
OK05511	-	48	70	42	55	31	39	-	-	-	41
OK05526	24	-	-	42	59	29	35	49	58	43	-
OK06618	-	-	-	-	-	-	-	**45**	**54**	-	-
OK07231	-	-	-	-	-	**31**	**35**	-	**55**	-	-
STARS 0601W	-	-	80	38	-	-	-	-	-	-	-
Mean	**19**	**40**	**75**	**42**	**52**	**25**	**31**	**43**	**45**	**36**	**42**
LSD (0.05)	**6**	**5**	**5**	**7**	**4**	**4**	**4**	**6**	**6**	**5**	**4**

Partners in Progress WHEAT

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