Western Extension/Education Research Activity WERA 066
Integrated Management of Russian Wheat Aphid
and Other Cereal Arthropod Pests
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Department of Bioagricultural Sciences and Pest Management
Colorado State University, Fort Collins, Colorado

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II. WERA-066 Objectives Addressed

A. Development of integrated management strategies for cereal aphid and other arthropod pests in small grains to improve economic viability of small-grain cropping systems while maintaining environmental quality.

B. Facilitate research into improved integrated pest management approaches at the field and landscape level to manage cereal arthropod pests in the western U.S.

1. Coordination of biological control, host plant resistance and cropping system research including evaluation of natural enemy performance and resistant cultivars alone and in combination in order to identify complementary management systems.

2. Coordinate research in genetics, genomics, physiology, taxonomy, and ecology of arthropod pests and their natural enemies that aid in implementing integrated management strategies in diverse agricultural systems.

3. Enhance efficient development of resistant varieties by coordinating the identification, monitoring, and characterization of Russian wheat aphid and Hessian fly biotypes.

III. Current Accomplishments

A. Biological control

1. 116 species of spiders were collected from wheat production systems, and a manuscript is being drafted. (Objectives A, B2)

2. Results from an exclusion cage study suggest that naturally occurring biological control has increased since similar studies were conducted in the early 1990s. The study currently is being repeated for a third year. (Objectives A, B2)

B. Plant Resistance

1. Russian wheat aphid Biotype RWA1-resistant wheat cultivars are now planted on more than 50% of Colorado's wheat acreage. The pest management benefits of these varieties is unknown, although anecdotal evidence suggests that they can be noticeable. (Objectives A, B3)

2. Winter wheat lines with the 2414-11 (Dn7) resistance source continue to be advanced. Seed is being increased and commercial release for at least one line is anticipated. (Objectives A, B1)

3. An experiment to develop an economic injury level for Biotype RWA2 is being initiated using an one of the advanced 2414-11 lines. (Objectives A, B2)

4. Surveys were conducted to determine the presence of Dn4-virulent

Russian wheat aphids. In 2009, all but one sample contained aphids virulent to Dn4. No virulence to 94M370 (Dn7) was detected. (Objectives A, B3)

C. Biology and Management

1. Aphid flights were monitored at four locations by means of suction traps. Trap catches were higher than they have been for several years, which was reflected in widespread insecticide use. (Objectives A, B2)

2. Noncultivated grass hosts were surveyed in montane environments along the Cache La Poudre River for a third season. Oversummering Russian wheat aphids, as well as other cereal aphids, were found at most elevations. Russian wheat aphid biotypic diversity in these environments is being examined. (Objectives A, B2, and B3)

3. Insecticide treatments containing chlorpyrifos (Lorsban Advanced and Cobalt Advanced, Dow Ag Sciences), dimethoate and lambda cyhalothrin (Warrior II, Syngenta) were effective against Russian wheat aphid as well as brown wheat mite in winter wheat. Producers now have some research-based guidelines for selecting treatments for situations in which their crop is infested with both pests. (Objective A)

4. A foliar thiamethoxam + lambda cyhalothrin product (Endigo, Syngenta) was equal to chlorpyrifos in efficacy against Russian wheat aphid in malt barley. This is a promising alternative to lambda cyhalothrin, which has been used for several years under Section 18 registrations. (Objective A)

IV. Publications

F. B. Peairs. 2009. Brown wheat mite research in 2009. Pp. 43 - 44 in Johnson, J. J., ed. 2009. Making better decisions: 2009 Colorado wheat variety performance trials. Colorado State Univ. Agric. Exp. Sta. Tech. Rep. TR09-05, 61 pp.

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Haley, S. D., J. J. Johnson, P. H. Westra, F. B. Peairs, J. A. Stromberger, E. E. Heaton, S. A. Seifert, R. A. Kottke, J. B. Rudolph, G. Bai, R. L. Bowden, M.-S. Chen, X. Chen,

Y. Jin, J. A. Kolmer, and B. W. Seabourn. 2009. Registration of 'Thunder CL' Wheat. J. Plant Reg. 3: 181 - 184.

Peairs, F. B., J. B. Rudolph, and T. L. Randolph. 2009. 2008 Colorado field crop insect management research and demonstration trials. Colorado State Univ. Agric. Exp. Sta. Tech. Rep. TR09-11, 27 pp.

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Merrill, S. C., C. B. Walker, F. B. Peairs, T. L. Randolph, S. D. Haley, and R. W. Hammon. 2009. Displacement of Russian wheat aphid, *Diuraphis noxia* (Kurdjumov), Biotype 1 in Colorado by Russian wheat aphid biotypes virulent to the wheat resistance gene *Dn4*. Colorado State Univ. Agric. Exp. Sta. Tech. Bull. TB09-01, 19 pp.

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Merrill, S. C., T. O. Holtzer, and F. B. Peairs. 2009. *Diuraphis noxia* reproduction and development with a comparison of intrinsic rates of increase to other important small grain aphids: A meta-analysis. Environ. Entomol. 38: 1061-1068

Nkongolo, K.K., S. D. Haley, N. S. Kim, P. Michael, G. Fedak, J. S. Quick, and F. B. Peairs. 2009. Molecular cytogenetic and agronomic characterization of advanced generations of wheat x triticale hybrids resistant to *Diuraphis noxia* (Mordvilko): Application of GISH and microsatellite markers. Genome 52: 353-360.

Merrill, S.C., T.O. Holtzer, F.B. Peairs, and P.J. Lester. 2009. Modeling spatial variation of Russian wheat aphid overwintering population densities in Colorado winter wheat. J. Econ. Entomol. 102: 533-541.

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New approaches to resistance in wheat to Hessian fly

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The Hessian fly is the most important insect pest of wheat in the southeastern United States. While the use of resistant wheat is an effective means for controlling Hessian fly, it places a selective pressure on populations and has led to the appearance of genotypes of the pest that can overcome resistance. A recent evaluation of 21 of the identified resistance (*R*) genes in wheat to Hessian fly documented that only 5 of the *R* genes would provide effective protection of wheat to Hessian fly in the Southeast. These results indicate that new approaches to the deployment of *R* genes such as gene combinations, identification of new and effective sources of resistance, and genetically engineered resistance are needed if genetic resistance is to continue as a viable option for protection of wheat in the Southeast.

Our long-term goal is to ensure effective and durable resistance in wheat to Hessian fly. One approach we are taking toward this goal is to test combinations of effective undeployed *R* genes. Results will test the hypothesis that deployment of a combination of two highly effective *R* genes will be more efficacious and potentially more durable than single gene releases. We are also employing an *in planta* bioassay with Hessian fly larvae to discover toxic proteins that could be utilized in transgenic resistance. Using this assay we are testing lectins for toxicity as well as various *Bacillus thuringiensis* Cry δ-endotoxins. These results are testing the hypothesis that toxic proteins can provide effective transgenic resistance to Hessian fly that can be pyramided with combinations of native genes for resistance. A third approach we are pursuing toward developing genetically engineered resistance in wheat to Hessian fly is the application of plant mediated RNA interference (RNAi). We have used RNAi as a functional genomics tool with Hessian fly larvae. Preliminary results with RNAi suggest we have identified a secreted salivary gland protein (SSGP) that is a virulence effector involved in the stunting of seedling wheat by Hessian fly larvae. When the gene encoding this SSGP is silenced by RNAi larvae appear to be unable to stunt wheat and cannot develop properly. We propose to test the hypothesis that plant mediated RNAi silencing of this gene and other genes essential to the interaction of Hessian fly larvae with wheat can provide effective resistance.

Shukle, R. H., Subramanyam, S., Saltzmann, K. A., Williams, C. E. 2010. Ultrastructural changes in the midguts of Hessian fly larvae feeding on resistant wheat. Journal of Insect Physiology, 56:754-760

Zhang, S., Shukle, R. H., Mittapalli, O., Zhu, Y. C., Reese, J. C., Wang, H., Hua, B.-Z., Chen, M.-S. 2010 The gut transcriptome of a gall midge, *Mayetiola destructor*. Journal of Insect Physiology, 56:1198-1206

Behura, S.K., Shukle, R. H., Stuart, J. J. 2010. Assessment of structural variation and molecular mapping of insertion sites of *Desmar*-like elements in the Hessian fly genome. Insect Molecular Biology, available online early at http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2583.2010.01028.x/pdf

Wheat resistance and susceptibility to Hessian fly

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Wheat pathways and genes involved in induced resistance and susceptibility have been characterized through molecular genetic approaches. Soon after wheat is attacked by Hessian fly larvae, many changes are detected in the first line of defense, the plant cuticle. The virulent insect is able to silence a suite of genes involved in cutin and wax synthetic pathways as they altered the host plant's physiology. Genes encoding lipid transfer proteins, which are thought to deliver substances like cutin and waxes to the protective cuticular layer, are nearly silenced by attacking virulent Hessian fly larvae. As a result, the cuticular integrity is not maintained, cutin and surface waxes degrade, and the epidermis becomes porous in the newly induced susceptible plant. This porosity appears to be a method by which the plant delivers nutrients to the larvae in the first few days of the compatible interaction, before gall-like nutritive tissue is formed.

In resistant wheat, defense responses are induced by avirulent larvae as the plant becomes resistant. Class III peroxidases and reactive oxygen species increase in abundance. Other defense compounds such as mannose-binding jacalin-like lectins are also produced by wheat during incompatible interactions. These toxic molecules rapidly affect the morphology of the lumen surface in first-instar Hessian fly larvae; the microvilli, which are finger-like projections that absorb nutrients, are completely destroyed within just a few hours of the ingestion of plant fluids.

New sources of Hessian fly resistance are being pursued. Tightly linked markers for the Hessian fly-resistance gene, *H32*, were identified for marker-assisted selection in breeding programs. And although *Triticum aestivum x Lophopyrum elongata* disomic substitution lines did not yield resistance to Hessian fly, this set of material contained resistance to BYDV, CYDV and *Mycosphaerella graminicola*.

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Shukle RH, Subramanyam S, Williams CE. 2010. Ultrastructural changes in the midgut of Hessian fly larvae feeding on resistant wheat. Journal of Insect Physiology 56:754-760.

Yu GT, Williams CE, Harris MO, Cai X, Mergoum M, Xu SS. 2010. Development and validation of molecular markers closely linked to *H32* for resistance to Hessian fly in wheat. Crop Science:50:1325-1332.

Anderson JM, SB Goodwin, D Bucholtz, N Sardesai, G Gyulai, J Santini, and CE Williams. 2010. Evaluation of Triticum aestivum x Lophopyrum elongata disomic substitution lines for resistance to Mycosphaerella graminicola, Blumeria graminis, Barley and Cereal Yellow Dwarf Virus and Hessian fly. Euphytica 172:251-262.

Hessian fly population genetics and microsatellites

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Brandi Schemerhorn's laboratory was the first to use the method of BAC superpooling in any insect species to map more than 250 molecular markers. The purpose of mapping these clones and microsatellites was two-fold. One was to create markers that cover all of the Hessian fly chromosomes in order to answer fundamental questions about population structure. The second purpose was to help create a saturation map for assembling genome sequence of the Hessian fly. We have also determined that only two distinct HF populations inhabit the southeastern US and small but significant levels of gene flow occurs between them. Sequencing data and microsatellite diversity studies indicate that multiple introductions of HF occurred, rather than the previously hypothesized single introduction. In addition, it is also apparent that the most important factor studied to date relating how the populations are associated with each other appears to be directly and positively correlated with the amount of wheat planted for hay in a given area.

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Li, H.M., L. Sun, W. Muir, J. Xie, B.J. Schemerhorn, and B.R. Pittendrigh. 2009. Transcriptional signatures in response to wheat germ agglutinin and starvation in *Drosophila melanogaster* larval midgut. Insect Mol Biol 18: 21-31.

Abdel-Rahman, M.A., M.A.A. Omran, I.M. Abdel-Nabi, O.A. Nassier, and B.J. Schemerhorn. 2009. Neurotoxic and cytotoxic effect of the venom from different populations of the Egyptian *Scorpio maurus palmatus*. Toxicon 55: 298-306.

Aggarwal, R., T.R. Benatti, N. Gill, C. Zhao, M.S. Chen, J.P. Fellers, B.J. Schemerhorn, and Stuart, J.J. 2010. A BAC-based physical map of the Hessian fly genome anchored to polytene chromosomes. BMC Genomics.

Benatti, T.R., F.H. Valicente, R. Aggarwal, C. Zhao, J.G. Walling, M.S. Chen, S.E. Cambron, B.J. Schemerhorn, and J.J. Stuart. 2010. A neo-sex chromosome that drives postzygotic sex determination in the Hessian fly (*Mayetiola destructor)*. Genetics 184: 769-777.

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PROJECTS:

Wheat Gene Expression is Differentially Affected by a Virulent Russian Wheat Aphid Biotype

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Abstract - An improved understanding of the complex interactions between plants and aphids is emerging. Recognition of aphid feeding in plant tissues involves production of several defense response signaling pathways and downstream production of defense and detoxification compounds. Feeding by Russian wheat aphid, *Diuraphis noxia* (Kurdjumov), a serious pest of cereal crops worldwide, induces foliar deformity and chlorophyll loss during compatible wheat-*D. noxia* interactions. Experiments conducted to better understand the temporal expression of wheat genes controlling signaling and metabolism during compatible and incompatible *D. noxia* interactions revealed significant differences in level and pattern of gene expression in defense response signaling and metabolic pathways. The jasmonate (JA)-signaling genes *LOX, AOS,* and *AOC* were significantly more upregulated (~3- to 7 fold) in incompatible interactions than in compatible interactions (~2.5 to 3.5 fold) as early as 1 hr post *D. noxia* infestation (hpi). In contrast, glycolysis and citric acid cycle genes were expressed comparatively less (~1.5 to 2 fold) and significantly downregulated in incompatible interactions and upregulated or less downregulated in compatible interactions from 6 to 72 hpi. Differences in expression of JA-signaling genes between feeding site tissues and non-feeding site tissues suggest that *D. noxia* defense response signals in wheat are primarily restricted to aphid feeding sites in the initial 6 hpi. This is the first report of differential

upregulation of plant genes at 1 hpi in incompatible interactions involving aphid herbivory. Early wheat plant defense responses in incompatible *D. noxia* interactions at 1, 3, and 6 hpi appear to be important aspects of *D. noxia* resistance in wheat.

Reactive Oxygen Species Are Involved in Plant Defense against a Gall Midge

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Abstract Reactive oxygen species (ROS) play a major role in plant defense against pathogens, but evidence for their role in defense against insects is still preliminary and inconsistent. In this study, we examined the potential role of ROS in defense of wheat and rice against Hessian fly (*Mayetiola destructor*) larvae. Rapid and prolonged accumulation of H_2O_2 was detected in wheat plants at the attack site during incompatible interactions. Increased accumulation of both H_2O_2 and superoxide was detected in rice plants during non-host interactions with the larvae. No increase in accumulation of either H_2O_2 or superoxide was observed in wheat plants during compatible interactions. A global analysis revealed changes in the abundances of 250 wheat transcripts and 320 rice transcripts encoding proteins potentially involved in ROS homeostasis. A large number of transcripts encoded class III peroxidases that increased in abundance during both incompatible and non-host interactions, whereas the levels of these transcripts decreased in susceptible wheat during compatible interactions. The higher levels of class III peroxidase transcripts were associated with elevated enzymatic activity of peroxidases at the attack site in plants during incompatible and non-host interactions. Overall, our data indicate that class III peroxidases may play a role in ROS generation in resistant wheat and non-host rice plants during response to Hessian fly attacks.

Barley Tolerance of Russian Wheat Aphid Biotype 2 Herbivory Involves Expression of Defense Response and Developmental Genes

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Abstract Previous phenotyping experiments revealed that plants of the barley variety Stoneham resist *D. noxia* damage from the Russian wheat aphid, *Diuraphis noxia* (Kurdjumov), via tolerance. In the present study, genes involved in upstream regulation of jasmonic acid (JA), salicylic acid (SA), ethylene (ET), auxin (AUX), and abscisic acid (ABA) biosynthetic pathways were monitored using qRT-PCR in Stoneham and susceptible Otis barley plants after *D. noxia* biotype 2 feeding. Results indicate that *D. noxia* tolerance in Stoneham plants is related to greater expression of JA-, ET-and AUX-biosynthetic pathway genes than in susceptible Otis plants, suggesting the possibility of immediate plant adjustments due to the stress of *D. noxia* feeding. There was limited induction of genes in the ET- (*ACCS*) and IAA (*TDC*) pathways in Stoneham tissues after *D. noxia* feeding. JA pathway genes upregulated in Otis tissues after *D. noxia* infestation failed to successfully defend Otis plants. AUX and ABA transcripts in Otis may be associated with developmental collapses resulting from source and sink adjustment failures.

Interaction of Wheat Streak Mosaic Virus Infection with Wheat Resistance to Wheat Curl Mite *Aceria tosichella* Keifer

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Abstract The wheat curl mite, *Aceria tosichella* Keifer (1969), is a growing and consistent yield reducing menace in cereals worldwide, particularly in bread wheat in the western plains of the United States and Canada. *A. tosichella* is capable of spreading wheat streak mosaic virus (WSMV) and High Plains virus, both important diseases of wheat and maize. Evaluations of germplasm for resistance to *A. tosichella* are often complicated by a lack of knowledge of the number of mites being infested on plants and by potential interactions between WSMV infection and mite infestation. Results of several experiments demonstrated that resistance or susceptibility of germplasm to *A. tosichella* is independent of initial infestation levels. *A. tosichella* population development and mite plant damage on wheat genotype OK05312 at 14 d post infestation were significantly lower than on susceptible Jagger plants. *A. tosichella* infestations and plant damage were significantly greater on WSMV-infected plants of susceptible genotypes than on corresponding uninfected plants. In *A. tosichella* - resistant plants, there were no statistical differences in *A. tosichella* infestations on healthy or WSMV - infected plants.

Interactions Between Biological Control, Cultural Control and Barley Resistance to the Russian Wheat Aphid in Colorado, Kansas and Nebraska

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Abstract The Russian Wheat Aphid, *Diuraphis noxia* (Kurdjumov) (RWA) is an important pest in the U. S. Western Plains, causing hundreds of millions of dollars of losses to wheat and barley production each year through reduced yields and increased pesticide treatment costs. The objectives of this research were to evaluate the performance of two RWA-resistant barley varieties planted at early- and normal planting dates, and to evaluate the effects of these varieties on RWA and RWA natural enemy populations. The research was conducted in three experimental barley fields located at Fort Collins, Colorado, Tribune, Kansas, and Sidney, Nebraska during 2007, 2008 and 2009. The experimental design used was a split-plot design with two main plot treatments - early and normal planting dates. Four split plot treatments (barley varieties) were randomized within each main treatment plot. Variety treatments included the Stoneham and Sydney RWA-barley resistant varieties, and the susceptible variety Otis under thiamethoxam-protected and unprotected regimes. Sampling of RWA and RWA natural enemy populations was conducted on four dates from late May through early July. RWA populations in early-planted (first week of March) plots were significantly lower in all three years at the Colorado and Kansas sites. Within samples from early planting dates, RWA-resistant varieties yielded reduced RWA populations similar to those in insecticide-treated Otis plots at the Colorado and Kansas sites. Very low RWA populations were present in samples from both planting dates collected at the Nebraska site, resulting in no differences in RWA populations between varieties. Early planting dates and RWA-resistant varieties did not affect the natural occurrence of RWA biological control agents.

Virus-Induced Gene Silencing of Putative *Diuraphis noxia* (Kurdjumov) Resistance Genes in Wheat

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Abstract Because of the development of virulent biotypes of the Russian wheat aphid

Diuraphis noxia (Kurdjumov), the identification of new sources of barley and wheat resistance is necessary. Virus-induced gene silencing (VIGS) utilizes the plant defense system to silence viruses in inoculated plants. The accumulation of virus RNA in plants triggers the defense system to silence sequences homologous to the introduced virus and sequences of interest from a plant are inserted into the virus and silenced along with the virus. The VIGS method was tested to determine the ability of barley stripe mosaic virus (BSMV) to serve as a VIGS vector in wheat plants containing the *Dnx* gene for resistance to *D. noxia*. *Dnx* leaves with silenced BSMV virus yielded *D. noxia* populations that were significantly no different from populations produced on healthy *Dnx* leaves. Thus, BSMV silencing does not interfere with *Dnx* resistance. Several different methods were examined to determine how best to confine aphids to the silenced leaf, and a modified plastic straw cage was chosen as the optimum cage type. Microarray and gene expression data were analyzed to select two NBS-LRR type disease resistance protein genes - NBS-LRR1 and NBSLRR2 - in order to assess their role in *Dnx* resistance. NBS-LRR1 and NBSLRR2 were silenced by inoculating leaves of *Dnx* plants with barley stripe mosaic virus (BSMV) containing sequences of each gene. Controls included *Dnx* and Dn0 plants inoculated with BSMV and non-BSMV inoculated plants. Aphids were allowed to feed on control and treatment plants to assess aphid population and mean weight of aphids surviving at the end of the experiment. There were no differences among treatments based on aphid population, but there were significant differences the mean weights of aphids reared on several different treatments.

The Gut Transcriptome of a Gall Midge, *Mayetiola destructor*

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Abstract The Hessian fly, *Mayetiola destructor*, is a serious pest of wheat and an experimental organism for the study of gall midge-plant interactions. In addition to food digestion and detoxification, the gut of Hessian fly larvae is also an important interface for insect-host interactions. Analysis of the genes expressed in the Hessian fly larval gut will enhance our understanding of the overall gut physiology and may also lead to the identification of critical molecules for Hessian fly – host plant interactions. Over 10,000 Expressed Sequence Tags (ESTs) were generated and assembled into 2,007 clusters. The

most striking feature of the Hessian fly larval transcriptome is the existence of a large number of transcripts coding for so-called small secretory proteins (SSP) with amino acids less than 250. Eleven of the 30 largest clusters were SSP transcripts with the largest cluster containing 11.3% of total ESTs. Transcripts coding for diverse digestive enzymes and detoxification proteins were also identified. Putative digestive enzymes included trypsins, chymotrypsins, cysteine proteases, aspartic protease, endo-oligopeptidase, aminopeptidases, carboxypeptidases, and α-amylases. Putative detoxification proteins included cytochrome P450s, glutathione *S*-transferases, peroxidases, ferritins, a catalase, peroxiredoxins, and others. This study represents the first global analysis of gut transcripts from a gall midge. The identification of a large number of transcripts coding for SSPs, digestive enzymes, detoxification proteins in the Hessian fly larval gut provides a foundation for future studies on the functions of these genes.

Differential Accumulation of Phytohormones in Wheat Seedlings Attacked by Avirulent and Virulent Hessian Fly (Diptera: Cecidomyiidae) Larvae

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Abstract We analyzed the accumulation of six phytohormones and phytohormone-related compounds in a wheat [*Triticum aestivium* (L.)] genotype 'Molly' following attacks by avirulent and virulent Hessian fly [*Mayetiola destructor* (Say)] larvae, respectively, and examined the expression of genes in the jasmonic acid (JA) pathway by Northern blot analysis. Compared to uninfested plants, attacks by avirulent larvae resulted in increased accumulation of salicylic acid (SA) by 11.3- and 8.2-fold, 12-oxo-phytodienoic acid (OPDA) by 36.4-and 18.7-fold, 18:3 fatty acid by 4.5- and 2.2-fold, and 18:1 fatty acid by 1.8- and1.9- fold at 24- and 72-hours post initial attack (hpia), respectively, but an 20% decrease in JA accumulation at 24-hpia at the attack site. Attacks by the virulent larvae did not affect the accumulation of SA, OPDA, 18:3 and 18:1 fatty acids, but dramatically increased the concentration of auxin (AUX) from undetectable in uninfested plants to 381.7 ng/g fresh weight at 24-hpia and 71.0 ng/g fresh weight at 72-hpia in infested plants. Transcript levels of genes encoding lipoxygenase 2 (LOX2), allene oxide synthase (AOS), and *Arabidopsis* storage protein 2 (AtVSP2) were increased following avirulent larval attacks, but decreased following virulent larval attacks. Our results suggest that OPDA and SA may act together in wheat resistance to the Hessian fly, whereas AUX may play a role in the susceptibility of wheat plants. The increased OPDA accumulation following avirulent larval attacks was at least partially regulated through gene transcription.

K-State Wheat Insect Extension Activities

J. P. Michaud and R. J. Whitworth

We continue to add to our wheat insect website at: http://www.entomology.ksu.edu/DesktopDefault.aspx?tabindex=195&tabid=405 and to revise our wheat insect management guide annually (http://www.oznet.ksu.edu/library/ENTML2/MF745.PDF).

In addition we cooperate with the Plant Pathology Department to revise the Wheat Variety Disease and Insect Ratings each year (http://www.oznet.ksu.edu/library/plant2/mf991.pdf).

Plus we make presentations at numerous County Extension meetings and crop tours as requested.

We recently revised our Extension publication on the Hessian fly (http://www.oznet.ksu.edu/library/entml2/MF2866.pdf) and added new publications on the bird cherry-oat aphid (http://www.oznet.ksu.edu/library/entml2/MF2823.pdf) and flea beetle (http://www.oznet.ksu.edu/library/entml2/MF2832.pdf).

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2010 Orange Wheat Blossom Midge

In 2010, OWBM continued to present in high numbers in the Flathead Valley. Growers are becoming familiar with the pest, which has recurred in significant numbers since a massive outbreak in 2006. They have adapted to using host phenological timing to apply insecticide to minimize losses. OWBM is present in low numbers in the northeastern part of the state, with some evidence of parasitism. There is no evidence of biological control agent establishment in the Flathead Valley, although parasitoids have been released twice at multiple locations. The major wheat producing area in Montana, the 'Golden Triangle' (apices at Great Falls, Cut Bank and Havre) was monitored using pheromone traps by County Extension Personnel. Thus far, there is no evidence of OWBM in this area.

1. The Northwestern Agricultural Research Center continues to be a location for assessing germplasm from MSU, NDSU and other breeding programs due to heavy pressure (more than 200 larvae in heavily infested spikes).

2. We assessed oviposition preferences using a series of RILS developed from an attractive and unattractive parent. Oviposition preference was heritable, and NILs were developed to confirm QTL. We also assessed potential attractants for ovipositing females in the field.

3. We also assessed wheat lines incorporating *Sm*1 type host plant resistance that are being developed specifically for northwestern MT growing conditions.

2010 Wheat Stem Sawfly

WSS continues to be a tremendous concern for Montana wheat growers. The area impacted by populations increasing in size is expanding, and many farmers are dealing with heavy damage for the first time. Populations sampled during peak flight averaged more than 15 sawflies per sweep in a series of 5 sweeps per sample. Many fields had levels of larvae-induced stem cutting (resulting in lodging) of nearly 100%. Host plant resistance, mainly in the form of solid-stemmed wheat provided variable levels of resistance under heavy pressure, with cutting ranging from 10 to over 50% in fields with stem infestation approaching 100%. Natural enemy populations, including two congeneric braconid parasitoids and a clerid predator, were present at levels up to 70% in some fields, but the overall average parasitism was approximately 20%

1. For several years, we have been researching the role of host volatiles in oviposition preference in WSS. The idea is to deploy attractive and unattractive varieties in a trap crop paradigm. This has the potential to be very effective due to the type of agriculture, available antibiosis, and behavioral characteristics of WSS. In 2010, we continued research assessing plantings of attractant solid stem 'Choteau' around unattractive 'Conan' for a total of 4 site years – 2 at each of 2 sites. The control is Choteau around attractive Reeder. These are large scale plots and for each site*year we have seen a significant higher infestation in solid stem Choteau surrounding the unattractive Conan while the infestation in the interior Reeder was much greater, often equivalent to that in the peripheral Choteau.

2. Crosses between Conan and Reeder yielded a series of RIL that were tested at 2 sites for 2 years. The oviposition preferences of female wheat stem sawflies were clearly heritable. QTL associated with oviposition preference were identified and these were not correlated with any other known agronomic or host plant resistance traits. NILs were tested to confirm the role of these loci and to provide lines for testing for volatile production.

3. Investigations on varietal tolerance and the interactions between physiological yield loss, water stress and nutrient limitations indicated that the impact of WSS larval feeding on yield varied by variety. A key finding was that yield losses were much greater for nutrient limited (P) plants with sawfly-cut stems than for water and nutrient stressed uninfested plants or for water-stressed plants that were cut by the wheat stem sawfly. The role of nitrogen was not explored in this study, but MT soils are frequently deficient in phosphorous and phosphorous levels are often not tested each year.

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WERA-O66 Cereal Insect Pests
North Dakota Report 2010

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Highlights of the 2010 Small Grains Season

The 2010 growing season (April through September) was close to the long term averages for both climate and crop progress. An early spring allowed for much of the grain crop to be planted in April. Timely rains kept most of the grain crop rated as "good" to "excellent" for most of the season. A total of 6.7 million acres of spring wheat was planted this year, up 4% from 2009. Durum wheat acres were up 9% to 1.8 million acres, while winter wheat acreage was down 41% with only 340,000 acres planted. The reduction in winter wheat acres was due mostly to wet weather and a delayed harvest in the fall of 2009. Wheat harvest started at the beginning of August and progressed at a good pace due to optimal harvesting weather. Most growers had finished harvest by the beginning of September. Overall North Dakota produced a good wheat crop. State wide yields were projected to be 46.0 bu/ac for hard red spring wheat, 48.4 bu/ac for hard red winter wheat and 38.4 bu/ac for durum wheat.

2010 IPM Survey

Maps from the 2010 IPM survey in North Dakota were uploaded onto the NDSU IPM website at the following address: (http://www.ag.ndsu.nodak.edu/aginfo/ndipm/)

A state-wide survey of small grain diseases and insects continued during the 2010 growing season. Types of insects monitored include: aphids (species not distinguished), grasshoppers (species not distinguished), wheat stem maggot, cereal leaf beetle and barley thrips. All 53 counties in North Dakota were surveyed in 2010. The survey was initiated on May 29 and continued through August 13, 2008. Crops were surveyed from the 1-leaf stage through hard kernel (ripening) stage. Field scouts surveyed for insect pests of winter wheat, hard red spring wheat, durum wheat, 2-row barley and 6-row barley. All other judgments of pest problems encountered in 2008 are based on reports from County Extension Agents and farmers.

Grain aphids

Grain aphids occurred at relatively low levels in 2010. In North Dakota the treatment threshold is when 85% of the stems have one or more aphids present prior to the completion of heading. There was little insecticide spraying for control of wheat aphids in 2010.

Grasshoppers

The 2010 APHIS rangeland grasshopper forecast indicated potentially heavy grasshopper infestations in many states including North Dakota. Cropland adjacent to grasshopper infested rangelands could potentially have been at risk to significant crop loss. Fortunately ample rain and periods of cool weather in the early summer delayed grasshopper emergence and slowed the development of nymphs. Few wheat fields reached the economic threshold and needed to be treated.

Wheat stem maggot

Maggots were counted on 100 stems per field (20 stems at 5 locations in each field). Maggots boring in the stem cause characteristic ‘white heads’. These heads fail to develop seeds, and are found in otherwise uniformly green fields. White heads were observed from late June to the end of July. Wheat maggot damage was apparent in a number of wheat fields across the state this season, however, incidence of the insect was much lower than what was seen in 2007 when 40% of the wheat fields in the state had maggot damage. Preliminary research done at North Dakota State University suggests that tank mixing insecticides (Warrior II and Baythroid XL) with the early season herbicides during 5-leaf to jointing stage helped reduce the incidence of white heads and increased yields when large numbers of wheat stem maggot adults were present. At this time no economic threshold has been developed.

Cereal leaf beetle

Cereal leaf beetle is an export concern for the shipment of hay from ND to California and is monitored for state regulatory purposes. Although crop scouts found what they thought was cereal leaf beetle damage, no infestations of cereal leaf beetles were confirmed in ND in 2010.

Barley thrips

Barley thrips per stem were counted from a sample of 40 plants per field. Extenstion specialists observed thrips in early June in the North Central and South Central parts of the state. However, seasonal weather conditions were not conducive for barley thrips development and thrips populations never reached levels high enough to cause crop loss.

Wheat stem sawfly

Wheat stem sawfly continues to be a concern for farmers in the southwestern and south-central parts of the state. Although sawfly are usually considered a problem isolated to the western part of the state, reports from numerous growers indicate that it is moving eastward across the state. The most common method for controlling sawfly is with solid stemmed varieties. Mott, a new hard red spring wheat variety which has a semi-solid stem was released in 2009 through the North Dakota county crop improvement associations for seed increase. This variety has sawfly resistance and appears to yield better than most of the current sawfly-resistant varieties including Ernest which is the last NDSU variety released with sawfly resistance.

Hessian fly

Wheat producers in North Dakota generally do not consider Hessian fly a pest of great economic importance and until recently there has been little research done on Hessian fly within the state. Initiated in 2008, surveys using a five component pheromone blend have been successful in providing a great deal of valuable information. Our survey has provided us with information on:

- The geographic distribution of Hessian in North Dakota.
- Phenology of Hessian fly in the Northern Plains.
- Methods for using the Hessian fly pheromone traps.
- The specificity of the pheromone blend for the Hessian fly versus other insects.

Work is also being done to:

- Biotype a population of Hessian fly to determine the virulence status of North Dakota flies to *H3*, *H5*, *H6* and *H7*/*H8*.
- Evaluate North Dakota Hard red spring, durum and barley for resistance to Hessian fly.
- Assess the level of virulence in the North Dakota Hessian fly population to Hessian fly resistance genes *H1-H32*.
- Examine native and non-native grasses as possible hosts to Hessian fly.
- Identify parasitic hymenoptera found attacking Hessian fly.

Orange wheat blossom midge

Soil samples collected in the fall of 2009 indicated increased levels of overwintering wheat midge larvae in the Northwestern and North Central parts of the state. Yet, problems did not occur because early sowing of wheat negated synchronization of wheat midge adult emergence and the vulnerable heading stage. We are only aware of a few reports of wheat midge damage, and we do not think spraying for midge control was wide spread.

Additional information on the orange wheat blossom midge as well as maps of the wheat midge survey for the last 14 years are available at the following address: (www.ag.ndsu.nodak.edu/aginfo/entomology/entupdates/Wheat_Midge/owbm.html)

Wheat curl mite (wheat streak mosaic virus)
Wheat streak mosaic virus (WSMV) was severe in a number of wheat fields in North Dakota this year. The virus was confirmed in 71 wheat samples sent to the NDSU Plant Diagnostic Lab, with a majority of these samples from counties in the north central region of the state. Reasons for the high number of cases this year were last year's late harvest, which made volunteer grain and weed control difficult, and abundant snow cover, which allowed for greater survival of mites and infected plants.

Background on North Dakota Survey for Diseases and Pests
For the last ten field seasons, aphid monitoring has been carried out as part of a larger effort to survey diseases and insect pests in North Dakota cereals. The state is covered by 5-6 scouts who monitor fields within a county every 1-2 weeks from May through August. The insects that are monitored in cereals include: aphids, grasshoppers, and cereal leaf beetle. Results from these surveys can be found on the NDSU extension entomology website. For aphids, a plant is scored as infested if one or more insects are found. Scouts record any aphid found on the plant rather than separating different aphid species. In North Dakota, common aphids in cereals are bird cherry oat aphid, English grain aphid, corn leaf aphid, and greenbug. Scouts also provide qualitative information on species composition and have been instructed to report the occurrence of the Russian wheat aphid. The cereal aphids that are found in North Dakota are assumed to fly north from breeding sites in Kansas and Nebraska. These same winds are believed to bring rust pathogens to the state. Natural enemies of aphids are not monitored in North Dakota.

Background on North Dakota Autumn Survey for Wheat Midge
In the mid 1980s, a major wheat midge outbreak began in northern Canada and subsequently spread in the 1990s to large areas of Manitoba, Saskatchewan, North Dakota, and northwestern Minnesota. Although wheat midge numbers have declined in recent years the North Dakota Wheat Commission is still concerned enough about wheat midge to pay for an annual soil survey that provides estimates of overwintering wheat midge populations. For this survey county agents send in soil samples in September and October from the current years wheat fields. In our lab, we examine these soil samples for wheat midge cocoons. Cocoons contain overwintering third instar larvae. When wheat midge cocoons are found, larvae are dissected to estimate parasitism levels. A map of wheat midge larval numbers, which takes into account expected mortality from parasitism, is made available to wheat farmers in February/March each year.

It should be noted that the wheat midge is an insect that is easy to miss unless wheat spikelets are opened and developing seeds examined. The wheat midge is very small and has an adult stage that lives for only a few days. Because the adult hides in the canopy during the day and is only seen on wheat heads at dusk (when high mosquito populations make it unpleasant to be out examining wheat fields) the wheat midge is rarely reported except when third instar larvae are noticed in large numbers during wheat harvest. Yet even at harvest, observations of wheat midge larvae only occur under particular conditions. If the weather is very dry in August (after larvae finish feeding and before wheat is harvested), larvae remain in the wheat head and are threshed from the heads as the grain passes through the combine. At this time the orange larvae are quite apparent covering the harvesting equipment and can frequently be found in large numbers in the harvested grain loaded onto trucks.

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II. OVERVIEW OF CURRENT RESEARCH AND ACCOMPLISHMENTS

A. Barley Breeding Program (Dr. Do Mornhinweg)

Eight RWA-resistant, 6-rowed, winter, feed barley germplasm lines (STARS 1006B-1013B) resistant to both greenbug and RWA will be released by the end of September, 2010. These lines are in a Post 90 background and carry the *Rsg1* gene for greenbug resistance. They also have RWA resistance each from 1 of 8 different sources. This brings the total number of RWA resistant germplasm lines released from this program to 60. STARS 9301B and STARS 9577B are unadapted, 6-rowed spring barleys each with a high level of resistance controlled by multiple genes. STARS 0501B – STARS 0507B are 6-rowed winter germplasm lines in a feed barley background, STARS 0601B - STARS 0619B are 6-rowed, spring germplasm lines in 4 malting barley backgrounds, STARS 0620B - STARS 0636B are 2-rowed spring barley germplasm lines in 4 malting barley backgrounds, and STARS 0637B- STARS 0643B are 2-rowed spring barley germplasm lines in 3 feed barley backgrounds. These germplasm lines encompass 36 different sources of resistance. These lines were developed by USDA-ARS in Stillwater, and evaluated and selected in Idaho, Colorado and/or Nebraska with assistance of. Phil Bregitzer and Don Obert, USDA-ARS, Aberdeen, ID, Frank Peairs, Colorado State University, and Gary Hein, University of Nebraska. Four RWA-resistant barley cultivars are now available. Sidney and Stoneham are 2-rowed feed barleys bred for the high and dry plains of eastern CO and western NE. Burton and RWA1758 are 2-rowed spring feed barleys developed for dryland or irrigated production from ID to CO. Sidney and Burton have resistance from STARS 9301B and Stoneham and RWA1758 have resistance from STARS 9577B. QTL analysis done in cooperation with Shipra Mittal and Lynn Dahleen, USDA-ARS, Fargo, identified 3 QTL's associated with RWA resistance in STARS 9301B. Only 2 of these three were associated with resistance in STARS 9577B one of which showed a different gene action than in STARS 9301B.

A cooperative project with Texas AgriLife is ongoing to map RWA resistance genes and *Rsg1* and *Rsg2* greenbug resistance genes in 3 winter barley germplasm lines.

A breeding program was initiated in 2004 to develop winter, hulless, feed barleys resistant to both RWA and greenbug, adapted to Oklahoma and the Southern Plains, and suitable for ethanol production. Hulless winter barleys, selected for adaptation to OK as well as percent starch of grain, were crossed as males to RWA and greenbug resistant lines developed by USDA-ARS in Stillwater. Crossing and backcrossing of hulless lines to selected females is ongoing. 4,000 F_4 RWA/GB resistant hulless head rows were in the field in 2009 and again this year for evaluation. 4,000 RWA/GB resistant F_3 are being increased to F_4 in the greenhouse and 233 F_2 bulks were planted in Woodward in the fall of 2009 for head selection.

A seedling screening test for BCOA resistance has been developed and tested for repeatability. Two replications of the Barley Core Collection (960 accessions) were screened with this new technique in the summer of 2006. Survivors were grown in pots in the greenhouse and data collected for plant height, grain yield, and yield components. Five seed each of 364 survivors were screened with BCOA in the summer of 2007. An aphid free set of identical flats was also grown. Selected survivors from the screening were rescued and, along with their matching non-infested checks, transplanted into pots in the greenhouse. Infested and non-infested pots for each line were placed side by side on greenhouse benches for increase. Yield and yield components were measured in the spring of 2008. Results indicated that the proposed 1-7 rating scale should be downsized to 1-4. Confirmation of the 1-4 rating scale was attempted in the summer of 2009 but the experiment was a total loss due to wheat curl mite and army worm infestation in the greenhouse. A repeat of this experiment is planned for the summer of 2010.

B. Wheat Breeding Program (Cheryl Baker)

The main thrust of the wheat program has continued to be the identification and purification of germplasm lines that will provide consistent and reliable differentials for the identification of newly emerging biotypes of the Russian Wheat Aphid. To further this effort, seed was requested from GRIN for: 1) seed of all of the wheat lines in the collection that were resistant to RWA1, but had no rating for RWA2 (received 79 lines), and seed of all of the wheat lines in the collection that were resistant to RWA2, but had no rating for RWA1 (received 165 lines). Screenings were conducted with the appropriate RWA1 and 2, and results are being prepared for submission back to GRIN.

This year, over 50 lines that were previously identified as being resistant to RWA2 (rated 1, 2, 3, or 4) were identified as also being resistant to RWA1. Over 30 were highly resistant to RWA1. A few appear to be less resistant to RWA1 than they are to RWA2 (an unusual combination); this may be useful in biotyping work. In addition, four additional lines that were previously identified as being resistant to

RWA1 are also resistant to RWA2. This information will be useful to wheat breeders who are looking for diversity in the sources of RWA resistance in their breeding programs. Resistant plants from these tests were rescued and raised for seed increase. Some crosses were made this year, but progeny testing will be done in the fall of 2010 to determine if these newly identified resistance lines are pure breeding for resistance, and if they have levels of resistance that are worth pursuing. In the past, even after several successive generations of selection and purification, many of the individual plant selections continue to show heterogeneity for resistance. For this reason, each of the individual plants harvested for increase must be pre-screened prior to use in the biotyping screening tests, and only those plants that are homogeneous for resistance for successive generations should be used for crosses that will be used for genetics evaluations. Since Stillwater ARS was selected by WERA-66 as the go-to source for pure seed of these differentials, for all US researchers working with RWA biotypes, it has been important for this process to proceed with care and diligence.

C. RWA Biotypic Diversity, Ecology, and Molecular Biology (Drs. Gary Puterka and Scott Nicholson)

A new RWA biotype distribution and diversity study began this year in collaboration with researchers throughout the western United States. The last study was conducted in 2005 and covered Texas, Colorado, Oklahoma, Kansas, Nebraska, and Wyoming. The discovery of sexually reproducing RWA and extensive biotypic diversity that resulted in 2007 in western Colorado made this necessary. In this study, we hope to include states in the northwestern United States. Efforts were made to collect RWA in Oklahoma, Colorado, and New Mexico this spring but only a few samples were made because of a very unusual year of low RWA numbers. Dr. Edsel Bynum was able to make collections at 14 sites in eight High Plains counties in April. These . Preliminary screening for only Dn4 (Yumar) virulence indicated 96% of the samples gave an RWA1 response and 4% RWA2. Although testing will include the other RWA-resistance genes, there is a clear indication that the biotypic diversity in Texas has changed.

Research on the salivary constituents of RWA continues with comparisons between RWA biotypes being conducted by Dr. Scott Nicholson, who joined the program as an ARS-Postdoc in May. Comparisons in salivary proteins between RWA1 and RWA2 using 2-D electrophoresis indicates that these two biotypes differ considerably in salivary protein composition. Research will focus on comparing RWA biotypes using Orbitrap MS analysis. Studies also include Diuraphis spp. pea aphid, and greenbug biotypes C and E.

E. Molecular Ecology of Cereal Aphids and their Natural Enemies (Dr. Kevin A. Shufran)

The rose-grain aphid (*Metopolophium dirhodum*) was collected from wheat at several locales in the Sacramento Valley of California. Sequencing of the mtDNA cytochrome oxidase subunit I (COI) gene revealed the presence of three unique haplotypes, with sequence identities of 97.9 – 98.6%. The frequency of haplotypes 1, 2, and 3 was 0.86, 0.07, and 0.07, respectively. This suggests that a host race especially adapted to annual grain crops may exist and is predominant in the population. However it is not yet known if there are any host associated differences in the biology of the rose-grain aphid possessing a specific haplotype. In developing experiments to ascertain if there is host adaptation associated with the three mtDNA haplotypes, we successfully established populations on *Iris*. Although grasses are the secondary hosts of rose-grain aphid, *Iris* has been reported as an occasional host. We have established colonies on, barley, wheat, and oat for host adaptation experiments. However, *M. dirhodum* did not colonize maize.

Greenbug (*Schizaphis graminum*) populations and biotypes were previously found to be made up of three unique groups based on DNA sequences of mitochondrial the COI, suggesting that populations were made up of host-adapted races or possibly sub-species. Nuclear DNA (nDNA) sequences were obtained for greenbugs used in the 2000 study, plus more recently collected (2008) individuals from Oklahoma. Based on both mtDNA and nDNA data, three distinct genetic lineages were found in greenbug biotypes and populations. This supports the hypothesis that greenbug populations in the US are made up of three host races (or perhaps subspecies) that are reproductively isolated in the field. Previously it was thought that sexual reproduction between host-races occurred which led to biotypic diversity. However, the molecular genetic data do not support this hypothesis. The molecular data support the hypothesis that biotype C, or the sorghum biotype and its derivatives (E, I, and K), were the result of an independent introduction into the US during the late 1960's, and these have not interbred with the previously extant population since that time.

A total of 367 aphids identified as *S. graminum* caught in suction traps at 9 locations in the UK during 2009 were provided by Rothamsted Research, Harpenden. DNA sequencing of the COI was performed. To date, mtDNA from 7 UK 2009 aphids were sequenced. Sequence identity ranged from 98.6 – 99.8% between UK and USA *S. graminum*. Although sequence identity was high, molecular phylogenetic analysis of UK *S. graminum* formed two distinct two sister clades to Clade 1, the agronomic biotypes in the USA. These are preliminary results and suggest that while UK populations are most closely related to Clade 1 greenbugs, they are significantly diverged and reproductively isolated.

F. Remote sensing of cereal aphids (Drs. Norm Elliott, Georges Backoulou, Kris Giles, and Mahesh Rao

A study was completed to determine the potential of spatial pattern metrics derived from multispectral images, in combination with topographic and edaphic variables to differentiate stress induced by RWA from other stress causing factors. Areas within fields stressed by RWA, drought, and planting and fertilization issues in six wheat fields located near Boise City, OK. A discriminant function analysis was applied to 15 variables quantifying the spatial attributes of stressed areas within the fields caused by each of the three stress factors, and topographic and edaphic variables associated with each patch. Thirteen variables were retained in the discriminant function. Overall, 97% of original patches of stress were correctly categorized. Stressed patches caused by RWA were 96.8% correctly classified, patches caused by drought were 95.8% correctly classified, and patches caused by planting and fertilization issues were 99% correctly classified. We conclude that it is possible to discriminate stress induced by RWA from other stress causing factors using multispectral imagery processed to quantitatively characterize spatial attributes of stressed areas within a field and knowledge of topographic factors related to the physical location and intensity of particular types of stress.

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Wheat Research in Oklahoma.

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Synopsis of Arthropod Pest Activity in Wheat, 2008-2010

Wheat pest pressure was variable in 2008-10. An outbreak of brown wheat mite was reported in Ellis county in March 2009, and brown wheat mite infestations were reported in April of 2010 in Ellis, Harper, Woods and Alfalfa counties. Greenbug infestations were reported in several western Oklahoma counties in 2009-2010. Army cutworms were reported in wheat and canola in Major county, spring 2010. Winter grain mites were treated in scattered locations in 2009. An outbreak of Russian wheat aphid occurred in Beaver county in 2009, with reports of scattered Russian wheat aphid infestations continuing to come from the Oklahoma Panhandle throughout the spring of 2009.

Integrated Pest Management of Wheat

Objectives : 1) document the distribution and impact of Hessian fly in Oklahoma winter wheat systems, (2) describe the relationship among aphids, host plants, and natural enemy biology, (3) evaluate current insect management plans for wheat production systems in Oklahoma, and (4) describe the ecology of aphidophagous natural enemies in simple and diverse wheat agroecosystems.

During the 2009-2010 winter wheat growing season in Oklahoma, project investigators (1) monitored first and second generation Hessian fly abundance on susceptible, semi-resistant, and resistant wheat, and (2) monitored the effectiveness of Gaucho XT wheat seed treatment for control of first generation Hessian fly. As expected, first generation Hessian fly numbers were lowest in resistant wheat compared with susceptible cultivars (Table 1).

Table 1. First + Second Generation Hessian fly abundance on Susceptible and Resistant wheat cultivars, 2009-10 field season, El Reno OK.

Resistant ('Duster')	0.0
Susceptible (Combined)	0.27

According to Alvey (2009), Hessian flies occur throughout the state, and the economic injury level is approximately 1 fly/tiller. This means that producers are losing money at infestations above 1 fly/tiller. According to our data, infestations were too low to induce economic losses for this past field season. Despite these low numbers, the value of resistance for long term management remains clear: resistance prevents Hessian fly buildup over multiple field years, especially in no-till fields and saves producers future management costs.

In the insecticidal seed treatment study, as predicted, first and second generation Hessian fly numbers were lower for seed treated with Gaucho XT (Table 2).

Table 2. First + Second Generation Hessian fly abundance on wheat treated with Gaucho XT.

Untreated	1.29
Gaucho XT	0.84

Seed treatment effectiveness breaks down during spring growth, and we expect second generation numbers in increase, however, seed treatments do provide some level of multigenerational protection. Multi-year Hessian fly counts and yields will ultimately provide the data required for producers to judge the cost-effectiveness of insecticidal seed treatments.

Studies were completed (see publications below) describing pest and natural enemy ecology, natural enemy biology in simple and diverse wheat agroecosystems, and detection of aphid infestation with remote sensing. Data is also being summarized from a multi-year / multi-state study completed evaluating the Glance n' Go sampling approach in the Southern Plains.

Plans for next year. Continue with outlined research objectives, and studies associated with iWheat RAMP grant.

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1. **Vol. 7, No. 3 ... Feb 4, 2008** --- Greenbug Management in Winter Wheat with Glance 'n Go: Using the Henson Rule ...
2. **Vol. 7, No. 34 ... Aug 27, 2008** --- Be On the Watch for Fall Armyworms in Pastures and seedling wheat.
3. **Vol. 7, No. 40 ... Oct 14, 2008** --- Dry Fall = Presence of Transitory Insect Invaders in Wheat (and Canola), Aster leafhopper and Canola
4. **Vol. 8, No. 3 ... Mar 12, 2009** --- Brown Wheat Mite Showing Up in Winter Wheat
5. **Vol. 8, No. 23 ... Aug 31, 2009** --- Plan to Manage Hessian Fly
6. **Vol. 8, No. 24 ... Sep 2, 2009** --- Yellow Soybean Plants, Effect of Planting Date and Seed Treatment on Diseases and Insect Pests of Wheat
7. **Vol. 8, No. 29 ... Oct 2, 2009** --- Keep a Close Watch for Fall Armyworms in Seedling Wheat, Questions and Answers Regarding Fall Armyworm in Wheat and
8. **Vol. 8, No. 31 ... Nov 24, 2009** --- Fall Wheat Pests: Winter Grain Mite in Wheat Pasture
9. **Vol. 9, No. 2 ... Feb 22, 2010** --- Army Cutworms Reported in Some Wheat Fields
10. **Vol. 9, No. 12 ... Apr 20, 2010** --- Brown Wheat Mite Showing Up in Winter Wheat,
11. **Vol. 9, No. 21 ... Jun 1, 2010** --- Late Flush of Armyworms Generating Concern in Wheat
12. **Vol. 9, No. 31 ... Aug 16, 2010** Effect of Planting Date and Seed Treatment on Diseases and Insect Pests of Wheat

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Overview of Pest Activity in Wheat, 2009-2010

Greenbug and Russian wheat aphid numbers were very low in the fall of 2009 in the Texas Panhandle. After severe winter conditions in January and February, aphids were difficult to find in fields. From March through May sporadic infestations of greenbugs, Bird Cherry- oat Aphids, and Russian wheat aphids were present in relatively low numbers in fields south of Amarillo, TX. None of the fields sampled for Russian wheat aphids North of Amarillo from March to May had any aphids (greenbugs, RWA, Bird Cherry- oat Aphids). Even with the light aphid infestation, there was a high incidence of Barley Yellow Dwarf in fields across the Texas High Plains and the Panhandle region. Infections were not extremely severe, but fields seemed to uniformly infected across the fields.

A foliar insecticide trial was conducted against greenbugs in wheat. Cobalt (DowAg Sciences) provided comparable control to the standard chlorpyrifos treatment. A pyrethroid product, Declare (gama-cyhalothrin), by Cheminova was a little slower than chlorpyrifos in its control of greenbugs. A mixture of Declare with chlorpyrifos was equal to the chlorpyrifos alone and Cobalt treatments.