Partners in Progress
WHEAT

Wheat Research at OSU 2006

Supported by the

Oklahoma Wheat Commission

and the

Oklahoma Wheat Research Foundation

Oklahoma State University
Division of Agricultural Sciences and Natural Resources
Oklahoma Agricultural Experiment Station
Oklahoma Cooperative Extension Service

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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 OSU'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 2005-2006. 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.

Food or Fuel

How Arable Acres are Used in the Future

In past publications of *Partners In Progress* I have discussed at length changes in agriculture, including how those changes have/will affect how we do business and produce agricultural crops. Those discussions have centered on climate, cost of production, and industry changes in regard to customer base and evolutions in that base. The new emerging discussion of "change," however, now includes talk of how we will deal with the battle for agricultural acres to produce food or fuel. As energy costs continue to escalate the use of renewable resources for energy becomes much more cost effective. Add to that the use of government incentives to stimulate production, and a significant shift in crops grown has already begun. Wheat millers continue to be concerned about the annual down trend in wheat acres across the nation in favor of other crops. That downward trend started long before ethanol was a factor, but more recently ethanol (and higher energy prices) has, and will ever increasingly, heighten those concerns.

While this downward trend has not yet led to a shortage of mill stocks, it does raise milling industry concerns about the availability of reliable quality on a consistent basis. There has already been discussion among domestic millers that in the future there may be a need to contract needed acres to ensure production and quality at the mill. It is also an issue that has been discussed with us by our foreign customers.

This brings me to the theme behind this publication, *Partners In Progress*. It is imperative we work together as an industry to ensure all our needs are met (food and biofuel). This can only be done through communication and investment. I use the term investment because this implies there is, and will be, a return on resources, and indeed there has been and will continue to be. The base of our investment is the breeding program. You are now seeing new releases emerge that have been through more than 10 years of development with a standard focused on providing value to the producer. That value is realized by the producer in multiple facets, not just in yield or grazing potential, but in its value for quality to the end user. After all, if wheat has no end use value the price will be based on its feed value, not food value, a price that would be dramatically lower than today. All the research cited in this publication is, directly or indirectly, focused on value to the producer which ultimately involves the end use.

Through the cooperation and research illustrated by this publication, the industry can be confident there is a focus and investment on ensuring the future is secure for all elements of the marketing chain, and it can be defined as *Partners In Progress*.

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Partners in Progress WHEAT

Genetic Improvement and Varietal Release of Hard Winter Wheat

Wheat Improvement Team

2005-2006 progress made possible through OWRF/OWC support

- Released a new hard red winter (HRW) wheat variety that provides a substantial upgrade in yielding ability according to regional breeder trials, with Hessian fly resistance and dual-purpose adaptation as featured add-ons (Duster).
- Released a new HRW wheat variety that truly brings CLEARFIELD® technology to the central core of the Oklahoma wheatbelt (Centerfield).
- Released a new, improved HRW wheat germplasm line (STARS 0601W) with a high level of genetic resistance to the Russian wheat aphid. STARS is short for STillwater - ARS (our USDA partners).
- Achieved a level of preharvest sprouting tolerance in white wheat that may bring in more territory for white wheat to explore. Two such candidates were placed under foundation seed production.
- Reached a critical turning point in the development of highly unique breeding lines derived from synthetic wheat, such that statewide replicated field testing of the first 23 synthetic derivatives is now underway.
- Published nine new issues of the Wheat Production Newsletter during the 2005-2006 crop year.
- Improved Extension materials and websites to increase accessibility, aesthetic appeal, and overall impact, as recognized nationally by the American Society of Agronomy in 2006.
- Discovered 190 of the 195 breeder lines selected for advancement toward variety development in 2007 are resistant to the wheat soilborne mosaic virus/wheat spindle streak mosaic virus (WSBMV/WSSMV) complex, a complete turn-around from when this screening process was initiated in the early 1980s.
- Scored reactions to leaf rust and WSBMV/WSSMV complex among 2,000 breeder lines from across the Great Plains, providing the Wheat Improvement Team (WIT) a first-hand look at the availability and status of resistance to these critical diseases. Took additional readings on WIT-bred materials for reaction to powdery mildew, tan spot, and spetoria.

- **Brought 400 new lines featuring durable resistance to leaf and/or stripe rusts into the variety development pipeline at the point of preliminary yield testing, providing new sources of resistance currently absent in the program.**
- **Based on 65 samples from 16 counties, certified that Oklahoma wheat was produced in a state not known to be infected with Karnal bunt, thereby allowing the wheat to move freely into international markets.**

After eight years of teamwork, OSU's Wheat Improvement Team (WIT) has become a true example of what a group of OSU faculty can accomplish when united by a common purpose – in this case, to develop and disseminate winter wheat varieties custom-fit for Oklahoma's wheat industry. Most of the scientists on the WIT have served since day one, which has ensured stability and continuity for the team. Nevertheless, research is a dynamic process, requiring new directions as new challenges and opportunities emerge. Hence, the WIT takes on a bit different appearance today than it has in the past.

Riding on eight years of coordinated research and Extension programming are seven OSU faculty: **Brett Carver**, wheat breeding and genetics; **Jeff Edwards**, information exchange; **Bob Hunger** and **Art Klatt**, wheat pathology and development of disease-resistant germplasm; **David Porter (USDA-ARS)**, aphid resistance; **Bjorn Martin**, stress physiology; and **Patricia Rayas-Duarte**, cereal chemistry. Just this past year, the WIT scoured the country for the best molecular geneticist it could find, and we found it. His name is **Liuling Yan**, and he brings an impressive record in wheat genetics research to our table. In future editions of the *Partners in Progress* report, you will be learning about new approaches to some old problems – such as using experimentation at the DNA level to better understand genetic control of complex traits like arrival at first-hollow-stem stage.

We have been confronted with the challenge of providing new varieties with tolerance to the Hessian fly, and we are hitting that challenge head-on...actually, with two heads. OSU is fortunate to have two entomologists who already have the necessary expertise – **Kristopher Giles** and **Tom Royer**. Through the WIT, their talents become more accessible, both to us and to you.

In this report, you can read more about these significant breakthroughs: 1) the release of a new hard red winter wheat variety that offers real genetic solutions to Oklahoma producers, such as Hessian fly resistance and stellar grazing and yield performance, 2) the release of a CLEARFIELD® variety with top-notch virus resistance, 3) the release of a germplasm line featuring novel resistance to the new Russian-wheat-aphid biotype, 4) the continued transfer of unique leaf rust resistance genes that vary widely in their origin and their effect on the rust pathogen, and 5) development of the first wave of unique breeding lines derived from synthetic wheat for statewide yield testing.

Last year, we reported on how stripe rust moved from virtually a last-place position on our target trait list 10 years ago to a top-level position today. It took out many breeding lines and made the program look a little thin. Though stripe rust was absent in 2005-2006, our emphasis on stripe rust resistance remains unchanged.

Information Exchange

Jeff Edwards
Plant and Soil Sciences

The Wheat Improvement Team's attention to information exchange 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. Nine issues of the Wheat Production Newsletter were published during the 2005-2006 wheat production season and the e-mail distribution list for this publication more than doubled from the previous year.

Wheat variety trial results were again published before the due date for Oklahoma Foundation Seed orders, which allowed farmers and seed producers to make well-informed decisions regarding seed purchases. In addition, the look of the wheat variety trial report was updated, reflecting our continuing effort to make OSU Cooperative Extension wheat publications among the best in the nation.

Our presence on the Web was increased via the World of Wheat podcast, and the wheat extension website (www.wheat.okstate.edu) was updated to include new publications and links to additional Extension websites.

Wheat Pathology Research and Development of Disease Resistant Germplasm

Bob Hunger
Entomology and Plant Pathology

Intensive greenhouse and field testing continued in 2005-2006 for reaction to leaf rust and to the wheat soilborne mosaic virus/wheat spindle streak mosaic virus (WSBMV/WSSMV) complex for breeder lines submitted from across the Great Plains. Oklahoma Wheat Research Foundation (OWRF) funds also supported limited testing of Wheat Improvement Team (WIT) materials in the greenhouse for reaction to tan spot, septoria, and powdery mildew, and for testing WIT materials in the field for reaction to stripe rust in southern Texas.

We have a success story to share that literally would not have been possible without the long-term partnership between the Oklahoma Agricultural Experiment Station (OAES) and the OWRF/Oklahoma Wheat Commission (OWC). More than 400 WIT breeding lines were subjected to WSBMV/WSSMV testing last year, and of those, 195 were advanced toward variety development for continued testing in 2007. Of those 195 lines selected, 190 (97%) were found to be resistant to the WSBMV/WSSMV complex. When screening for reaction to these diseases began in the early 1980s, this proportion of resistance to susceptibility was nearly the exact opposite. Again, uninterrupted support by OWRF/OWC is what sustained the progression from general susceptibility to general resistance.

Starting in 2006-2007, OWRF support will be used to characterize the effects of tan spot and septoria leaf blotch on winter wheat, with an emphasis on the effects of these two diseases on wheat production and incorporating resistance to these diseases into the base germplasm pool. This new research is important because of the increased emphasis on minimum-tillage wheat production, which leaves significantly greater amounts of wheat residue on the soil surface. The fungi that cause tan spot and septoria leaf blotch survive on this residue, so the incidence and severity of these diseases increase dramatically with minimum tillage. Kazi Kader, a doctoral student jointly supported by the OWRF and the OAES, has been planning the research to address these issues.

Funds provided by the OWRF supported the testing of the 2006 Oklahoma wheat crop for the presence of Karnal bunt. The results 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.

We have reported in the past that isolates of the fungi *Rhizoctonia* spp. and *Sclerotium rolfsii* from wheat and peanut were pathogenic to both crops, but the peanut isolates were more virulent than the wheat isolates. We have learned further that the increased virulence was related to production of endopolygalacturonase and oxalic acid, which are compounds that enhance virulence. This information indicates that wheat following peanuts in a rotation is more apt to be damaged by Rhizoctonia root rot. Vijay Choppakatala, a student partially supported by OWRF funds, received his doctorate based on this research.

Art Klatt
Plant and Soil Sciences

While Bob Hunger's research largely monitors pathogen trends and characterizes current genetic variability for pathogen resistance, this program is primarily responsible for creating genetic variability for disease resistance by incorporating and combining novel sources of resistance from outside Oklahoma. Improving leaf and stripe rust resistance for Oklahoma, and especially the durability of resistance, is a top priority in this germplasm development program.

On-going efforts include transferring multiple minor genes for leaf and stripe rust resistance found in many spring wheats from CIMMYT into our adapted winter wheats. These genes are called minor, because any one gene by itself has a small incremental effect on resistance, but the combination of several genes produces a desired level of resistance. This type of resistance has survived several race changes in Mexico and in other parts of the world, and is now labeled durable rust resistance. Experimental lines (n=400) featuring different gene combinations from multiple genetic backgrounds were produced in 2006. These currently are being evaluated in preliminary yield trials before moving on to statewide replicated yield trials. This initial round of preliminary testing will provide us with a report card on how this material stands up to diseases in Oklahoma. Of course, they must also pass several other tests for adaptation (i.e. dual-purpose fitness) and end-use quality.

Another major priority of the program is the introduction of synthetics. More than 100 new crosses were made after choosing from several hundred synthetics introduced during the 2005-2006 season. The synthetic wheats – produced from crosses between cultivated durum varieties (*Triticum durum*) and selected goatgrass accessions (*T. tauschii*) – should provide new genes for rust resistance, as well as enhanced drought tolerance, improved leaf characteristics, and better resistance to many of the minor diseases such as tan spot. CIMMYT recently reported that more than 60 percent of their spring wheat materials developed for semi-arid conditions were derived from crosses to synthetics (i.e. synthetic derivatives). We have produced our own set of synthetic derivatives from a first set of crosses made in 2000. Seven years later, we now have 23 synthetic derivatives in replicated yield trials across the state. The results from these trials in 2006-2007 should give us an idea of their yield and quality potential, drought tolerance, winter-dormancy pattern, and resistance to diseases.

To select for leaf and stripe rust resistance, we need a reliable site where relevant races of each pathogen can be found. For that we go to south Texas as a hotspot selection site, where any introduced materials targeted for crossing are prescreened. Early-generation populations (F_2) from those crosses also are evaluated under severe rust pressure in south Texas. Beginning in 2006-2007, any materials that enter preliminary yield testing will be tested in south Texas to confirm their rust resistance. This way we can be certain that the required rust resistance is present in the populations and materials that are advanced.

Four years of research (in cooperation with CIMMYT) has shown that spectral reflectance can be used as an indirect selection tool for grain yield and total biomass in spring and winter wheat. This technology currently is being evaluated under breeder circumstances in Oklahoma to determine the best way to use it. If successful, spectral reflectance measurements may increase the effectiveness of selection for grain yield when grain yield potential is difficult to assess due to inadequacy of materials.

Aphid Resistance

Dave Porter
USDA-ARS
Plant and Soil Sciences

Testing and selecting for Russian wheat aphid (RWA) and greenbug resistance in Wheat Improvement Team (WIT) breeding lines continued this year. Several excellent lines with high levels of resistance were advanced through the variety development process. Single-plant selections from six experimental lines were retested to confirm their resistant reactions to the predominant RWA biotypes (RWA1 and RWA2). One experimental line (OK03825) with a very high level of resistance to both biotypes was selected for release to the public as a germplasm line under the name of STARS 0601W. This new source of RWA resistance will now be available for use around the U.S. and worldwide. This germplasm line and other RWA-resistant lines with better agronomic traits continue to improve as they proceed through the various phases of the variety-development process.

Widespread integration of greenbug biotype E (the predominant biotype in Oklahoma) resistance genes into WIT breeding lines remains a high priority. During 2005-2006, nine nurseries (total of 300 wheat entries) were tested for reaction to greenbug biotype E feeding damage. While the percentage of all lines with greenbug resistance genes remains low, good progress has been made to move very effective greenbug resistance into lines that are now stable and uniform for resistance. One population of almost 800 plants of Okfield and Centerfield was retested to determine segregation ratios for biotype E resistance and susceptibility (approximately 50:50 ratio).

Plans are being made to accelerate work on incorporating bird cherry oat aphid (BCOA) resistance into WIT breeding lines. These plans include further testing and genetic analysis of populations derived from crosses between WIT breeding lines and good sources of BCOA resistance identified in previous studies. Developing BCOA resistant wheats for Oklahoma is a high priority, and even though this process is more difficult than developing RWA and greenbug resistant wheats, we intend to devote the time and resources necessary to be successful.

Stress Physiology

Bjorn Martin
Plant and Soil Sciences

In the past year, we have extended ongoing research into explaining the role the *mtlD* gene from *E. coli* may play in drought resistance when it is transformed into wheat. Expression of the same transgene in several model plants, and also in preliminary work on wheat in our laboratory, has shown elevated tolerance of both drought stress and salinity stress, but the mechanisms leading to the tolerance are unknown.

Previous Oklahoma Wheat Research Foundation/Oklahoma Wheat Commission-sponsored research has shown that it is unlikely the benefit of the osmotic effect of the accumulating mannitol in the transgenic wheat. The tissue mannitol concentration is simply too low. However, mannitol is also known to scavenge reactive oxygen species. These destructive molecules are known to accumulate under stress. We have therefore redirected our research in the last year to concentrate on this issue. We have learned and fine-tuned protocols for assaying the general ability of wheat tissue extracts to reduce the level of hydroxyl radicals; to quantitate the antioxidant chemicals ascorbate and glutathione; and to determine the activities of the antioxidant enzymes superoxide dismutase, catalase, ascorbate peroxidase, and glutathione reductase. We are just finishing a drought-stress experiment where these properties as well as gas exchange and water content have been measured on a weekly or biweekly basis for two months. These data have not yet been analyzed.

In the past year, we also received USDA and institutional approval to test the transgenic *mtlD* wheat in the field. This is being done with USDA funding by collaborators in Colorado and North Dakota, as the transgenic wheat is a spring wheat. Preliminary analyses from the first year of trials in Colorado show no benefit of the transgene. The North Dakota trial results have not yet been analyzed. At this point, the preliminary data suggest that the *mtlD* transgene may be differentially expressed in callus tissue and potted greenhouse plants versus in the field. Field validation of tolerance to drought stress is what is needed to advance this research to the next level – introgression of *mtlD* into new, improved varieties.

In the last year we used an increased number of transgenic lines in our work. This is because different lines, although they contain the same transgene, may express the gene differently. This may be because the transgene is incorporated into different locations of the wheat genome in the different transformation events. Also, different transformation events very likely contain different copy numbers of the transgene.

Cereal Chemistry

Patricia Rayas-Duarte
Biochemistry and Molecular Biology

Dough strength and extensibility are important properties that contribute to optimum baking performance. Together, they comprise gluten quality. Historically, Oklahoma wheat varieties have been selected for gluten strength, but this would not necessarily guarantee adequate extensibility. A balance of strength and extensibility is desirable for optimum baking performance of yeasted breads.

At the present time, we do not know for certain the specific amounts of strength and extensibility that would produce the most desirable baking functionality. We have focused our efforts to study varieties and elite lines that will help us understand the combination presently available and to build a data base that will suggest which combinations give better baking performance and which ones we need to avoid. This will allow us to breed future varieties with improved extensibility while maintaining desirable strength. Our long-term objective in this Oklahoma Wheat Research Foundation/Oklahoma Wheat Commission-sponsored research is to compare key functionality parameters among elite lines in the breeding program.

Extensibility is measured by extending in one direction a well-developed dough to the point of breaking – or tearing the dough apart. From the information recorded, we obtain the force needed to break the dough (measure of strength) and the distance that the dough can be extended (a measure of its extensibility). Dough with adequate extensibility will be able to expand and hold the gas (mainly carbon dioxide and water vapor) produced during the fermentation and baking steps. This is also translated to acceptable bread volume and external and internal appearance of the baked product.

Figure 1 shows representative extensibility curves of four Oklahoma varieties. The height of the curve (vertical axis) gives an estimation of the strength of the dough; the higher the curve the greater the force needed to extend the sample. The horizontal axis gives an indication of the extensibility of the dough; the more extensible dough will have a larger distance (in mm) before it breaks. OK Bullet produced the strongest dough and Endurance had lower strength, but it was more extensible. Intrada's and Duster's extensibility curves indicate they have intermediate properties with greater balance of strength and extensibility.

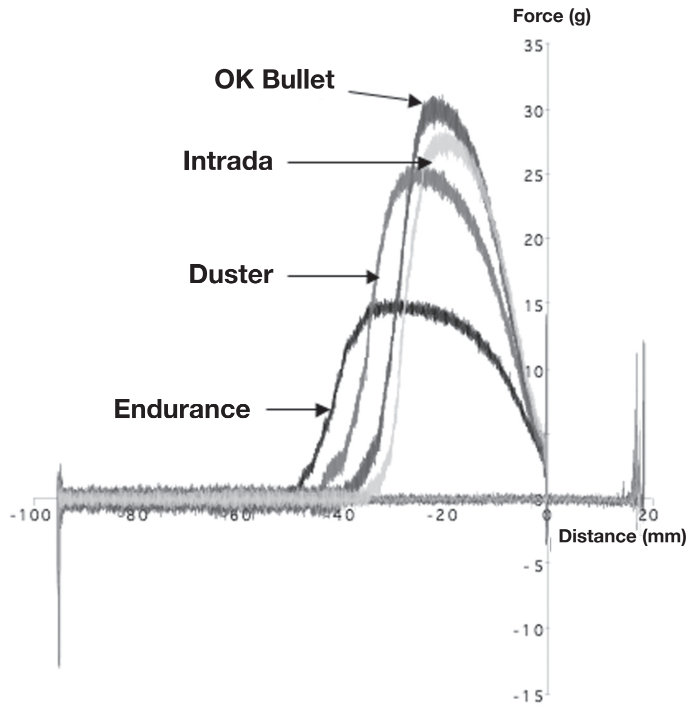

Figure 1. Extensibility graphs of four Oklahoma varieties.

Wheat Breeding and Variety Development

Brett Carver
Plant and Soil Sciences

*Breeding program at a glance...*We reported in the 2005 issue of *Partners in Progress* that stripe rust did more to trim the overall size of the breeding program than all other traits combined. This was after several years of linear expansion of the program. Though sheer numbers do not always tell the story, the following summary shows how the numbers stacked up for breeding materials during the 2005-2006 crop season (Table 1). This includes all phases of the breeding program, from population development and line development to replicated testing of breeding lines. The program may not have grown in numbers in 2006, but we see little value in continued testing of breeding lines that fail to stand up to stripe rust.

Some years leave an indelible imprint on the breeding program. Last year (2005-2006) was a prime example. While the Wheat Improvement Team (WIT) certainly applied selection pressure for the target traits (agronomic or quality), it was the type of selection applied by nature – for drought tolerance – that will leave its imprint for generations to come. One could argue the same happened in 2005, but the imprint was for stripe rust resistance that year. Most of our materials faced drought stress throughout much of the 2005-2006 season, thus making that stress factor exceed all others. We have certainly seen the effects of drought stress in previous years, with spring 2004 being most recent, but seldom do we see that level of stress span the entire crop season. To

Table 1. Summary of numbers for breeding materials during the 2005-2006 crop season.

901	Hybrid crosses produced (no change from 2005)
713	F_1 populations increased for further selection (up 2%)
2,189	Bulk populations screened in grazed and grain-only systems (up 7%)
40,287	Head rows searched for disease resistance and seed quality (up 4%)
	8,000 of these circumvented the *GRAZEnGRAIN* breeding system (see report by Art Klatt)
1,687	Preliminary lines evaluated in the Dual-purpose Observation Nursery (up 8%)
	394 of these (23%) were hard white (HW) wheat
398	Breeding lines tested statewide for agronomic, quality traits (down 1%)
	61 of these (15%) were HW wheat

sum it up over the last two years, our breeding materials have been fortified with an extra dose of resistance to stripe rust and drought stress. Despite their curse, we did glean something good out of two very tough years of wheat production in Oklahoma.

Duster, a new hard red winter wheat variety... While the subject is drought stress, this is a good time to bring up one of OSU's next big releases, Duster. Duster does not have unusual drought stress tolerance, but it does have an eye-catching ability to germinate and emerge in marginal soil moisture. We have observed this in other years, and the dry fall of 2005 was no exception.

So what is the big deal about Duster? Why did OSU release another hard red winter wheat right after OK Bullet, which followed on the heels of Endurance and Deliver? Let us take the second question first, but before we do that, single out Deliver.

Deliver has the unique feature of being beardless, but otherwise it is no different than a bearded wheat that might be taken to the elevator to produce bread. As a tri-purpose wheat, Deliver is well suited for grain-only production, for dual-purpose production (graze-plus-grain), and for hay production or even graze-out. The beauty of that is producers can make their decision on how to use Deliver after it is planted, not before.

Now compare Duster with Endurance and OK Bullet, because they do have their differences. One obvious difference is in their pedigrees as they appear on their PVP certificate (Table 2).

These three varieties cut a wide swath across the gene pool for HRW wheat, as no two varieties have a single parent (or grandparent) in common, and only one variety has family ties with Jagger. Diversity in the cultivated gene pool helps to minimize genetic vulnerability to disease epidemics. It also triggers future progress in the breeding program.

Table 2. Pedigrees of Duster, Endurance, and OK Bullet.

Duster	W0405/NE78488//W7469C/TX81V6187
Endurance	HBY756A/Siouxland//2180
OK Bullet	KS96WGRC39/Jagger

Moving on to agronomic and quality traits of economic importance, the differences become even greater (Table 3).

Duster most closely resembles Endurance in agronomic capability, yet offers definite improvement in spindle streak mosaic virus resistance, Hessian fly resistance, test weight, and baking quality. Duster appears also to accumulate fall forage at a greater rate prior to grazing initiation than does Endurance, but Jeff Edwards will report further on fall forage differences as clipping data become available. After the cattle are turned out on the pasture, the forage differences between Endurance and Duster will be hard to detect. Like all varieties, Duster has some imperfections. Those are bolded in the chart.

One more feather in Duster's cap comes from grain yield data collected across the southern and central Great Plains from the Hard Winter Wheat Nursery Program, administered and disseminated by the Agricultural Research Service of USDA (http://www.ars.usda.gov/Research/docs.htm?docid=11932). Duster was tested, along with other leading candidate varieties from breeding programs across the region, in the stripe rust year of 2005 and the drought-stress year of 2006, under its experimental number, OK93P656H3299-2C04. Table 4 contains grain yield data that were extracted from the above website (Dec. 2006), under the tabs 2005 SRPN and 2006 SRPN.

Duster ranked first among 48 to 50 experimentals and checks when

Table 3. Agronomic and quality traits of economic importance for Endurance, OK Bullet, and Duster.

Character	Endurance	OK Bullet	Duster
First hollow stem	Late	Early, temperature-driven	Moderately late
Grazing tolerance	Very good	Sensitive to stocking rate	Very good
Acid soil tolerance	Very good	Very good	Very good
Lodging resistance	Good	Very good	**Fair**
Leaf rust	Resistant	Resistant, for now	Resistant
Stripe rust	Intermediate	Resistant	**Inconsistent**
Soilborne mosaic	Moderately resistant	Resistant	Resistant
Spindle streak mosaic	Susceptible	Resistant	Resistant
Powdery mildew	Moderately resistant	Susceptible	Moderately resistant
Hessian fly	Moderately susceptible	Susceptible	Resistant
Test weight	Fair	Very good	Good
Kernel size	Moderately large	Large	**Moderately small**
Baking quality	Intermediate	Very good	Good

Table 4. Grain yield data for Duster and OK Bullet from across the Great Plains.

	2005	2006
Duster		
Rank	1	1
Mean yield, bu/ac	61.1	53.0
OK Bullet (OK00514) or OK Bullet sib (OK01420)		
Rank	5	5
Mean yield, bu/ac	58.2	52.5
Entire nursery		
Number of entries	48	50
Mean yield, bu/ac	53.0	47.5
LSD (0.05)	4.1	4.0

averaged across the region in each year. It exceeded the mean of the nursery in each year by an average of 13 percent. This level of performance in two consecutive years indicates wide geographic and climatic adaptation of Duster, even in a grain-only management system, plus it shows Duster has consistency.

Centerfield vs. Okfield...Duster will certainly get the bulk of attention among the two new OSU releases, but as efficacy and economics of the CLEARFIELD® production system improves, the 2006 release named Centerfield will allow adoption of the system where it currently is not – in the center part of the state. Centerfield provides good resistance to wheat spindle streak mosaic virus and to wheat soilborne mosaic virus, unlike the imazamox-resistant hard winter wheat varieties currently available, including Okfield. Centerfield should exhibit insignificant losses to these viral diseases. Added bonuses are good lodging resistance and straw strength (similar to 2174), and moderate tolerance to acidic soils with high aluminum toxicity. Centerfield shows an intermediate reaction to stripe rust, and is moderately too highly resistant to leaf rust. Okfield may have better yield performance west of Alva, whereas Centerfield gains strength to the east. Centerfield's milling and baking quality is unquestionably better, though Okfield will produce a larger berry.

Current status on candidate varieties...Read more in Table 5 about selection decisions made and action taken on candidate HRW and HW varieties in the Wheat Improvement Program. Do not be too surprised to see some kernel color differences in the line up for next year. As our export markets continue to call for HW wheat, the WIT remains committed to developing new improved varieties, both red and white. The genetic pipeline is full, and ready to *D*eliver.

Table 5. Candidate HRW and HW wheat varieties tested in 2005-2006.

Selection	Action	Pedigree	Comments
OK93P656H3299-2C04	Released	W0405D/NE78488//W7469C/TX81V6187	Released as Duster. Topped the regional trials in 2005 and 2006, so it will yield. Rapid emergence, high tiller survival and grazing tolerance, and Hessian fly resistant. Inconsistent reaction to stripe rust is main limitation. Moderately lower protein, but good strength. Substitutes for Endurance well, especially in north central Oklahoma. **HRW**
OK03918C	Released	TAM 110-FS4/2*2174	Now called Centerfield. An improved Okfield, with wheat spindle streak and soilborne mosaic virus resistance. Better test weight and foliar package. Goes where Okfield cannot, in north central Oklahoma. **HRW**
OK01307	Terminated	OK94406/Jagger	Could not compete with Duster for forage capability, though better grain producer in north-central OK. Resistant to stripe rust, and a new, hot race of stem rust, but leaf-rust susceptible. First-hollow-stem arrival is too early. **HRW**
OK00611W	Holding	KS96WGRC39/Jagger	HW for central Oklahoma with superb sprouting resistance, high test weight. Resistant to WSBMV, stripe rust, and low pH. Must plant late, but it can catch up. Cast from the same mold as OK Bullet. **HW**

Table 5 is continued on the next page.

Table 5. Continued.

Selection	Action	Pedigree	Comments
OK02522W	Advanced	KS96WGRC39/ Jagger	Another OK Bullet brother, with white bran. Slightly more consistent for yield than OK00611W. Intermediate sprout resistance - better than Intrada and Guymon but not as good as OK00611W. Seed increase lost to hail in 2006; will increase again. **HW**
OK00514W	Advanced	KS96WGRC39/ Jagger	Looks like OK Bullet, performs like OK Bullet, it is OK Bullet, with white bran. Took the 2 percent white out of OK Bullet and this is what we got. Used an electronic eye to breed this one. **HW**
OK02405	Terminated	Tonkawa/ GK50	Stripe rust and leaf rust resistant. Great genetic combination for parents, with Hungarian connection. Thought we had a tri-purpose beardless replacement for Deliver, but threshability is its disability. **HRW**
OK00310	Terminated	Custer/Jagger	Passed the test for grain yield out west, but not for quality. Interesting first-hollow-stem pattern – holds winter dormancy well and not fooled by temperature. Actually held it too long in 2006. **HRW**

Wheat Variety Trials

Jeff Edwards
Plant and Soil Sciences

2005-2006 progress made possible through OWRF/OWC support

- **Extreme drought in 2006 reduced wheat grain yield and resulted in some research locations being abandoned prior to harvest.**
- **Despite the drought, some varieties such as Jagger, Duster, OK Bullet, Jagalene, and Overley performed well at many locations (Table 1 on page 17).**
- **Due to abnormally dry conditions, 2006 variety trial results will be most useful when viewed in conjunction with two- and three-year averages.**
- **The full wheat variety trial report (Production Technology Report 2006-5) is available at www.wheat.okstate.edu.**

The 2005-2006 wheat production season will go down among the driest in recorded history for many areas of Oklahoma. There were a few late-summer/early-fall rains that allowed emergence of early September-sown wheat, and some areas of the state benefited from an early-October rainfall. The majority of the state, however, did not see significant rainfall again until April 2006. As a result there were many acres of wheat sown in fall 2005 that did not emerge until spring 2006.

Those who sowed wheat in early September into adequate moisture conditions were pleasantly surprised by their forage production and cattle gains. Production in the wheat forage variety test sites was around 500 lbs/a below average, which was not bad considering the extreme drought conditions. Reports of cattle gains above 3 lbs/hd/day were not uncommon and outstanding gains were probably the result of very few cold days and almost no damp/wet conditions during the 2005-2006 winter.

Although initial wheat forage production was adequate in many areas of Oklahoma, regrowth during and after grazing was almost nonexistent due to drought. Further, drought conditions inhibited root growth and plants were not anchored well at the time of grazing, which led to pulled plants and stand losses. As a result, dual-purpose wheat yields across the state were extremely low and there was great disparity between grain yield of grazed versus non-grazed wheat.

Herbicide efficacy was generally much lower than normal. This was mostly due to drought-stressed weeds and a lack of activating rainfall. This frequently resulted in weedy fields at harvest and prompted some growers to apply chemical harvest aids.

High nitrogen fertilizer prices, low yield potential, and extreme drought meant that most producers were very conservative in top-dress nitrogen application rates. With all things considered this generally proved to be the right call, as response to supplemental nitrogen fertilizer was less than normal.

In March, spring freezes injured some wheat in low-lying areas of north central and northeastern Oklahoma. Likewise, temperatures dipped below 32°F in the Panhandle on April 26. Unfortunately, this cold snap caught some fields just at flowering and greatly reduced the yield potential of some outstanding irrigated wheat fields.

Harvest proceeded well ahead of schedule in 2006 and the majority of wheat was harvested by mid-June (approximately one to two weeks ahead of schedule). Harvested acreage was much lower than normal, with most acres west of I-35 and south of I-40 being abandoned prior to harvest.

Pest Problems

Drought certainly reduced yield potential of the 2005-2006 wheat crop, but it did not seem to have a significant effect on insect pests. Some newly emerged wheat fields were lost and many others were sprayed for fall armyworm in September. Hessian fly was a widespread problem in north central Oklahoma, with some fields having infestation levels high enough to result in total crop loss.

Aphid numbers were generally not that high in fall 2005, but barley yellow dwarf virus symptoms were still widespread in spring 2006. In addition, many fields in central and southern Oklahoma had to be sprayed for greenbugs in spring 2006. Other insect problems included brown wheat mite and wheat head armyworm. Damage from these two insects, however, was not as widespread as that from Hessian fly and greenbugs.

High plains virus and wheat streak mosaic virus were both major problems in the Oklahoma Panhandle. These two viruses resulted in the destruction of several fields of irrigated wheat, and theories about the wheat curl mite over summering in conservation reserve program acres in the corners of pivots have regional producers rethinking management strategies for these viruses.

Dryland root rot caused by the fungus *Fusarium* was another disease that caused significant losses in certain areas and fields of Oklahoma wheat this past season. In the late fall, fields infected with dryland root rot and common root rot, *Bipolaris*, were both found. However, the dry and hot conditions through the winter and spring greatly favored dryland root rot, and by early April fields severely infected with dryland root rot were observed across southwestern, central, west central and to a lesser extent, northern Oklahoma. Many of these fields were abandoned or grazed-out.

Foliar diseases were generally not a major yield-limiting factor during the 2005-2006 wheat production season. There was some powdery mildew present on lower leaves of susceptible varieties, but infestations rarely made it up to the flag leaf. Leaf rust could be observed on some varieties later in the season, but disease incidence and severity were generally below economic thresholds for control.

Table 1. 2006 Oklahoma wheat variety trial summary.

	Grazed				Non-grazed												
	Cherokee	Elk City	El Reno	Gage	Alva	Apache	Apache fungicide	Balko	Buffalo	Haskell	Hooker	Kingfisher	Lahoma	Lahoma fungicide	Lamont	Marshall early-sown	Marshall late-sown
	bu/a																
2145	-	-	-	-	-	-	-	-	-	47	-	-	-	-	-	-	-
2174	5	30	34	11	24	25	29	14	26	39	-	27	55	56	33	23	31
AP502CL	8	34	37	14	33	25	26	17	26	38	-	22	68	78	43	13	19
Avalanche (W)	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-
Centerfield	-	-	42	-	-	-	-	-	-	44	-	27	-	-	40	-	-
Custer	-	29	34	8	25	26	27	15	24	-	-	21	-	-	-	14	9
Cutter	10	36	39	15	27	33	36	20	29	46	-	36	70	74	46	26	35
Danby (W)	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-
Deliver	3	28	39	12	23	27	29	13	26	37	31	22	57	62	36	17	16
Duster	8	33	40	12	27	28	31	19	31	51	-	21	75	73	50	27	36
Endurance	5	31	36	13	24	32	31	13	27	49	35	30	72	69	37	24	34
Fannin	4	30	26	8	26	24	25	13	19	36	-	22	61	65	40	15	26
Guymon (W)	-	-	-	11	25	-	-	17	-	-	32	-	-	-	-	-	-
Ike	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-
Intrada (W)	-	-	-	-	-	-	-	16	-	-	28	-	-	-	-	-	-
Jagalene	15	36	41	13	30	37	35	19	31	44	34	28	70	76	50	23	36
Jagger	20	35	39	12	31	34	33	17	31	44	34	35	67	72	52	23	35
JEI 110	8	29	31	19	24	26	30	14	31	42	-	27	60	60	42	14	27
Lakin (W)	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-
Neosho	5	-	-	-	-	-	-	-	-	35	-	-	67	70	35	-	-
OK Bullet	10	40	44	19	29	35	35	20	27	47	38	29	73	73	48	32	31
Ok101	7	28	35	17	24	27	32	15	-	37	-	27	67	66	39	26	28
Okfield	8	32	40	12	27	26	27	18	27	42	-	29	60	62	39	20	27
Overley	13	34	46	11	31	33	35	15	29	44	-	28	76	74	43	23	33
Protection CL	11	-	-	-	-	-	-	-	-	34	-	-	70	73	44	-	-
Santa Fe	10	35	36	13	28	31	33	16	24	43	-	31	69	68	49	21	35
Stanton	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-
TAM 110	-	-	-	-	-	-	-	18	-	-	39	-	-	-	-	-	-
TAM 111	-	27	42	15	28	27	27	20	28	-	30	20	-	-	-	18	15
Trego (W)	-	-	-	-	-	-	-	20	-	-	35	-	-	-	-	-	-
OK03928C	-	-	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK01307	15	33	42	-	28	28	35	15	31	48	-	32	68	71	47	31	40
OK01310	2	30	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-
OK01420	9	32	35	-	30	-	-	-	-	-	-	28	76	73	49	-	-
OK02405	7	30	34	-	-	29	28	-	-	-	-	-	-	-	-	-	-
OK00224	11	28	-	-	25	26	29	-	-	-	-	-	-	-	45	-	-
OK0522W	5	-	40	-	24	26	31	-	-	-	-	24	-	-	44	21	23
OK00611W	7	-	41	-	28	27	28	-	-	-	-	20	-	-	43	24	18
Mean	**9**	**32**	**38**	**13**	**27**	**29**	**31**	**17**	**27**	**42**	**34**	**27**	**67**	**69**	**43**	**22**	**28**
LSD $_{(0.05)}$	4	3	10	4	4	6		4	11	7	4	6	8		6	9	

Partners in Progress
WHEAT

Development of a Weather-based Model for Predicting First Hollow Stem in Winter Wheat

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in cooperation with
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Plant and Soil Sciences

2005-2006 progress made possible through OWRF/OWC support

- **Using the optimal soil-temperature based models for first hollow stem (FHS) developed last year, model FHS predictions were compared with independent FHS observations in dryland wheat from 2004 to 2006.**
- **The 4-inch (under sod) soil-temperature based models performed poorly in 2006, probably due to the intense drought that was in place. Onset of FHS was delayed by up to 24 days past model predictions.**
- **Dropping 2006 from the analysis, model predictions were compared against FHS observations from 2004 and 2005. Altering the start date (for degree-day accumulations) improved model results for the Altus and Goodwell areas; the original start dates worked best for the Stillwater and El Reno areas.**
- **Considering all sites, the soil-temperature based FHS models outperformed the calendar-based method (FHS = March 15) for each of the three categories of winter wheat analyzed. As compared to the calendar method, the models reduced the average error in FHS prediction by 10 days for early FHS varieties, by seven days for middle FHS varieties, and by three days for late FHS varieties. The maximum errors were reduced by three days (late varieties) to as much as 12 to 14 days (early and middle varieties).**
- **Results from 2004-2005 suggest that, regardless of location within Oklahoma, March 15 is almost always too late for FHS, especially for early and middle varieties, and that soil-temperature based FHS models are more reliable. Special consideration, however, must be given in extreme drought, which in 2006 was the probable mechanism that delayed the onset of FHS by one to three weeks past model predictions, depending on variety.**

*retired

The purpose of this multi-year project is to develop optimal weather-based models to predict the occurrence of first hollow stem (FHS) in winter wheat, with a goal of implementing such a model on the Oklahoma Mesonet, the state's automated weather monitoring network of more than 110 stations. Such a product could be used as a management tool for producers who use winter wheat as a dual-purpose crop, as it would provide guidance as to when to remove cattle from grazed fields – not only to avoid wheat yield loss after FHS date, but also to be able to keep cattle on the fields as long as possible (up to FHS date).

The FHS database (dates of first occurrence) used in this project for model development consisted of 10 years of observations from wheat variety trials at Marshall (1994 to 1997 plantings) and Stillwater (1998 to 2003 plantings). For purposes of this study, wheat varieties were grouped into three categories with respect to appearance of FHS (early, middle, and late). Early (E) varieties are represented by Jagger; middle (M) by Custer and OK101; and late (L) by Ike, 2174, and OK102. The goal is to develop an optimal weather-based model for estimating FHS date for each category of wheat.

Last year, optimal soil-temperature based models to predict FHS date were developed. The models use the Mesonet-measured 4-inch soil temperatures under sod cover and are based on degree-day accumulations from specific start dates and with specific temperature thresholds. Information on these models can be found in last year's wheat research report, *Wheat Research at OSU 2005*.

Over the past several years, independent FHS observations on ungrazed dryland wheat were taken at Altus, Goodwell, El Reno, and Stillwater. Varieties utilized in our analysis were: Altus (2004, 2005) – Jagger, Custer, OK101, 2174, and OK102; Goodwell (2004) – Jagger and Custer; Goodwell (2005) – Jagger, Custer, OK101, 2174, Ike, and OK102; El Reno (2004) – Jagger; El Reno (2005) - Jagger, Custer, OK101, 2174, and OK102; El Reno (2006) – Jagger, Custer, OK101, and 2174; Stillwater (2005) – Jagger, Custer, OK101, 2174, Ike, and OK102; Stillwater (2006) – Jagger, Custer, OK101, 2174, and Ike. For a given site and year, the observed FHS date was taken as the average of the FHS dates of all those reporting varieties in the same category (E, M, or L).

Using these observed FHS dates from 2004 to 2006 and 4-inch soil temperature data from the Altus, Goodwell, El Reno, and Stillwater Mesonet sites for these years, predictions of FHS dates were made using the optimal soil-temperature based models developed last year. These predictions were compared against the standard calendar-based method, in which March 15 is used as a general date for FHS.

The soil-based models performed poorly in 2006, apparently due to the intense drought that was in place at the time. The winter 2005-2006 (Dec. 2005 – Feb. 2006) ranked as the second driest Oklahoma winter since 1895 (Oklahoma Climatological Survey, Norman, OK). Coupled with lack of moisture, warm temperatures (13th warmest since 1895) put additional stress on the wheat crop. All areas where FHS was measured in 2006 (Stillwater and El Reno) received less than one inch of moisture for the entire three-month period. Results showed onset of FHS was delayed by 19 to 24 days past model predictions for early FHS varieties, by 14 to 17 days for middle varieties, and by 9 to 11 days for late varieties. With its historic winter dryness, 2006 was clearly outside the realm of the 10 years used to develop the soil-based models.

Accordingly, focus next shifted to testing the models on 2004 and 2005 FHS data. These winters (2003-2004 and 2004-2005) were more normal (48^{th} wettest and 31^{st} wettest since 1895, respectively) than 2006. Despite this, it became clear that these models do not necessarily perform well in geographical areas outside of those in which the models were developed (Stillwater/Marshall). This was especially the case in the Altus area, where FHS was predicted to arrive 10 to 14 days too early during both years. At Goodwell, the problem was not as bad, but overpredictions (FHS too late) of four to nine days were seen for the middle and late varieties.

It was decided to alter the start dates for soil degree-day accumulations at these two locations. This would correspond to some type of latitude dependent behavior. At Altus, start dates of January 1 and January 8 were tested for early (E) and middle (M) varieties, and January 8 and January 15 for late (L) varieties (representing shifts in start dates of plus one to two weeks). At Goodwell, start dates of December 8 and December 15 were tested for E and M varieties, and December 15 and December 22 for L varieties (representing shifts in start dates of minus one to two weeks). Moving forward the start date at Altus by two weeks and moving back the start date at Goodwell by one week seemed to work best. The temperature thresholds (31°F for E and M varieties, and 34°F for L varieties) and degree-day predictors (763.5 for E, 898.2 for M, and 698.7 for L) remained the same.

Using these altered soil-based models for Altus and Goodwell (and keeping the original models for Stillwater and El Reno), we compared FHS model and calendar-based (March 15) predictions with FHS observations for these two years. The results are shown in Table 1.

The soil-based models in general performed admirably at each site. As compared to the March 15 approach, only at Goodwell did the calendar method seem to do better (by one to three days) and that was because, for these two years, FHS for all reported wheat categories occurred around March 15 and all within a week's time period (March 15 to 16, 2004; March 11 to 19, 2005). It is unlikely that such a scenario would be repeated over multiple years featuring a variety of weather conditions. In-depth observations will be taken at Goodwell in 2007, and it will be interesting to see if model results improve in 2007.

Considering all the FHS observations from all sites, the soil-based models performed better than the March 15 approach in all statistical categories listed. The average model error (the average number of days the FHS prediction is off from the observed FHS date) ranged from -2 days to +3 days (depending on wheat category), while with the March 15 approach, average model errors ranged from +3 days for late varieties to +10 to 12 days for early and middle varieties. This indicates March 15 is on average too late a date for FHS, especially for E and M varieties. The maximum prediction error is as large as +22 days (too late) for E and M varieties using the calendar approach and +9 days for L varieties. In contrast, the soil-based temperature models have maximum prediction errors ranging from +6 to 10 days,

Table 1. Performance of optimal soil degree-day based models for first hollow stem (FHS) occurrence versus the calendar-based method for the three classes of winter wheat varieties (2004-2005).

	Model Error (days) [Model - Observed FHS Date[1]]					
	Early FHS Varieties		Middle FHS Varieties		Late FHS Varieties	
	Soil-based Model[2]	Calendar Model (March 15)	Soil-based Model[3]	Calendar Model (March 15)	Soil-based Model[4]	Calendar Model (March 15)
Altus						
Average	1.5	15	4	11	-1.5	2
Largest Error	8	20	10	15	-4	2
Smallest Error	-5	10	-2	7	1	2
El Reno/Stillwater						
Average	-1.5	>17	3	17	0	8
Largest Error	-6	>22	7	22	0	9
Smallest Error	3	14	-1	12	0	7
Goodwell						
Average	-5.5	2	1.5	1	6	-4
Largest Error	-7	4	4	3	6	-4
Smallest Error	-4	0	-1	-1	6	-4
All Sites						
Average	-1.8	12.3	2.8	9.7	0.6	3.2
Standard Error	2.4	3.1	2	3.4	1.6	2.3
Maximum	8	22	10	22	6	9
Minimum	-7	0	-2	-1	-4	-4
Range	15	22	12	23	10	13
Standard Deviation	6	8.2	5	8.4	3.6	5.1

[1] Independent FHS observation on dryland wheat.
[2] TLOW = 31°F; SDATE = Dec. 15 (Goodwell), Dec. 22 (El Reno/Stillwater), Jan. 8 (Altus); 4" Soil (Sod Cover) Degree Days = 763.5
[3] TLOW = 31°F; SDATE = Dec. 15 (Goodwell), Dec. 22 (El Reno/Stillwater), Jan. 8 (Altus); 4" Soil (Sod Cover) Degree Days = 898.2
[4] TLOW = 34°F; SDATE = Dec. 22 (Goodwell), Jan. 1 (El Reno/Stillwater), Jan. 15 (Altus); 4" Soil (Sod Cover) Degree Days = 698.7

representing improvements of 3 to 14 days over the calendar method. Also, the standard error, range, and standard deviations for all three categories are better using the soil-temperature model approach.

Admittedly, two years represent a small sample set of independent observations on which to test these models. However, more FHS observations will be taken at these sites in 2007 for inclusion in the 2007 analysis. Using the 2007 data in conjunction with 2004 and 2005, the goal for 2007 is to fine-tune the soil-based models to produce the best results. Such models could then be later implemented on the Oklahoma Mesonet in real-time using daily soil temperature measurements; producers would be able to access the products at http://agweather.mesonet.org, the Oklahoma Agweather site.

The current soil-based models predict a single date for FHS occurrence (for each wheat category) – this date is based on the degree-day accumulation predictor value (763.5 for E varieties, 898.2 for M varieties, and 698.7 for L varieties). In addition to this approach, which gives the average or "best" FHS date estimate for any given year, it might also be useful to predict the earliest possible degree-day based FHS date (based on the lowest FHS degree-day total for a particular wheat category from our observational database). The models could then be used as a scouting tool to indicate the earliest possible day to begin scouting for FHS at any given location and year. This would give producers time to get into the fields to scout for FHS before it actually occurs. To prevent grain yield decline in grazed fields, it is important to monitor FHS before or as it is occurs, rather than after the fact. Since in some years, the average FHS model estimates would result in overpredictions (FHS actually occurring earlier), having an earliest possible date for FHS would result in not missing FHS if the producer scouts. A similar approach could be taken to predict the latest possible degree-day based FHS date, although as just discussed, such a prediction would not be as useful. To tighten up the range of predicted dates, these approaches could utilize values from the 10 to 90 percent percentile of degree-day totals for observed FHS dates (rather than the 0 to 100 percent range, which would represent the lowest to highest degree-day totals to FHS). The value at the 10 percent level could be used as the "earliest" degree-day based FHS date and that at the 90 percent level as the "latest" FHS date for any given year. This approach would thus be based on 80 percent of past FHS observations, which would fall somewhere between the earliest and latest modeled values for a given wheat category (E, M, or L) in any given year.

Effects of Rice Root Aphid Infestations on Wheat Forage and Grain Yield in Oklahoma

Partners in Progress WHEAT

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2005-2006 progress made possible through OWRF/OWC support

- **The rice root aphid (RRA) was found throughout the wheat growing counties of Oklahoma.**
- **RRA occurs primarily on seedling to early tillering wheat.**
- **Over two field seasons, increasing infestations of RRA had no observable effect on plant growth and yield components.**
- **Controlled growth chamber studies demonstrated that RRA had little to no effect on wheat forage dry weights.**
- **Based on these studies the RRA should not be considered an important pest in Oklahoma winter wheat.**

Rhopalosiphum rufiabdominalis Sasaki (rice root aphid, RRA) is a newly encountered species in Oklahoma. Primarily due to a lack of sampling effort below the soil surface and frequent misidentification as *Rhopalosiphum padi* L. (bird cherry-oat aphid, BCOA), RRA has until recently gone unaccounted for in the Southern Plains. RRA and BCOA can only be properly distinguished from one another by the presence or absence of microscopic hairs on the antennae; it is impossible to separate the two without the aid of a microscope.

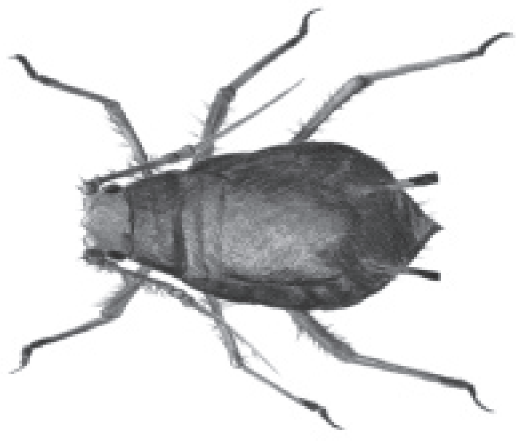

Figure 1. The Rice Root Aphid.

An initial greenhouse study (Kindler et al. 2004) in Oklahoma demonstrated that wheat infested with RRA produced less forage and grain. These reductions in plant growth and seed production caused by RRA appeared to be similar to the negative effects caused by the closely related BCOA (Trent 2003). Preliminary field observations near Stillwater revealed that RRA is often the most abundant aphid on emerging early planted wheat (for grazing or dual-purpose). These early infestations were cause for concern because of the great potential for damage on seedling wheat. Because of the potential economic impact of RRA, we documented (1) the distribution of this aphid species, and (2) evaluated the effects of increasing RRA populations on wheat growth and yields.

Methods

Distribution

We traveled to several counties in each of the agricultural regions of Oklahoma to sample for RRA on early planted winter wheat. Fields in each county we visited were sampled using a narrow shovel; we collected up to four shovel samples in each field. The samples consisted of 15.24 cm of row and contained the root systems as well as the leafy portion of the plants. Individual shovel samples were placed into a Berlese funnel for seven days and all of the aphids were collected into glass jars filled with a 1:1 solution of antifreeze and water for counting and identification (Kindler et al. 2004).

Field Plot Evaluation

Our field study was conducted in Perkins and took place over two wheat growing seasons. Each year the field was planted with OK101. A completely randomized block design with 10 replications (blocks) was used. In each replication, 0, 0.25, 0.5, 1, or 2 pots of RRA infested rye were released (at early tillering) into an outer 1/3 of mesh covered plots (60.96 cm x 91.44 cm) in an effort to establish increasing infestation levels of RRA. Within the plot, the middle third was designated for destructive sampling (described below) whereas the remaining outer third of the plot was treated with insecticide for intra-plot evaluation of infested versus noninfested subplots. Mesh tents were used to cover each plot for several weeks to assist in the establishment of the aphids in the field.

In each plot, samples were taken two to three times during the fall using a narrow shovel (described above). Each sample was placed into a Berlese funnel for counting and identification (Kindler et al. 2004). Since RRA only occurs during the fall, we were attempting to evaluate the effects of fall infestations on spring yields. In the spring, insecticides were used to prevent spring infestations of aphids. Aphid-days or the cumulative RRA infestation was estimated for each plot.

In each plot, the mature wheat from both outer sub-plots was harvested by hand. The tillers from each yield sample were placed into paper sacs and taken to the lab for threshing. Each tiller was carefully threshed by hand so every seed could be counted. All seeds from each plot were dried in an oven to obtain similar grain moisture levels. The test weight for each plot was estimated by using a test weight funnel and a Seedburo Model 8800 Computer Grain Scale. Regression analyses were performed to evaluate the effects of aphid days on yield components. We statistically compared yield measures for infested versus noninfested subplots.

Environmental Chamber Forage Evaluation

A replicated study was conducted in a walk-in environmental chamber (Conviron® CMP 3244) at the Controlled Environmental Research Laboratory (OSU). A range of cultivars important to wheat production systems in the Southern Plains (Jagger, OK101, OK102, TAM105, TAM107, and TAM110) was evaluated. Single seeds of each wheat cultivar were planted in 4 × 20 cm Cone-tainers™ (Stuewe & Sons Inc., Corvallis, Oregon) and covered with 30 cm tall mesh-vented cellulose nitrate tubes. The soil mixture was a 1:1 ratio of Scott's Redi Earth® and Absorb-N-Dry. The outside rim of each Cone-tainer™ was wrapped with four layers of labeling tape to ensure a tight fit and to prevent aphids from entering or escaping after infestation. Cone-tainers™ were organized in a rack that stood in a 6 × 32 × 60 cm tray that would allow easy watering. A replication consisted of randomly arranged Cone-tainers™, each with a single cultivar seedling infested with one of four aphid levels (see below). Six to seven replications for each aphid level × cultivar treatment were evaluated during this study. Cone-tainer™ racks were maintained at 64°F with 10 hours of light, and at 52°F with 14 hours of darkness to simulate fall conditions in Oklahoma.

Twenty days after planting, aphids were used to infest the individual wheat seedlings. Individual Cone-tainers™ of each cultivar were infested with aphids; 0, 15, 25, or 35 rice root aphids. Cone-tainers™ were checked daily and maintained as previously described for an additional 30 days. This length of time was chosen to simulate typical fall infestations of aphids on seedling wheat prior to grazing initiation in wheat forage systems.

Fifty days after planting, the Cone-tainers™ were removed from the environmental chamber and each plant was graded using the Zadok and Feeke's Scale to ensure that each plant was in the same stage of development. Each Cone-tainer™ was then carefully split down the side with a pair of scissors so that the entire root mass would remain intact and could be removed. Each plant and root mass was then placed individually onto 15.24 cm diameter plastic trays that were set inside Berlese funnels. Plant samples remained inside the funnels up to seven days to ensure that all aphids were removed and the plant material was thoroughly dry. Individual plants were cut at the soil surface and dry forage weights were recorded. Based on initial infestations and total aphids present after 30 days, aphid days were calculated. Relationships between dry forage weights and aphid days were investigated by regression analysis.

Results

Distribution

In 2003, the known distribution of the rice root aphid in Oklahoma consisted of only four counties. Based on the current survey, the rice root aphid is clearly present throughout the wheat growing regions of Oklahoma. A total of 28 of the remaining 73 counties were surveyed; rice root aphids were recovered from 19 of these counties (68% of the counties surveyed) (Figure 2 Rawlings 2006) and all of the agricultural regions (Figure 3 Rawlings 2006).

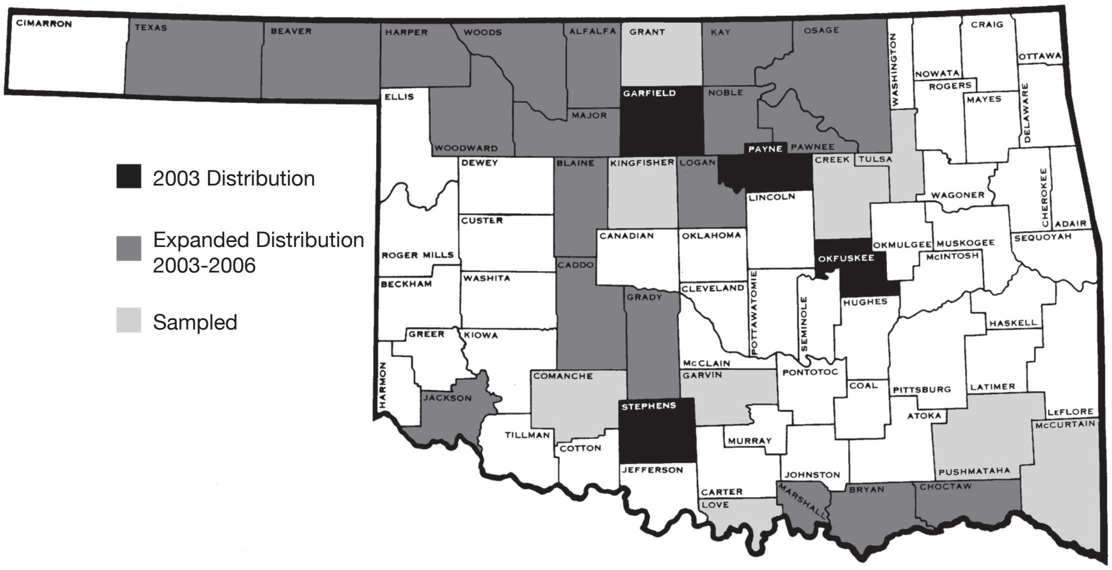

Figure 2. Rice root aphid [*Rhopalosiphum rufiabdominalis* (Sasaki)] distribution across Oklahoma.

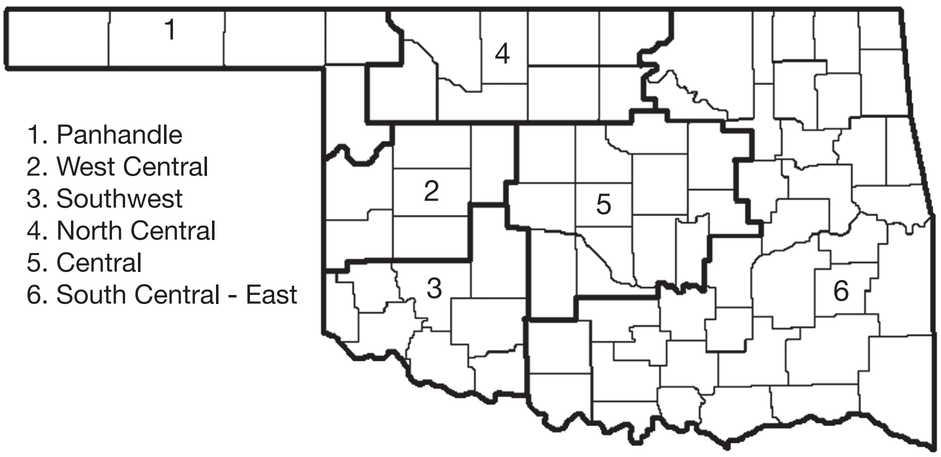

Figure 3. Agricultural regions of Oklahoma.

This survey indicates that the rice root aphid is present among a diverse set of environmental and agricultural habitats having been found in counties that receive less than 20 inches (Texas County) and as much as 52 inches (Choctaw County) of precipitation each year; it was found in counties where up to 380,000 acres of wheat were planted (Garfield County) and where as little as 4,300 acres (Choctaw County) of wheat were planted; it has been found in regions that are dominated by grain-only (Panhandle Region), forage-only (South Central-East Region), and dual-purpose (Central Region) practices. The apparent distribution pattern coincides with the presence of wheat in nearly every county and covers the entire state. The rice root aphid is clearly an adaptable species that can thrive in all the climatic conditions that exist in Oklahoma.

Field Plot Evaluation

Regression analyses of the field data revealed no significant relationships between aphid infestations and yield measures (Table 1 Modified from Rawlings 2006). The differences in results between these analyses and the study conducted by Kindler et al. (2004) could be attributed to differences between greenhouse and field conditions. During my study, conditions in the field were ideal for growing and moisture was not a limiting factor. Greenhouse studies on plant growth are often constrained by artificial components such as soil characteristics, pot size, and watering schedules. Pot size and soil structure can artificially influence root growth and subsequent colonization by the rice root aphid to levels not observed in field situations.

Compared to other field studies that established quite high aphid levels, we were only able to establish relatively low infestations of the rice root aphid. The highest infestation level observed in my study peaked at 16,604 aphid days per subsection (15.24 cm of row) during the 2003-2004 season, and 63,348 aphid days per subsection during the 2004-2005 season. This comes down to 111 and 960 aphid days per tiller respectively. Even with such low infestations, we did observe significant differences for the 2003-2004 growing season in mean number of tillers, mean sample weights, and mean seed weights between aphid infested subsections and subsections treated with insecticide (Table 2 Modified from Rawlings 2006). The mean number of tillers was actually significantly higher in rice root aphid infested subsections, which is contradictory to the finding of Kindler et al. (2004). Despite this increase in tiller numbers, the rice root aphid infested subsections still produced fewer seeds and lower test weights, though not significantly. The 2004-2005 growing season data may have been skewed by extremely high weed pressure that reduced all yield components. No significant differences in yield measures were observed between infested and non-infested subsections during the second growing season (Table 2).

Table 1. Wheat yield measures versus aphid days per plot over a two year period.

	Yield Measure	df	R^2	P
Year 1 (2003-2004)	Tillers	49	0.007	0.5527
	Seed Weight	49	0.002	0.7386
	Number of Seeds	49	0.007	0.5588
	Test Weight	37	0.023	0.3674
Year 2 (2004-2005)	Tillers	47	0.002	0.7899
	Seed Weight	47	0.061	0.0898
	Number of Seeds	47	0.007	0.5659
2 Year (2003 to 2005)	Tillers	97	0.020	0.1707
	Seed Weight	97	0.000	0.9394
	Number of Seeds	97	0.022	0.1443
	Test Weight	37	0.023	0.3674

df = (degree of freedom) indicates the number of observations-1.
R^2 = values approaching 1.0 indicate very strong relationships.
P = values less than 0.05 indicate significant relationships.

Table 2. Wheat yield measures for two growing seasons for RRA infested versus noninfested subplots.

		Treatment Means				
	Yield Measure	Aphids	Insecticide	df	t Value	Pr > |t|
2003-2004	Tillers	139.78	130.08	98	2.26	0.0260
	Sample Weight	63.6431	68.9808	98	-2.20	0.0300
	Seed Weight	0.03013	0.03125	98	-2.62	0.0101
	Number of Seeds	2121.47	2212.71	98	-1.11	0.2700
	Test Weight	61.5027	61.5797	80	-0.40	0.6870
2004-2005	Tillers	60.4375	57.913	92	0.67	0.5057
	Sample Weight	27.9385	26.6639	92	0.61	0.5424
	Seed Weight	0.02599	0.02587	92	0.32	0.7502
	Number of Seeds	1067.19	1028.06	92	0.52	0.6040

df = indicates the degrees of freedom.
t Value = value for the statistical comparison.
Pr > |t| = values less than 0.05 indicate significant differences between infested versus noninfested subplots.

It is possible that the rice root aphid cannot exist at sufficiently high densities in the field to seriously affect wheat growth and yield when adequate rain and moisture are available. However, the 2005-2006 growing season was much drier than the previous two growing seasons and rice root aphid numbers appeared to be much higher (M. Rawlings, personal observations). Kindler et al. (2002) showed that drought conditions exaggerate the effects of greenbugs on wheat grain yield production and it is likely these same environmental conditions enhance the ability of the rice root aphid to do the same. Based on data from this study, rice root aphid, although common and occasionally prevalent on winter wheat in the southern plains, does not appear to be as serious a pest as greenbugs and bird cherry-oat aphids.

Environmental Chamber Forage Evaluation

No significant linear relationships between aphid days and dry forage weights were detected for RRA (Table 3 Modified from Rawlings 2006). As noted earlier, Kindler et al. (2004) documented reduction in plant height and the number of tillers in rice root aphid infested wheat compared with noninfested controls.

The results from our study suggest the rice root aphid has no impact on wheat seedling development and forage weights. The levels of rice root aphid established for this study may have been low compared to those established by Kindler et al. (2004), however, the soil and growing conditions used in this study are more comparable to natural field conditions. Kindler et al. (2004) used wood chip media, which may have artificially enhanced survival, reproduction, and subsequent impact on wheat.

Table 3. Wheat dry forage yield measures versus aphid days.

Species	Maximum Aphid Days	Cultivar	R^2	df	P
R. rufiabdominalis	585	Jagger	0.0007	26	0.8991
	660	OK101	0.0041	27	0.7458
	630	OK102	0.0400	27	0.3077
	780	TAM105	0.0495	26	0.2646
	570	TAM107	0.0130	26	0.5712
	825	TAM110	0.0000	27	0.9869

R^2 = values approaching 1.0 indicate very strong relationships.
df = (degree of freedom) indicates the number of observations-1.
P = values less than 0.05 indicate significant relationships.

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Partners in Progress
WHEAT

Going from a Wheat-ryegrass Mix for Grazing Back to Wheat for Grazing Plus Grain

Tom Peeper and Case Medlin
Plant and Soil Sciences

2005-2006 progress made possible through OWRF/OWC support

- **Current wheat grain prices may warrant the conversion of graze-out fields infested with ryegrass to a grazing plus grain system.**
- **Products such as Axial®, Finesse® Grass and Broadleaf, Hoelon®, Olympus® Flex, and Osprey® can effectively control ryegrass.**
- **Timely application of these products relative to ryegrass stage, soil moisture conditions, and cold stress is critical for optimum ryegrass control.**

In the past several years, numerous Oklahoma and north Texas farmers have converted part or all of their operations from wheat for grazing plus grain to wheat plus ryegrass for grazing only. Now, the drought has thinned herds, lack of fall rains dimmed the prospects for wheat pasture, and the price of wheat has increased to where the economics of the wheat-cattle mix have quickly shifted back to grazing plus grain. This has prompted questions from growers on how to get the ryegrass out of their fields so that they can combine wheat again.

Fortunately, growers have a choice of new postemergence herbicides available that can effectively take the ryegrass out of wheat to permit harvesting a wheat grain crop. These include Axial®, Finesse® Grass and Broadleaf, Olympus® Flex, and Osprey®. Hoelon® also is a highly effective herbicide for ryegrass control in wheat. However, in areas where ryegrass has been sprayed with Hoelon® for several years, some of the ryegrass has developed resistance to this herbicide. This is why it is critical to rotate herbicide modes of action from year to year when possible.

In fields across Oklahoma where the main target weed is ryegrass, growers should consider Axial®, Finesse® Grass and Broadleaf, Hoelon®, or Osprey® as the first choices. All of these products will perform better if applied in the fall to small (two leaf to three tiller), actively growing ryegrass. If a late-spring application is forced, then the herbicides most suited are Axial® and Hoelon®.

Regardless of the herbicide chosen, it is critically important that the ryegrass be actively growing for a few days before the herbicide is applied. Do not apply herbicides when the ryegrass is stressed due to drought or excessive cold temperatures. Instead give the ryegrass several days to resume growth after these conditions diminish. A rule-of-thumb that many use for temperature is "at least four consecutive daytime highs of at least 50ºF prior to application," however, a better practice is to follow the label directions for each product, as requirements for each herbicide will most likely differ.

Axial®, which contains the active ingredient pinoxaden, is a new herbicide from Syngenta. It is highly effective on ryegrass (it is also labeled for wild oat but has not been evaluated by OSU researchers for this weed), but is not active on most other weeds (i.e. broadleaves such as henbit and chickweed). As is the case with most herbicides, optimum control is obtained when it is applied in the fall when the ryegrass has three tillers or less. However, our research with late-winter applications has shown effective ryegrass control. Of course, delaying application until spring reduces wheat yield because the wheat does not have time to recover from the competition in the fall and winter. Axial® has a 50 day grazing restriction, which for many growers means that it will have to be applied after the cattle are pulled in February or early-March. This year will be our first year for commercial use of Axial® in Oklahoma, so check with your chemical dealer early to make sure it is available.

Finesse® Grass and Broadleaf, often called FG&B, is a combination of two active ingredients and is labeled for control of ryegrass. The application rate depends on the season and size of the ryegrass. This product had the misfortune of being introduced into the market during a time when dry weather was prevalent. Under those conditions it did not work very well and several growers were disappointed. That does not mean that we should not try it again when growing conditions are favorable. It is the strongest of these herbicides as far as control of broadleaf weeds is concerned, and like Olympus® Flex, is often a good choice when a grower is not sure if cheat, wild oat, or ryegrass is his worst problem.

Osprey® is new sulfonylurea herbicide from Bayer CropScience that is very effective on ryegrass. Osprey® is one of the two active ingredients in Olympus® Flex. Growers who have ryegrass as their main weed do not need the other active ingredient, so they should apply the straight Osprey® rather than the mixed product Olympus® Flex. If a grower is not sure about what his various weed problems are, then Olympus® Flex is a good shotgun approach for controlling cheat, wild oat, and ryegrass. As is the case with most herbicides, Osprey® works better when applied to smaller ryegrass in the fall. The label says it should be applied to ryegrass with one-leaf to two tillers. Osprey® is also fairly effective on wild oats and suppresses henbit, but is weak on the brome grasses (i.e. cheat). It has a 30 day grazing restriction.

Hoelon® has been around for more than 25 years but was never used much in Oklahoma because it had a full-season grazing restriction. The grazing restriction has now been reduced to 28 days, which makes this herbicide much more useful in Oklahoma. It is very strong on ryegrass and wild oats, but does not control any of our other grass or broadleaf weeds. Somewhat like the other herbicides mentioned above, the label says to apply it before the ryegrass passes the two-tiller stage. That is not very practical in Oklahoma, and our research has shown that it can kill ryegrass that is considerably larger. Liquid fertilizer should not be used as the carrier because it reduces ryegrass control.

With these various options available for controlling ryegrass, the wheat grower's main decision is simply to do something about the ryegrass so that he can capitalize on the current high prices for wheat grain. Once that critical decision is made, it is much easier to make the second decision of which herbicide to use. In the long run, it has proven difficult to completely get rid of ryegrass once this weed gets established. Growers will likely want to consider a rotation with winter canola or perhaps cotton or milo to help reduce this weed, but if continuous wheat production is necessary, growers should rotate herbicides, using the various products mentioned to incorporate new herbicide modes of action and help prevent weed resistance in their fields.

OKLAHOMA STATE UNIVERSITY

RESEARCH