NC IPM

For our environment, for our future

North Central Regional Integrated Pest Management Grants Program 1998–2000

NC IPM

For our environment, for our future

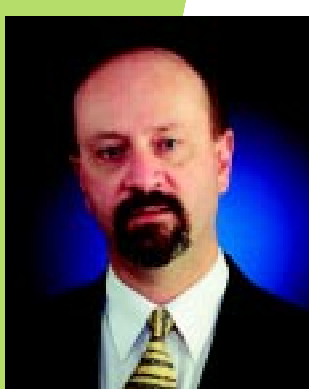
USDA-CSREES North Central Region Integrated Pest Management Grants Program 1998–2000

For more than 30 years, the USDA-CSREES (U.S. Department of Agriculture Cooperative State Research, Education, and Extension) and Land-Grant universities have partnered to develop, evaluate and share new methods to manage the pests that inflict economic loss on our crops and invade our living spaces. New integrated pest management (IPM) strategies provide economically viable alternatives, including chemical and non-chemical control methods, to effectively manage insects, plant diseases, and weeds while reducing risk to human and environmental health. The CSREES-Land Grant University IPM partnership is implemented by an experienced network of research and extension staff located in all 50 States and six Territories. Each year this network directly influences urban and agricultural pest management decisions by transferring research-based knowledge through demonstrations, clinics, workshops, scouting programs, consultations, and a wide variety of printed and electronic media.

The CSREES-Land Grant University IPM Program is conducted through: 1) Research directed toward the development of new knowledge and solving real production problems; and 2) Extension education to hasten implementation of IPM systems through pest management teams, accelerate the technology transfer process, and assist the private sector in developing and improving delivery of pest management services. Each state has an IPM coordinator who serves as a liaison between their state IPM program, CSREES and regional IPM programs. At the end of this publication we have listed, by state, IPM coordinators and included their mailing addresses, telephone numbers and email addresses. We encourage you to contact these scientists to learn more about your state and regional IPM programs.

To compliment the state-based IPM research and extension efforts, a regional grants program provides critical funding through a competitive process. We are excited about the research and extension pest management programs that have been funded by this North Central Regional IPM Grants Program. This publication highlights proposals that were funded in 1998, 1999, and 2000. The summaries contained in this publication illustrate the diversity of pest management issues within our region. Examples include research and extension projects addressing insect, weed, and plant disease challenges in both agricultural and urban settings.

We hope these summaries will provide insight in to the successes that have been achieved by researchers and extension specialists who strive to provide answers to questions posed by their clientele. If you wish to receive more information regarding a particular project, we encourage you to contact the individuals involved with the project. For more information regarding the North Central Regional IPM Grants Program contact Michael E. Gray. For more information regarding the North Central Regional IPM Program or NCR-201 contact Susan T. Ratcliffe.



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The following titles reflect the great diversity of projects in the North Central Region:

Illinois

Indiana

Iowa

Kansas

Michigan

Minnesota

Missouri

Nebraska

Ohio

Wisconsin

Improved Assessment of Impacts of Parasitoids in the Biological Control of Flies

Richard A. Weinzierl, Carl J. Jones, Hugh M. Robertson, and Susan T. Ratcliffe, Department of Crop Science, University of Illinois

Production losses caused by stable flies, *Stomoxys calcitrans* (L.), and house flies, *Musca domestica* L., associated with feedlot cattle, coupled with the costs of controlling these flies, exceed $100 million annually. Reliance primarily on insecticides for fly control is ill advised and ineffective because of insecticide resistance, reduced numbers of registered insecticides, and concerns over environmental impacts and human health. Alternatives to insecticides for fly management include the release of parasitic wasps less than 3 mm in length that attack and kill fly pupae (but not other organisms); however, the results of parasitoid releases for biological control of flies have been mixed. As we undertook this project, assessments of the effectiveness of parasitoids (percentage of pupae parasitized) had depended on counts of flies and parasitoids that emerged from field-collected fly puparia, but these assessments are complicated by varying levels of unexplained mortality in field studies because some puparia are "duds," producing no adult fly or parasitoid. Developing a method to quantify the role of parasitoids in causing "duding" was necessary to better assess the impacts of parasitoid releases.

Parasitoid depositing egg in puparium

To detect parasitoid DNA within a fly puparium (as evidence of parasitism), we developed a polymerase chain reaction (PCR) assay. The internal transcribed spacer (ITS) region of the two fly species and four parasitoid species were characterized. Two parasitoid-specific primers, paired with a universal primer, amplified the target ITS1 region in 10 parasitoid species. PCR allowed detection of parasitoid DNA within house fly puparia. Digestion of PCR products with restriction enzymes produced restriction fragment length polymorphisms that allowed identification of individual parasitoid species. Nine field collections of fly puparia were split into subsamples for estimation of percentage of parasitism by traditional versus PCR-based methods. In collections where duds were prevalent in the portion of the sample held for adult emergence, PCR-based assays indicated significantly greater levels of parasitism than were estimated from adult emergence, indicating that parasitoids were responsible for a significant portion of the otherwise unexplained mortality (dudding) in those collections. Although PCR-based assays do not detect parasitoid DNA in fly puparia several days after both the host and the parasitoid have died, the PCR assays that we developed offer a way to more accurately assess the impacts of parasitoid release programs and may lead to more definitive answers about the potential for effective biological control of feedlot flies.

Adult stable fly

Project Start Date
7/1/98
Expected Completion Date
6/30/00
Grant Award
$52,649

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Interactive IPM on the Internet

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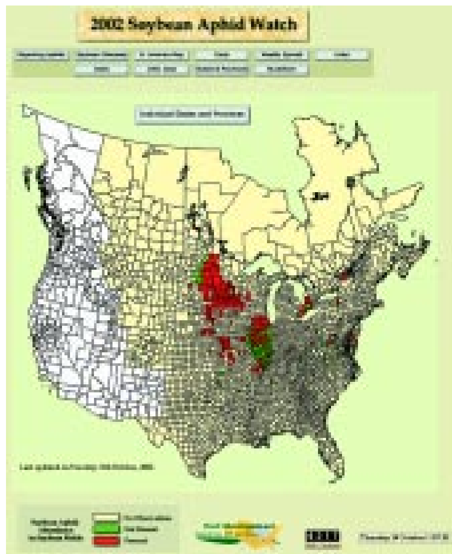
The primary mission of extension IPM in Illinois is to educate people about the principles of integrated pest management (IPM) and to encourage the use of practical and profitable crop protection tactics that are environmentally sound and socially acceptable. Electronic technology has evolved into one of the most powerful and universal methods of disseminating educational information and retrieving data. In 1999, our IPM Web site received ~100,000 hits per year and our *Pest Management and Crop Development Bulletin* newsletter received >215,000 requests from users in the first 11 months of 1999. Our project, Interactive IPM on the Internet, proposed the development of a data dissemination and retrieval system via the Internet as part of a comprehensive IPM learning module. Examples of interactive sites that resulted from this grant project include on-line monitoring reports, pest distribution maps, and on-line calculators to determine whether treatment is necessary based on scouting data. The 2000 Western Corn Rootworm Monitoring site allows growers to enter their scouting data on-line and the data are then used to generate a summary of western corn rootworm, *Diabrotica virgifera virgifera* LeConte, density and distribution. The 2001 and 2002 Soybean Aphid Watch Web site provides regional density and distribution information on the soybean aphid, *Aphis glycines* Matsumura, in near real-time display. The on-line calculators for first and second generation European corn borer, *Ostrinia nubilalis* (Hübner), allow users to input scouting data and determine whether it is economically advisable to treat.

In 2001, the University of Illinois' IPM Web site saw a dramatic increase in the number of hits (866,690) and the requests for the *Pest Management and Crop Development Bulletin* increased to 592,121. During 2002, the activity on the Web site continued to increase, receiving 1,422,975 hits and 799,321 requests for the *Pest Management and Crop Development Bulletin*. Hits to the *Pest Management and Crop Development Bulletin* typically are highest in May, June, and July. We attribute the substantial increase in activity to marketing of the site and expansion of educational materials included on the site. We have learned a great deal about the activities of our clientele from the monthly statistics. We suggest increased Web activity reflects our audiences' (agricultural and urban) need for pest management information and illustrates the importance of timely field-related articles.



www.pmcenters.org/Northcentral/Saphid/aphidindex.htm

Project Start Date	
7/1/00	
Expected Completion Date	
6/30/02	
Grant Award	
$41,206	

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www.ag.uiuc.edu/cespubs/pest/

Assessing and Managing Soil-borne Virus Disease in Wheat Production

Keith Perry, Department of Botany & Plant Pathology, Purdue University

Project Start Date
7/1/98
Expected Completion Date
6/30/00
Grant Award
$75,000

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The goal of this project was to enhance productivity in wheat in the North Central region through an assessment of virus tolerance or resistance in germplasm currently used in North Central region breeding programs. Research was conducted in 4 by 8-ft yield test plots planted at three locations: Indiana, Illinois, and Kansas. A structured, nonrandom sampling procedure was implemented for each plot in the early spring, with 10 plants sampled per plot. Visual ratings for disease severity also were made at that time. Leaf and root tissues were combined and processed for the immunological detection of viruses (enzyme-linked immunosorbent assay) and the incidence of infection was quantified. Yield data were taken at the end of the season. The germplasm tested consisted of six soft red wheat cultivars ('Patterson', 'Clark', 'Pioneer 2548', 'Caldwell', 'Cardinal', and 'Abe') and four hard red winter wheat cultivars ('Sierra', 'Century', 'KS92WGR22', and 'KS93U140').

Tolerant wheat breeding lines show no evidence of disease while susceptible lines exhibit classic yellowing symptoms associated with soilborne viruses.

Data were obtained from tests in Illinois in 1999 and 2000; there were three different planting sites, including "soilborne nursery." Data were obtained from two sites in Kansas in 1999 and one site in Indiana in 2000. All cultivars showed some level of infection at least once among the different sites and seasons. For soilborne wheat mosaic virus (SBWMV), Abe, Clark, KS93U140, and Sierra consistently showed very low levels of infection (0–12%). At the sites where disease pressure was high, three cultivars showed high levels of infection by SBWMV: Pioneer 2548 (67–95%), Cardinal (48–95%), and Century (6–100%). For wheat spindle streak mosaic virus (WSSMV), Century, Clark, and KS92WGR22 consistently showed very low levels of infection (0–20%). At the sites where disease pressure was high, four cultivars showed high levels of infection by WSSMV: Abe (18–80%), Caldwell (20–88%), Pioneer 2548 (28–90%), and Sierra (12–90%). Clark exhibited a high degree of tolerance to both viruses, exhibiting maximum incidences of infection of 8 and 15% by SBWMV and WSSMV, respectively.

Susceptible lines (right) are yellowed and stunted.

There were no obvious differences in cultivar tolerances from state to state, although an assessment of breakdown in tolerance was hampered by plot-to-plot variability. This same variability also precluded correlating incidences of infection with effects on yield. Of particular interest in this study was the identification of cultivars with high levels of tolerance. What remains unclear is whether the observed low levels of infection were true cultivar phenotypes, or whether there was genetic heterogeneity in the germplasm. Genetic heterogeneity would suggest that some progeny could be recovered from single heads (or seeds) that would be completely resistant to infection in the field. Alternatively, tolerance could be due to a reduction in the frequency of successful viral transmission and infection events.

The soft red winter wheat Clark has been identified as a valuable germplasm source for tolerance to soilborne WSSMV and SBWMV. Abe is tolerant to SBWMV; its sensitivity to WSSMV makes it a useful field indicator for this virus. Hard red winter wheat Century and KS92WGR22 are useful field indicators for SBWMV; the Sierra and KS93U140 are useful field indicators for WSSMV.

Economics of Bt Corn: Adoption and Optimum Refuge Consideration for the Corn Belt

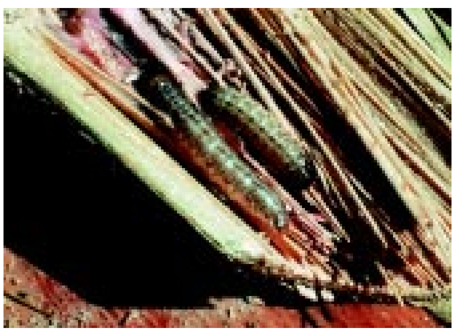
Marshall A. Martin, Agricultural Research Programs, Purdue University

Bt (*Bacillus thuringiensis*) corn has been genetically engineered to resist European corn borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae), and other insect pests. To decrease the potential for European corn borer resistance to Bt corn, growers must plant a non-Bt corn refuge as part of an insect resistance management plan. Refuge allows Bt-susceptible European corn borer to live and mate with any resistant European corn borer that may emerge from the Bt corn.

This research analyzed two aspects of the Bt corn adoption decision. First, the value of Bt corn under various conditions (e.g., different yields, European corn borer infestation pressure, and potential presence of other insects) was estimated. Regions of four states (Indiana, Illinois, Iowa, and Kansas) were analyzed using a decision analysis framework, i.e., a decision-tree computer spreadsheet that captures, for example, planting and harvest dates, European corn borer infestation probabilities during the growing season, potential yield losses, and economic costs. Second, a partial budgeting approach was used to analyze spatial configurations of refuges within a Bt cornfield. Two potential refuges were analyzed with non-Bt corn and a sacrificial popcorn refuge.

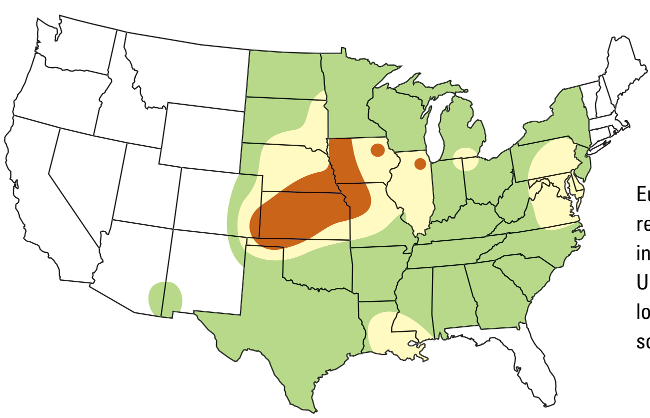
The value of Bt corn was estimated to be below current technology fees for most of Indiana. However, many Illinois growers may benefit from planting Bt corn because the probability of European corn borer infestation exceeds 75% in some regions of Illinois. Growers in the regions of Iowa with economically damaging European corn borer infestations in six or more of 10 years may benefit from planting Bt corn. In southwestern Kansas, economic infestations of some combination of European corn borer and southwestern corn borer, *Diatraea grandiosella* Dyar (Lepidoptera: Crambidae), occur in one of two years. There, the value of Bt corn far exceeds the current technology fee.

The economic cost of satisfying Environmental Protection Agency's 20% refuge requirement is relatively small for growers who choose to adopt the Bt technology, less than 2.6% of typical per-acre variable production costs. Results of the refuge analysis indicate that planting a block-U refuge scheme is only slightly more costly (<$3.00/acre) than planting strips. This result is due to increased labor costs and lower yields associated with additional planting time requirements. Market segregation may dictate a block within a field or adjacent fields as a refuge choice. A sacrificial refuge is only economical for a very high per-acre value of Bt corn or if the area planted to popcorn is <1%.



European corn borer larvae

This Ph.D. dissertation research was conducted by Jeffrey Allen Hyde under the supervision of Dr. Marshall A. Martin. Dr. Hyde is currently an assistant professor in the Department of Agricultural Economics and Rural Sociology at Pennsylvania State University. His research was supported by two grants—initially a Purdue Research Foundation Grant and then this USDA North Central Region IPM Grant (593 1145-0275/Proposal YF35). The results of his research have been widely disseminated through refereed journal articles, presentations at scientific meetings, and extension publications. Dr. Hyde research results also have formed the basis of about a dozen grower and agribusiness extension meetings. A list of the research output supported by this grant follows.



European corn borer is responsible for $1 to $2 billion in damages annually in the United States, with the greatest losses occurring in the southwestern Corn Belt.

Project Start Date
6/15/99
Expected Completion Date
6/30/01
Grant Award
$53,547

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Reducing Herbicide Input and Increasing Economic Output with Site-Specific Weed Management

Loree B. Johnston and Kevin Gibson, Department of Botany and Plant Pathology; Purdue University; and Case R. Medlin, Department of Plant and Soil Sciences, Oklahoma State University

Project Start Date
6/15/00
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6/14/02
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$65,000

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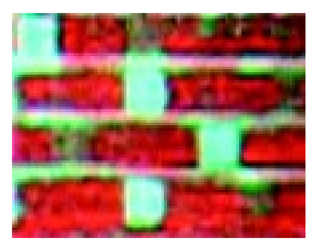
Growers in the United States rely heavily on herbicides to control weeds. The availability and use of herbicides have contributed to higher crop yields and made possible a reduction in human and mechanical labor. However, the continued reliance on herbicides faces several challenges for the future of agriculture. Environmental and human health concerns, shrinking profit margins for growers, and an increasing number of herbicide-resistant weed species are only a few of the reasons driving the need for a better herbicide application program.

Site-specific weed management has been used, to a limited extent, to reduce herbicide use and associated costs and risks. Site-specific production systems are used to optimize crop production by varying inputs and practices across fields in response to infield variability. For example, site-specific nutrient management has been used to address low grain yields caused by spatially variable soil types. Weed populations are also spatially variable in fields; however, herbicides are applied at a whole-field level. This approach is inefficient because herbicides are applied to some areas of fields without weeds, whereas areas with large weeds may be sprayed with rates that are too low. Variable rate technology (VRT) devices are currently being used in other production practices for real-time, automated, differential application of management inputs (such as liquid and dry fertilizers, lime, and crop seed planting rates).

The missing key for variable rate application of herbicides is the ability to differentiation among weed species. However, integrating VRT with remotely sensed images and the algorithms for differentiating among weed species may allow for the development of a real-time, site-specific herbicide applicator. Therefore, our goal was to make the initial steps toward developing the algorithms for species differentiation.

Location, environmental conditions, crop and weed developmental stage at the time of data collection, and the analytical procedure used impacted the outcome of species differentiation trials. Still, with these real-world variables confounding the issue, bare soil plots and plots of soybean infested with velvetleaf (*Abutilon theophrasti* Medicus), giant ragweed (*Ambrosia trifida* L.), common lambsquarters (*Chenopodium album* L.), or giant foxtail (*Setaria faberi* Herrm.) were correctly classified 88 to 100% of the time from aerial imagery at one location. On average, patches of these weeds growing alone or within a soybean stand were correctly classified 89% of the time from the same standard, multi-spectral, aerial images. Classification accuracies did not improve a great deal with high-quality, hyperspectral, ground-based imagery equipment. Incorporating this technology into this research resulted in correct classification of 89% of the weed-infested or weed-free areas. With further research to refine these and other algorithms, a real-time VRT herbicide applicator for in-season use will become a reality. The potential cost savings are estimated to be 20–80% of the current herbicide costs for any given field.

Site-specific herbicide applications may allow prescriptive treatment of weed infestations.



Herbicide applicators may rely on aerial imagery to assist with site-specific herbicide application in fields.

Weed Management in Cucurbits

Elizabeth T. Maynard, Department of Biological Sciences, Purdue University

Four years of field research have given North Central producers new information about how much broadleaf weeds reduce yield of winter squash (Figs. 1–6). In one set of trials, acorn squash was grown with various densities of lambsquarters. Analysis of squash yield showed that one lambsquarters in 10 sq ft would be expected to reduce marketable yield by 10 to 15%. The relative leaf area of the lambsquarters, which takes into account the relative sizes of the lambsquarters and the squash, also was used to predict squash yield loss. If lambsquarters leaf area per square foot were 1/20th that of squash by 5 weeks after transplanting, the expected yield loss would 13%.

Because experience with other crops has shown that weed density often is not a good predictor of yield loss, and because relative leaf area is time-consuming to measure with laboratory equipment, a simple line-transect method of estimating percentage of cover was tested. Relative cover of lambsquarters was then calculated and used to predicted squash yield. The research showed that if relative cover of lambsquarters was 0.1 by 5 weeks after transplanting, yield loss would be approximately 15%.

Leaves of acorn squash removed from plant and ready for measurement of leaf area (Pinney-Purdue Agricultural Center, Wanatah, IN, 2000).

The predictions of yield had a wide margin of error and could explain only 17 to 30% of the observed yield differences in experimental plots. Relative cover had the least power to predict. On other farms, yield predictions based on equations developed in this study would be even less accurate. Nonetheless, the equations provide a place to start when estimating yield loss of squash, and they can be refined and expanded to include more weed species with further work.

Butternut and buttercup squash also were grown to see whether weeds would reduce their yield to a similar extent. In these trials, all broadleaf weeds that came up were allowed to grow in the weedy plots. Over 3 years, the marketable yield in weedy plots averaged 45% of that in weed-free plots. The percentage didn't differ among cultivars, but did differ from year to year: the more dry matter weeds produced by the end of the season, the less the yield of weedy plots compared with weed-free plots. The size of marketable squash fruit also was reduced by weeds: the larger fruited butternut and buttercup squash decreased in average weight by 20%, and the acorn squash decreased by 14%. For squash delivered to markets where size is an important factor, weeds could have a bigger impact on the larger fruited types.

Squash producers might use results of this work to judge the potential for yield loss in weedy fields. This approach also may make it easier to evaluate costs and benefits of management options. The information could be useful when making weed management decisions during the growing season, as well as when developing weed management and crop rotation strategies in advance. Along with many others, this project has provided new information that producers can use to improve farm operation and management, making them more profitable and sustainable.

'Table Queen' acorn squash with 0.54 lambsquarters/sq m (Pinney-Purdue Agricultural Center, Wanatah, IN, 2001).

Project Start Date	
8/1/98	
Expected Completion Date	
7/31/01	
Grant Award	
$69,772	

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Development of a Regional "Weed Emergence Calendar" Poster Development of a Weed Emergence Poster

Bob Hartzler, Department of Agronomy, Iowa State University

Integrated pest management relies on understanding and predicting the biology and behavior of a pest species and how these processes interact with management practices. No other event in the life cycle of weeds affects scouting and management timing as greatly as weed emergence. The timing and intensity of weed emergence affect everything from the effectiveness of burndown herbicides and preplant tillage, to the timing of postplant tillage and herbicide application, to the competitiveness of weeds that escape control, to seed production by surviving plants, and eventually population shifts. Given the importance of weed emergence to all forms of weed management, it seems logical that we should give greater attention to understanding and predicting weed emergence as affected by environmental factors, weed species, and management practices.

Giant ragweed seedling

To facilitate transfer of information on weed emergence timing, a poster was developed that provides basic information on emergence patterns of several common weeds of corn and soybean. The information was based on an emergence sequence system developed at Iowa State University that places groups weeds according to their initial emergence date. For example, giant ragweed, common lambsquarters, Pennsylvania smartweed, and common sunflower are some of the earliest emerging weeds of the northern Corn Belt, typically emerging before planting of corn and soybean. These weeds are categorized as group 1 weeds. Giant foxtail and velvetleaf usually emerge 1 or 2 weeks after the previous weeds, and are classified as group 2 weeds.

Waterhemp seedling

The poster was printed in a large (14 by 24 in.) and small (8.5 by 11 in.) format. Information presented on the poster included 1) emergence group, 2) estimate of heat units required for emergence, 3) duration of emergence, and 4) a seedling photograph. Sixteen weeds were placed into four emergence groups. Large posters were distributed to ag chemical dealers who frequently display the posters at counters where growers congregate. The small version was distributed at extension meetings and other functions in which attendees were involved in weed management.

Herbicides dominate weed management systems used in corn and soybean. Growers and others involved in weed management have tended to focus largely on the efficacy of these products, ignoring other factors that influence the success of weed management programs. However, this poster, along with other educational programming focusing on weed biology, has begun to change views of weeds. Farmers no longer look at all weeds as being the same, but rather try to determine what allows specific weeds to escape control efforts. This change in mindset is allowing persons involved in weed management to design integrated weed management programs that are effective and profitable.

The poster was a collaborative effort between Iowa State University, University of Minnesota, University of Wisconsin, Illinois University, Leopold Center for Sustainable Agriculture, and USDA–ARS.

Project Start Date
7/1/99
Expected Completion Date
6/30/00
Grant Award
$6,200

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Prediction of Gray Leaf Spot Severity for Improved Management in Corn Seed and Grain Crops

Gary Munkvold, Pioneer Hi-Bred International, Inc.

Gray leaf spot, caused by the fungus *Cercospora zeae-maydis*, has become the most important leaf disease of corn in the United States, causing losses in grain and seed production from North Carolina to New York to Nebraska. Fungicides have emerged as an important tool for the management of this disease, especially in the production of corn seed, where selecting resistant cultivars is frequently not an option. The efficiency of fungicide applications for gray leaf spot control could be improved—current practices incorporate thresholds, but the accuracy of thresholds for predicting economic damage is limited.

In this project, we have worked toward developing a model for the prediction of gray leaf spot severity. The empirical model, when coupled with existing yield-loss models, provides a means to predict economic damage from gray leaf spot early enough in the season to assist in fungicide-application decisions. We developed a database by monitoring rainfall, wetness, temperature, and humidity at about a dozen locations in Iowa and several locations in Nebraska during three growing seasons. At each location, we (or our collaborators) planted a set of corn hybrids or inbreds that varied in gray leaf spot resistance. We recorded planting dates, corn hybrid or inbred characteristics, corn residue levels, and disease development for each hybrid or inbred. We tested a variety of modeling techniques, and found that an Artificial Neural Network (ANN) model was the most effective way to relate environmental and cultural factors to late-season disease severity.

Throughout the study, hybrid or inbred resistance clearly emerged as the most influential factor in gray leaf spot development. The other variables also influenced the disease significantly. Using the ANN model, we can account for 75% of the variation in disease severity.

In its current form, the model can be used as a tool to assist with fungicide application decisions in conjunction with a disease threshold. Further validation of the model is necessary, with some possible revisions. Subsequent work will focus on assessing the precision of the model in predicting disease levels near the economic injury level, and in developing a user interface for easily accessing and interpreting model results.

[left] Gray leaf spot, *Cercospora zeae-maydis*, on a non-resistant hybrid.

[above] Non-resistant hybrids are examined to determine the effectiveness of the model in predicting the severity of gray leaf spot.

Project Start Date
6/15/00
Expected Completion Date
6/14/03
Grant Award
$97,533

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Transgenic Maize for Integrated Management of Insects, Diseases, and Mycotoxins

Gary Munkvold, Pioneer Hi-Bred International, Inc.

Project Start Date
6/15/98
Expected Completion Date
6/14/00
Grant Award
$73,238

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Transgenic insect protection has become established as an important tool for the integrated management of insect pests of corn. But these insects frequently interact with plant pathogenic fungi, and how transgenic insect protection affects these interactions is not well understood.

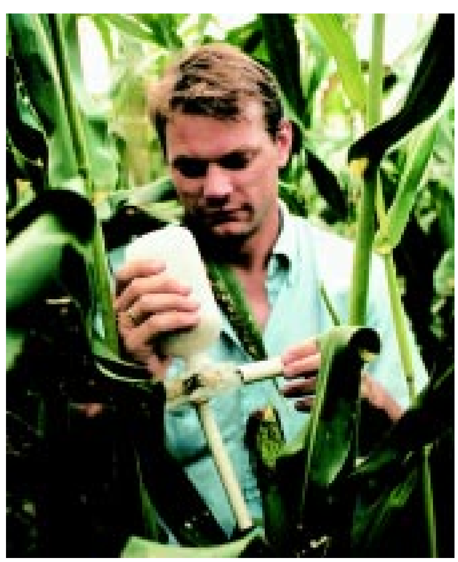
We examined the role of *Bacillus thuringiensis* (Bt) hybrids in the integrated management of European corn borer, *Ostrinia nubilalis* (Hübner); corn earworm, *Helicoverpa zea* (Boddie); Fusarium and Aspergillus ear rots; and the stalk rot complex in corn. *Fusarium* and *Aspergillus* species can produce harmful mycotoxins (fumonisins and aflatoxins), whereas stalk rots cause more yield loss than any other corn disease.

Field experiments were conducted with Bt hybrids and near-isogenic non-Bt hybrids exposed to natural or manual infestation with European corn borers, corn earworms, and fungal inoculum. Plants were evaluated for insect damage, stalk rot, and ear rot symptoms, fungal infection, and four mycotoxins. Demonstration plots were established in the 2nd year and focused on stalk rot and Fusarium ear rot affects of Bt hybrids.

Bt and non-Bt hybrids differed in terms of disease variables measured. Bt controlled European corn borers very well, but corn earworm control was not adequate. Stalk rot incidence and severity was lower in some Bt hybrids compared with their non-Bt counterparts, but the effect was limited primarily to Bt events BT11 and MON810. Fusarium ear rot and fumonisins were significantly lower in Bt hybrids than in their non-Bt counterparts. There were no significant differences in concentrations of the other three mycotoxins between the Bt and non-Bt hybrids, but levels were generally very low. Transgenic insect protection was more effective than foliar insecticides for all the variables measured.

The current results support the conclusion that BT11 and MON810 hybrids have a lower risk for Fusarium ear rot and fumonisins than their non-Bt counterparts. Although there seem to be many situations where Bt hybrids will not differ in stalk rot compared with non-Bt hybrids, overall these results indicate a lower risk of stalk rot in hybrids with Bt events BT11 and MON810. However, the background genetics of a corn hybrid will influence its vulnerability to stalk rot much more than the presence or absence of a Bt gene. Additionally, the fungal species composition of stalk rot pathogens seems to be altered in some Bt hybrids. Species that are closely associated with European corn borers, such as *Fusarium verticillioides*, are less prevalent in Bt hybrids, but are replaced by other species. The results of this study support the utility of Bt hybrid as a tool in the integrated management of Fusarium ear rot, fumonisins, and corn stalk rots.

Data from this project were presented at conferences in Wisconsin, Maryland, and Georgetown University, as well as several ISU Extension programs and field days. Media coverage has included *National Geographic* magazine, the *Ames Tribune*, the *Des Moines Register*, >20 midwestern radio stations, and ABC-TV Nightline. The project produced five published articles and supported one ISU graduate student. Iowa State



[left] *Bt* hybrids are manually infested with European corn borer larvae

[below] European corn borer larva in stalk of non-*Bt* hybrid

Using Site-Specific Weather Data Simulation to Accelerate IPM Implementation

Mark L. Gleason, Department of Plant Pathology, Iowa State University

Our 3-year research and extension project validated accuracy of commercially available, site-specific estimates of air temperature, rainfall, leaf wetness duration (LWD), and duration of relative humidity >90% at 15 sites in Iowa, Illinois, and Nebraska. These estimates were evaluated as inputs to disease-warning systems for tomatoes, potatoes, apples, and watermelons.

Based on a data set incorporating >6000 days, mean underestimates of LWD and periods of relative humidity >90% by site-specific technology (SkyBit, Inc., Bellefonte, PA) were greatest during days on which dew rather than rain was the source of environmental moisture. Mean air temperature overestimates of 1–2°C during the night corresponded to peak periods of underestimation of LWD and relative humidity >90%. Because periods of leaf wetness and relative humidity >90% occur primarily at night and depend on temperature, errors in temperature estimation at night may have caused errors in relative humidity >90% and LWD. Therefore, improving accuracy of temperature estimates at night could improve accuracy of the other parameters.

Disease warning systems reduced fungicide applications for sooty blotch-flyspeck complex on apples.

Use of disease warning system sensors improve farm profits and reduce pesticide-related health hazards.

Adding a wind speed correction to the empirical CART/SLD model (*Plant Disease* 78:1011–1016) reduced mean error in SkyBit estimates of LWD from 1.4 to 0.1 h/day and improved precision of LWD estimation by 42%. This model also improved accuracy of disease-severity-value estimates by 44% in simulated performance of the TOM-CAST disease-warning system for tomatoes. Simulations of the BLITECAST warning system for potato late blight revealed that SkyBit input data (duration of relative humidity >90%) resulted in delay of a spray warning by 65 days, whereas simulations of the P-Day warning system for potato early blight by using SkyBit inputs for mean daily temperature resulted in spray advisories that were almost identical to those provided by on-site temperature measurements. These results suggest that accuracy of site-specific estimates of moisture-related inputs (LWD and duration of relative humidity >90%) need to be improved to ensure their reliability in disease-warning systems.

In field experiments and on-farm demonstration trials, inputting uncorrected SkyBit LWD and temperature estimates to the Melcast disease-warning system for watermelon, and a warning system for the sooty blotch-flyspeck complex on apples, saved fungicide sprays and provided commercially acceptable disease control. Overestimated LWD triggered excessively frequent fungicide sprays on apples; we concluded that LWD estimates need to be calibrated to account for the influence of the apple-tree canopy.

In summary, our investigation revealed the strong and weak points of a new technology, site-specific weather data estimation, that has enormous potential to accelerate adoption of disease-warning systems on many high-value crops. These warning systems can reduce fungicide spray frequency by 25 to 50%, which would improve farm profits and reduce pesticide-related health hazards. Our study also showed that modeling dramatically improved the accuracy of LWD, which is a critical input to many disease-warning systems. In addition, our findings indicated the need for site-specific weather estimation to take account of the microenvironments within crop canopies. Our project thus made essential first steps toward defining this new technology as a reliable tool in integrated pest management.

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$65,826

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Integrated Crop Management: Spider Mites on Greenhouse-Grown Ivy Geraniums

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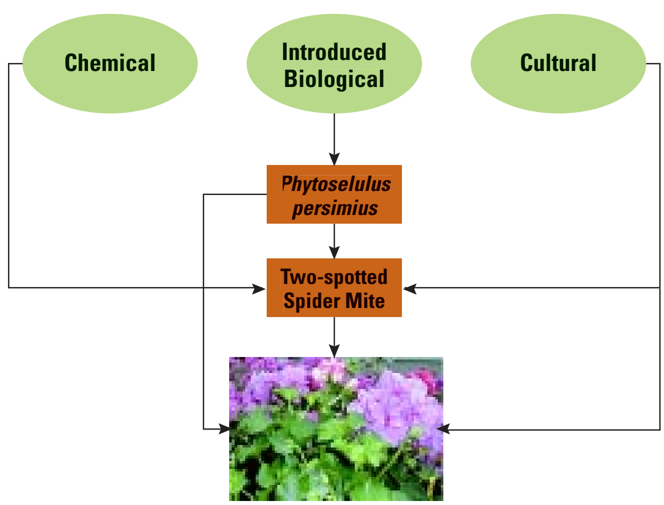
Biological control must be shown to be both economical and accessible to growers to be transferable into greenhouse operations. We have assembled a team of specialists in horticulture, entomology, and agricultural economics to examine the total floricultural production system with an eye on the bottom line. Our challenge is to understand the biological and economic processes of a complete crop production system and to assess how an alternative pest management approach fits into the broader context of greenhouse production and management. We began by focusing our efforts on a single crop, ivy geraniums, which represent a significant part of a large and lucrative national market in bedding plants.

Commercial producers are concerned with timely and profitable crop production. Based on replies to a questionnaire we sent to 1336 greenhouse operators in 21 states, we learned that most growers felt that current biological control was not practical, being either too expensive or ineffective. On the positive side, most producers said they would prefer to use biological control *if profits remained the same* and that they expected the use of biological control in their greenhouse to increase in the future.

On the production side, our research has shown that growers of ivy geraniums may obtain commercially acceptable plants by using fertilizer at rates lower than what is commonly recommended. Thus, growers can reduce fertilizer inputs without reducing crop quality or productivity, thereby increasing profitability. However, we also found that, contrary to conventional protocol, frequent irrigation to maintain a high soil moisture content (85% soil capacity) resulted in a lower incidence of oedema than less frequent irrigation. Therefore, growers can irrigate more frequently to maximize growth and speed the production cycle.

Fortunately, from the pest management side, spider mite populations on ivy geraniums are not influenced by irrigation frequency or nitrogen level within the range that produced quality plants; but phosphorus level may have a marginal effect. Also, host plant resistance is a viable mite management option. However, popular ivy geranium varieties may not exhibit resistance. To manage spider mites on these susceptible varieties, introduction of the predatory mite *Phytoseiulus persimilis*, guided by a fast and reliable spider mite sampling technique, can effectively reduce spider mite numbers and plant damage. A release ratio of one predator for every 20 pests worked well for moderate pest infestations (50–150 pests/plant), whereas a ratio of 1:4 was effective at high spider mite infestations (200–300 pests/plant).

The relevant biological and economic processes have been integrated into a pest management planning model to provide profit-maximizing decision rules to guide growers in ivy geranium production. Model results identify circumstances for introducing predators that are optimal for controlling spider mites, thus resulting in the highest grower profits. One important outcome of the model is that benefits are accrued by appropriately timing applications of natural predators to control pests. Growers maximize profits as more pests are killed by predators and fewer pests need to be controlled by chemical applications. Information we obtain from ongoing demonstration trials in commercial greenhouse operations will allow further refinement of the model and the decision-making rules.



Ivy geraniums represent a significant portion of the national market for bedding plants.

Spider mite populations are monitored in the greenhouse.

Protecting High-Value Fruit from Key *Rhagoletis* Species

Oscar E. Liburd, Department of Entomology and Nematology, Institute of Food and Agricultural Sciences, University of Florida

Rhagoletis species (Diptera: Tephritidae), among other key fruit fly pests, develop inside the fruit, rendering it unmarketable. These pests create a major problem for fruit growers due to the need for repeated applications of broad-spectrum insecticides to manage key fruit fly pests. Frequent applications of broad-spectrum insecticides negatively impact nontarget organisms, including beneficial insects. Therefore, as an alternative to broad-spectrum organophosphate insecticides for managing key *Rhagoletis* species, we evaluated the potential of using imidacloprid-treated spheres for control of apple maggot, *Rhagoletis pomonella* (Walsh); cherry fruit fly, *R. cingulata* (Loew); *R. fausta* (Osten Sacken); and blueberry maggot, *R. mendax* Curran. Initial studies were designed to investigate the feasibility of using imidacloprid-treated spheres to monitor and kill *Rhagoletis*, and subsequent studies evaluated various types of deployment strategies that may be used to prevent fruit injury in apples, cherries, and blueberries.

The spheres used in our experiments were biodegradable and made from sugar, starch, sorbic acid, and cayenne pepper. They were obtained from the USDA–ARS laboratory in Peoria, IL. Before field testing, spheres were brush-painted with a mixture containing red or green enamel paint (70%), sucrose (20%), imidacloprid (Provado 1.6, 2% a.i.) and water (8%). Our results indicated that significantly more *Rhagoletis* (apple maggot, cherry fruit fly, and blueberry maggot) were killed with spheres treated with imidacloprid compared with untreated spheres. In our monitoring study, a passive trapping system involving the imidacloprid-treated sphere with a sticky clear Plexiglas panel placed horizontally 15 cm below (the sphere) was used to effectively monitor fruit fly abundance within the study area. Preliminary data indicate that this monitoring technique yielded similar results to those obtained using yellow sticky boards, but was more labor-intensive.

The improved imidacloprid-treated plastic sphere with sucrose cap is deployed in the apple orchard.

In experiments to investigate strategies for sphere deployment, three patterns were investigated: 1) perimeter deployment, in which spheres were hung individually and spaced at equal distances around the border of apple cherry and blueberry field; 2) cluster deployment, in which groups of three spheres were hung in equally spaced perimeter locations; and 3) uniform deployment, in which spheres were placed at equal distance in a grid-like pattern throughout the field. The results showed that all plots containing imidacloprid-treated spheres had significantly lower fruit infestation levels compared with unsprayed control plots with no spheres deployed. In small blueberry plots, there were no significant differences between plots treated with imidacloprid spheres and plots sprayed with Guthion (azinphosmethyl). In addition, we recorded no significant difference among the various types of sphere deployment strategies.

Overall, our results indicate that it is possible to achieve good fruit protection in apples, cherries, and blueberries by using imidacloprid-treated spheres (2% a.i.). However, the sphere density used in our experiments was fairly high and at an estimated cost of a $1.00 U.S. per treated sphere, commercial use of this technology would require fewer spheres per acre than the 10–15-m distance (between each sphere) used in our study to be economically feasible. Nevertheless, the use of imidacloprid-treated spheres has several advantages over conventional broad-spectrum insecticide applications, including minimal effects on nontarget organisms and the absence of insecticide residue on fruit. The disadvantage is that biodegradable imidacloprid-treated spheres were found to be subject to consumption by rodents and deer. Subsequently, the use of plastic and wooden imidacloprid-treated spheres with sucrose caps is being explored. Our research has been a model system for several other studies investigating the use of attract-and-kill devices for pest control. The model system has been expanded to include other crops (citrus) and several other pest complexes. A new company, Fruit Spheres Inc. (Macomb, IL), was developed specifically to handle the marketing and further commercialization of insecticide-treated spheres.

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$60,000

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Aphid Alert: Virus and Vector Surveillance and Management Strategies for Potato

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6/30/01
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$97,000

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Aphid-transmitted potato viruses potato leafroll virus and potato virus Y (PVY) can be devastating to seed potato producers in Minnesota and North Dakota. For most potato growers and their pest management advisors, the aphid vector is the least understood component of the disease cycle. These two aphid-transmitted viruses differ in their transmission characteristics and vector associations. Consequently, management practices to reduce spread differ as well.

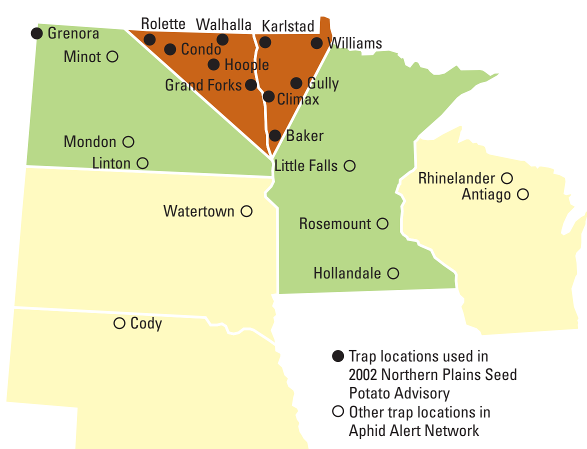
This research focused on expanding our aphid-trapping network with the goal of providing trapping data and management recommendations to potato growers the same week traps were processed. Growers can then make informed decisions for their farms on how best to manage aphids and the viruses they transmit. Management options might include rouging infected plant before vector aphids are being caught, early top-killing of vines combined with early harvest, or spraying mineral oil or insecticides based on which disease poses the greatest risk. Information on aphid abundance and management options are disseminated via a weekly newsletter, *Aphid Alert*. The newsletter was mailed to 150 seed potato growers in the two states, sent by E-mail to ~800 recipients worldwide, and posted on the Web at http://ipmworld.umn.edu/alert.htm.

High density aphid populations kill the plants and create aphid holes

The research component of *Aphid Alert* has confirmed the green peach aphid *Myzus persicae* (Sulzer) (is the most important and efficient vector of PLRV. Trap captures of green peach aphid were highly correlated with seasonal capture rate of winged green peach aphids. Incidence of PVY spread is best correlated with a combination of green peach aphid and bird cherry-oat aphid, *Rhopalosiphum padi* (L.), capture rates.

Aphid Alert has been accepted by area seed potato producers, state seed potato certification agencies, and pest management advisors as an important adjunct to the management of their crop. According to a reader survey conducted in 1999, 98% of respondents ranked the information in *Aphid Alert* as useful and 78% said they made pest management decisions based on information provided in the newsletter. The opening menu of *Aphid Alert* with links to archived back issues is currently accessed [mt]500 times per month.

Aphid Alert URL: www.ipmworld.umn.edu/alert.htm



Nebraska, S. Dakota, N. Dakota, Minnesota, Wisconsin

Development of a Green Manure System to Manage Soilborne Diseases in Vegetables

Linda Kinkel, Department of Plant Pathology, University of Minnesota

All soils harbor a diverse microflora, including bacterial and fungal plant pathogens, plant symbionts, microbial antagonists, and saprophytes. One constraint to effective biological control can be the competitive challenge that this indigenous microflora poses to inoculated microorganisms. In contrast, the success of naturally occurring suppressive soils is based upon the established, indigenous microbial community adapted to a particular field location. Recent research on green manures suggests that they may provide a means for specific enrichment of the densities or pathogen inhibitory activities of indigenous soilborne pathogen antagonists, or for the "creation" of suppressive soils. In addition, green manures can contribute to weed management, soil organic matter, nutrient management, and prevention of overwinter soil erosion. Our integrated pest management research has focused on the use of green manures in managing soilborne microbial communities and in reducing disease intensities on potato, alfalfa, and soybean. In particular, we have been studying the effects of fall versus spring green manure treatments on disease intensity and on soil microbial communities.

We also studied differences in disease and pathogen inhibition within the soil microbial community after distinct green manure–crop species–green manure sequences. Both crop species and green manure species have significant effects on pathogen inhibitory capacity in soil. Verticillium wilt intensity on potato (*Solanum* spp.) and Phytophthora on alfalfa (*Medicago* spp.) are significantly influenced by both the preceding green manure and the preceding crop species.

We are presently quantifying the effects of the green manure–crop species combinations on potato scab. Prewinter incorporation of green manures seems to produce slightly greater pathogen inhibitory capacity than a spring incorporation, although there are no apparent differences in disease intensity after the fall versus spring green manure incorporation. Work in progress is evaluating a broad collection of rotational strategies and their effects on pathogen inhibitory activity in soil. This information will be used to development optimal green manure–crop species sequences for the management of indigenous pathogen inhibitory activity with the target of minimizing soilborne plant disease. Our long-term goal is to develop practical strategies for managing microbial communities in soil to provide broad-based and effective disease management.

The impact of the proposed research is that it will reduce crop losses to plant pathogens and minimize pesticide use in soil and on seeds, thereby enhancing sustainability of U.S. agriculture. Furthermore, this work contributes to the diversification of agricultural landscapes through the inclusion of additional plant species (green manures) within a single-season rotation cycle and through its effects on soil microbial community diversity.

Project Start Date
6/15/99
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Grant Award
$94,880

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Flowering Cover Crops and Biological Control of Cabbage Pests

George Heimpel and Jana Lee, Department of Entomology, University of Minnesota

Parasitoid feeding on buckwheat nectar

Project Start Date

7/1/00

Expected Completion Date

6/30/02

Grant Award

$60,000

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Establishing nectar-producing cover crops within agroecosystems is often recommended to improve biological control of pests. Numerous laboratory and field-cage studies show that sugar feeding increases the life span of many parasitoid species and longer lived parasitoids can attack more pests. This knowledge brings the expectation that when flowering cover crops are planted, parasitoids will readily feed on this sugar source and parasitism rates will improve in the field. However, little is known about the frequency that parasitoids actually use sugar sources in the field. Our research investigated the following questions: 1) Are parasitoids feeding from nectar-producing cover crops? and 2) Do nectar sources enhance parasitism rates?

We conducted experiments in cabbage plots with and without bordering buckwheat strips. We monitored three lepidopteran pests, diamondback moth (Plutellidae), imported cabbageworm (Pieridae), and cabbage looper (Noctuidae) and their associated parasitoids. In 2000, four buckwheat and four control cabbage plots (12 by 20 m) were spaced 67 m apart within a single soybean field. In 2001, the same experiment was repeated in addition to a broad-scale experiment, where eight plots were situated at least half a mile apart to reduce cross-treatment movement of parasitoids.

Are parasitoids feeding from nectar-producing cover crops? Approximately 50–90% of captured *Diadegma insulare* (a wasp parasitoid of diamondback moth larvae) fed on sugar as determined by anthrone analysis (Fig. 1). *D. insulare* did not feed more in the presence of buckwheat when the experiment was conducted in a single field, which may have occurred due to cross-treatment movement of wasps. However, in the broad-scale study, 90% of *D. insulare* fed on sugar in buckwheat plots compared with 70% in control plots. The 70% found feeding in control plots suggest that other sugar sources also are being used in the field, such as wildflowers and aphid honeydew. Nevertheless, significantly higher proportions were found feeding in buckwheat plots, suggesting that wasps increase feeding in the presence of flowering cover crops.

Do nectar sources enhance parasitism rates? Parasitism of diamondback moth by *D. insulare* was higher in buckwheat than control plots in 2000 (Fig. 2). Parasitism of cabbage looper larvae by *Voria ruralis* was 70% in buckwheat plots compared with 50% in control plots in the broad-scale study of 2001. Yet, parasitism was not consistently higher in buckwheat versus control plots in all three trials, which led us to further analyze how sugar feeding affected parasitism rates. We found that plots with a large proportion of sugar-fed *D. insulare* did not necessarily have higher parasitism rates than plots with a low proportion of sugar-fed wasps. Thus, although flowering cover crops may increase parasitism rates, the mechanisms are not clear.

The presence of nectar-producing cover crops may increase feeding but how feeding influences parasitism activity requires further investigation. We are currently studying the behavioral and physiological changes that occur in parasitoids after sugar feeding, particularly the impacts on fecundity and dispersal. Once we better understand the interplay between sugar feeding and subsequent parasitism, we can improve conservation biological control practices.

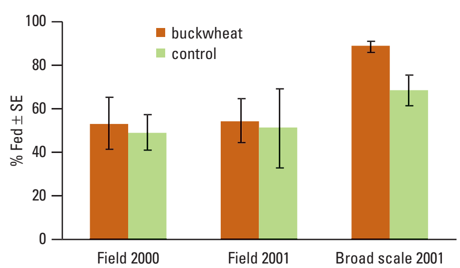

Fig. 1 • Percentage of *D. insulare* that fed on sugar in buckwheat and control plots for trials conducted in a single field or over a broad scale. Asterisk indicates when sugar-feeding occurred significantly more in buckwheat plots compared with control plots.

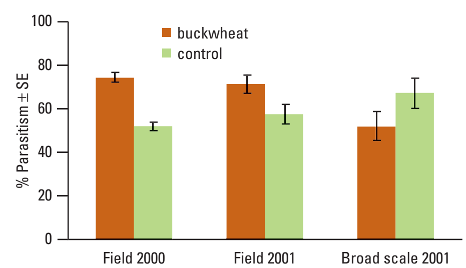

Fig. 2 • Percentage of diamondback larvae parasitized by *D. insulare* in buckwheat and control plots. Asterisk indicates that parasitism was significantly higher in buckwheat plots compared with control plots.

Implementation of Integrated Weed Management through Collaborative Learning

Nicholas Jordan and Susan White, Department of Agronomy & Plant Genetics, University of Minnesota

Sustainable, integrated weed management methods require the use of multiple tactics against problem weeds. To do so in a cost- and labor-effective manner, farm operations (e.g., tillage or fertility management) should be designed so that, when possible, they provide some weed management benefit. This approach to weed management cannot be identified by experiment station research; rather, it must be devised and implemented by individual growers, taking into account their own particular circumstances that affect weed management and other aspects of farm management. The learning ability of growers seems to be a critical resource for the more widespread adoption of integrated weed management, which currently is used by only a minority of U.S. growers. In this project, we have devised and tested a collaborative learning approach, carried out in learning groups, in which the knowledge and experience of research and extension weed scientists, crop consultants, and growers are pooled.

All participants viewed the learning groups as settings for information exchange and creative innovation that facilitated the ongoing and site-specific learning of growers. However, the impact of learning groups goes beyond simply promoting site-specific learning. Growers report that learning groups provide valuable opportunities for focused discussions that increase their ability to develop and improve integrated weed management on their farms, and to solve complex farming challenges themselves. Growers voiced their view that ongoing and site-specific learning is essential to coping with the dynamic nature of weed problems and avoiding a reactive stance in response to changes in weed problems. One grower participant observed that “Farming has such long lead times that it can take years to figure out what is wrong. If I can talk to others and speed up the learning process, that is really valuable.” A large-scale organic vegetable grower stated “Weed control is a really localized thing.” He continued, “The only way we are going to make headway (to control weeds) is by groups like this.” In interviews, growers report that they are more able to understand root causes of weed problems and to consider modifying farm operations to reduce weed problems.

An organic grower demonstrates how modifications to a cultivar allows cultivation closer to the crop row.

A group of growers tour soybean fields that are comparing reduced rate herbicide applications with increased cultivation to full rate herbicide applications without cultivation.

Extension educators and researchers also felt that the groups had increased their own effectiveness, via information exchange among growers, scientists, and educators. One educator stated, “I now realize that even the growers who are doing a really good job of controlling their weeds are making it up as they go along. It is empowering to remember that everyone has different tolerances to weeds and that each farm is a really individualized place.” Similarly, one researcher appreciated that “The learning group is a longer-term working group as opposed to individual encounters where you are set up as the expert,” and suggested that “A lot of us are trying to get out of the mold of being set up as the expert.” Extension educators and researchers noted several distinct perceptual shifts among the grower members, in particular heightened anticipation of long-term consequences and greater interest in monitoring the dynamics of weed situations.

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Natural Enemies and Resistance Management of *Bt* Corn

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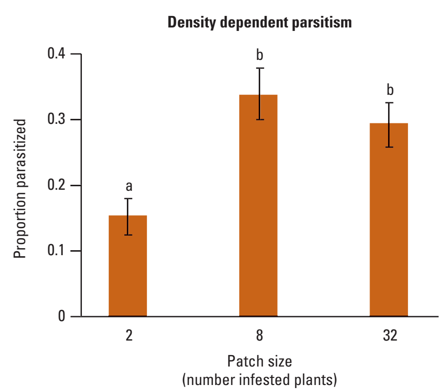
Transgenic *Bacillus thuringiensis* (*Bt*) crops, such as corn, have been genetically modified to express insecticidal *Cry* proteins that are naturally produced by the soil bacterium *B. thuringiensis*. Although some such crops potentially provide excellent pest control, widespread use of transgenic varieties could lead to strong selection for resistant pest individuals, rapid infiltration of resistance alleles into the population, and loss of Bt as an effective control measure. To prevent this outcome, the Environmental Protection Agency has adopted the high-dose/refuge (plantings of nontoxic crop varieties) strategy for some cropping systems, based on numerous theoretical models that suggest that the presence of refuges will sustain susceptible individuals in the herbivore population and slow the evolution of resistance.

From the pest's perspective, the high-dose/refuge strategy will create a mosaic of edible and inedible host plants across the landscape, which in turn will result in a patchy host distribution for natural enemies of the pest. Populations of specialized natural enemies (parasitoids) are expected to be reduced because vast acreages of crops will no longer contain appropriate hosts. However, hosts should still be abundant in refuge plantings, and the parasitoid's response to this heterogeneous host distribution can in turn influence resistance evolution in the herbivore. If the parasitoid shows a density-dependent response to herbivores, rare resistant herbivores in the transgenic crop will experience reduced parasitism pressure relative to their susceptible counterparts in the refuge. This response may increase the relative fitness of resistant individuals, causing resistance to spread more quickly than in the absence of natural enemies.

European corn borer larva

We measured the density-dependent response of *Macrocentrus grandii* Goidanich (Hymenoptera: Braconidae), a specialist parasitoid of the European corn borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae). We created a matrix of different-sized host patches within a field of *Bt* sweet corn by outplanting non-*Bt* plants and infesting them with *O. nubilalis* larvae. We then released *M. grandii* throughout the field and recorded larval parasitism. We found that *M. grandii* parasitism of *O. nubilalis* was approximately 50% lower in the smallest patch size relative to the larger patches, but that parasitism did not differ between medium and large patches. However, we also found that parasitism of *O. nubilalis* in the smallest patches was correlated with distance of the small patch from larger patches: parasitism was greater in small patches near larger patches than in more remote small patches. Using a similar design, we confirmed this result with a subsequent experiment, where we found that *M. grandii* parasitism of *O. nubilalis* in small patches was doubled if the small patch was located 10 m from a large patch, relative to small patches not associated with large patches. These results indicate that isolated resistant *O. nubilalis* in transgenic *Bt* corn may experience reduced parasitism, thus promoting the relative fitness and spread of the resistant genotype. However, to minimize the effects of differential parasitism, tight spatial coupling of transgenic crops and refuges could be used to reduce the isolation of resistant hosts within the transgenic crop.



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$69,212

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Corn Insect Pests: A Diagnostic Guide

George Smith, Missouri Department of Agriculture, Plant Industries Division

Collectively, corn insect pests in the Midwest are a significant risk factor in corn, *Zea mays* L., production because of the potential impact they may have on early-season stand reductions. Because optimum yields are achieved when corn is planted in a relatively narrow, early-spring window, growers are highly risk averse to the damage potential of these pests. Excellent integrated pest management (IPM) strategies have been developed that distinguish economic from noneconomic pests, yet field diagnostics was the weak link in IPM adoption. Thus, *Corn Insect Pests: A Diagnostic Guide* was produced to aid pest management field specialists in making real-time decisions as to whether economic pests were present and whether the injury level warranted treatment. The guide can be obtained as a printed publication or via a searchable and downloadable Web site.

Corn Insect Pests: A Diagnostic Guide illustrates the quality of work to which Missouri's IPM program aspired. In 1999, this guide generated more sales revenue for Extension Publications at the University of Missouri than all other publication sales combined, and it was the most popular pdf download from the Extension XPLOR site. This guide also received a bronze award in the class of technical publications in the Agricultural Communicators in Education Awards program. Furthermore, it represented the fulfillment of a common interest and need by industry and land-grant universities to provide the technical expertise required for the North Central Region's certified crop advisers. More than 10,000 hard copies of this guide were distributed throughout the 12 North Central states.

Corn Insect Pests: A Diagnostic Guide received a bronze award from the Agricultural Communicators in Education Award Program.

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Characterization of Genetic, Morphological, and Host Range Differences within and between Wheat Curl Mite Populations

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Wheat streak mosaic is considered the most serious disease of winter wheat, *Triticum aestivum* L., in the western Great Plains. The virus responsible for wheat streak is transmitted by the eriophyid mite *Aceria tosichella* Keifer (wheat curl mite). Recently, research indicates that the wheat curl mite transmits a second virus to both wheat and corn, *Zea mays* L. Kansas (through its annual disease survey) estimates that wheat streak losses average 2% annually (ca. $18 million in Kansas; $4 million in Nebraska). Despite its economic importance, the taxonomic status of the wheat curl mite is unclear. Success in managing this mite–disease complex has been limited by the lack of understanding of the biology and ecology of the mite and the epidemiology of the mite–virus complex. Findings at Kansas State University have indicated that geographically distinct mite populations exhibit considerable variation in their ability to transmit high plains virus and survive on mite-resistant wheat. The objective of our research was to determine the morphological, genetic, and host variation between five wheat curl mite strains that have been found to differentially transmit high plains virus.

By using polymerase chain reaction techniques, we amplified and sequenced regions of ribosomal and mitochondrial DNA. We have found genetic sequence differences between some of the mite populations, with the Kansas, South Dakota, and Texas mite strains being nearly identical genetically. The Nebraska strain shows the greatest difference from these three strains, with the Montana strain being intermediate. Both morphological and host response data indicate that the Nebraska strain is distinctive from all the other wheat curl mite sources. None of these differences are large enough to place the mite strains in a subspecies category; however, the potential importance of these differences is demonstrated by work at Kansas State University. The work shows that the distinctive Nebraska strain is the most efficient vector of high plains virus and that strain differences are important in mite resistance in wheat. In addition to comparisons between these populations, we also have obtained data on a closely related species, *Aceria tulipae* Keifer. We have been able to establish morphological, host range, and genetic differences between these five sources of wheat curl mites and *A. tulipae*.

Photomicrograph of the wheat curl mite (approx. length 200 microns)

Photomicrograph of the wheat curl mite.

Characteristic patterns on the prodorsal shield of the Nebraska strain of wheat curl mite.

With the results from this study, we can now delineate more clearly between *A. tulipae* and *A. tosichella*. Our genetic sequencing work allows for development of primers to aid in more rapid identification of wheat curl mite strains. More rapid identification of mite strains allows us to study the field ecology of these strains as it relates to virus transmission and plant resistance to the wheat curl mite. These improvements in our understanding of the mites' biology and ecology facilitate management of this mite–disease complex through host plant resistance and cultural methods.

Characterization of Naturally Occurring Seed Losses in Giant Ragweed (*Ambrosia trifid*)

Emilie Regnier, Department of Horticulture & Crop Science, Ohio State University

Giant ragweed, *Ambrosia trifida* L., is a native annual plant that behaves as an invasive weed of crops and undisturbed habitats throughout the eastern two-thirds of North America. Its pollen is a principal cause of seasonal hay fever in humans. Giant ragweed has been ranked as one of the most costly agricultural weeds in the midwestern United States. Season-long interference from a population of 1 plant/m^2 caused soybean yield losses >75% and corn yield losses >50%. Giant ragweed populations have developed in Ohio that are resistant to herbicides that inhibit acetolactate synthase, and resistance was documented for 12 populations after only 3 years of herbicide selection pressure.

Field experiments are being conducted in Ohio to determine natural sources of seed loss in giant ragweed and to determine the effects of tillage and cropping system on giant ragweed seedling establishment, competitiveness, and seed production. A delay in emergence of giant ragweed relative to corn effectively reduces giant ragweed competitiveness and seed production. However, to protect crop yield, the delay should be at least 4 weeks after crop emergence. Models based on Ohio corn yield loss data predict that an arbitrary 5% yield loss threshold would be reached at a giant ragweed density of 0.4 weed/10 m^2 when weeds emerge concurrently with corn, and at a density of 4.2 weeds/10 m^2 when weeds emerge 4 weeks after corn. A 4-week delay in giant ragweed emergence reduced giant ragweed seed production [mt]85%.

Natural sources of seed loss in giant ragweed include poor seed development and seed predation by invertebrates and rodents. Approximately one-half of the seed produced by giant ragweed is either nonviable or consumed by predators before dispersal. At least four different species of seed-eating insect larvae, including species of Curculionidae, Lepidoptera, and Tephritidae, were found in giant ragweed seed still attached to mother plants. Seeds dispersed to the soil surface are predated by rodents and ground beetles, with highest rates of predation occurring during the first 3 months after seed dispersal in the fall. Total predation of seed on the soil surface over a 12-month period was 88%.

Cross-section of a giant ragweed seed.

Giant ragweed emergence was monitored in no-tillage and chisel-plowed plots. Emergence spanned from mid-March to mid-August, but 95% of total emergence in both tilled and no-tillage plots occurred by mid- to late June. Depth of emergence ranged from 0 (soil surface) to 11.0 cm and averaged 2.5 and 1.2 cm in tilled and no-till treatments, respectively. In separate seed burial experiments, emergence was highest for seeds buried 0 to 5 cm and no emergence occurred from seeds buried 20 cm. Seeds on the soil surface remained viable for 1 year, but seeds buried 5 to 20 cm in depth remained viable for 4 years and the proportion of viable seeds increased as burial depth increased.

Mature giant ragweed in soybean field.

These results suggest that delaying seedling emergence beyond 4 weeks after crop emergence, preventing seed burial, and optimizing conditions for seed predators can reduce giant ragweed competition, seed production, and seed populations in the soil to near or below threshold levels.

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$63,700

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Glandular-Haired Alfalfa: A New Integrated Pest Management Tool

Ronald Hammond, R. Mark Sulc, Lanny Rhodes, and Harold Willson, Department of Entomology, OARDC, Ohio State University

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$74,627

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The potato leafhopper, *Empoasca fabae* (Harris), is the most serious insect pest of alfalfa in the midwestern and eastern United States. Glandular-haired potato leafhopper-resistant alfalfa, released to growers during 1996 and 1997 by private industry, offered much promise in potato leafhopper management. Ohio researchers conducted studies supported with a North Central-Regional Integrated Pest Management Program grant to determine the efficacy of new potato leafhopper-resistant alfalfa varieties in offering acceptable control of potato leafhopper.

Large plots were established in 1997 and 1998 by using two early-released, potato leafhopper-resistant varieties. Weekly sweep-net samples were collected for 2–3 years. Insecticide applications were made during the growing season each year for comparative purposes.

A glandular-hair potato leafhopper resistant alfalfa cultivar (right) compared with a leafhopper-susceptible alfalfa cultivar (left). *Note: the resistant is the green cultivar and the yellow is the susceptible.*

In the first field in 1997, an extremely large potato leafhopper population occurred, with a dramatic increase in adult PLH in the susceptible cultivar compared with the resistant cultivar. The difference in adult densities seemed to lead to a large reduction in nymphal densities in the resistant compared with the susceptible cultivar. However, insecticide treatment was deemed necessary in both susceptible and resistant varieties. Adult densities in untreated plots remained high on both cultivars, although the densities were greater on the susceptible cultivar. Hopperburn or leaf injury occurred in both cultivars. During the remaining years, adult densities were similar in both cultivars before the second cutting. Although densities were lower after the second cutting, they were usually higher in the susceptible cultivar.

Potato leafhopper adult.

In the second field planted in 1998, differences in adult densities between the susceptible and resistant cultivar were not as great. However, potato leafhopper densities were still always greater in the susceptible cultivar. Leafhopper density in the resistant cultivars still reached the threshold requiring treatment in this first year. Injury was more evident in the susceptible cultivar. This trend continued in subsequent years.

On-farm trials with the early-released, potato leafhopper-resistant cultivars confirmed results found in the research plots. Results were extended to growers at meetings, field days, and in newsletter articles and extension bulletins. A factsheet on potato leafhopper management was prepared, with information on resistant cultivars as part of the overall integrated pest management approach to managing this pest.

We have continued to examine the impact of glandular-haired varieties in research plots and on-farm trials, doing similar work with recently released varieties having much higher levels of resistance. Initial results suggest that these newest varieties are better able to reduce potato leafhopper numbers and consequent yield losses, approaching the level of control that growers expect. Our overall goal is to continue to examine potato leafhopper-resistant varieties as they are released to determine their ability to offer growers complete potato leafhopper control.

Partnering Ohio State University Interns and Ohio Greenhouse Floriculture Producers in Demonstration IPM Programs

Claudio Pasian, Department of Horticulture & Crop Science, Ohio State University

Traditionally, the greenhouse industry has depended on chemicals to ensure quality crops. Consumers' quality and aesthetic expectations for flawless plants are met currently with the aid of pesticides and plant growth regulators. With greenhouse ornamental crop production, pest populations must be kept at very low levels to prevent feeding injury that can weaken or even kill plants and to meet aesthetic demands: consumers are reluctant to purchase insect-damaged or pest-infected plants. Today's greenhouse growers are increasingly receptive to alternatives to commercial chemicals. The use of nonchemical cultural methods is on the rise to keep plant growth under control. Many growers are aware of integrated pest management (IPM) practices but only a few use them in producing their crops. We have noted over the years that despite that floriculture growers are aware of IPM techniques, many lack the practical knowledge and confidence to put them to practice.

Thus, we wanted to give some of our students the opportunity to apply their IPM knowledge and expertise in a "real-world" situation. By doing so, we hoped to give floriculture greenhouse growers the opportunity to experience the benefits of an IPM program. According to Chris Baker from Baker's Acres (Alexandria, OH), "The scouting program initiated by Ohio State was definitely beneficial. Many times scouting for insects is low on a list of priorities and it's nice having someone here to teach us how to do it methodically."

Visiting each grower 1 day a week and scouting on a portion of their crops allowed students to put into practice skills learned in courses as well as in the intensive week of training before the scouting started. Each grower received a simple report at the end of the intern visit consisting of a form with the sticky card insect count, results of the substrate pH and EC measurements, and a description of the health status of the crop as observed by the student.

Both students and growers benefited from using the Pest Diagnostic Clinic at The Ohio State University. When the intern was not sure about a specific problem, he or she would take samples to the clinic for diagnostic. After problem identification, the student informed the grower and suggested that contact with appropriate state specialists on campus be made. This process allowed growers to learn about problems they were not aware of or did not recognize. The emphasis of the program was on early detection and accurate diagnosis of the problem.

Overall, the program was very successful for the growers. Several expressed their desire to be part of the program if it was repeated. "The Student Intern Program provided a valuable service for our company, because we were able to use the expertise of the intern to help alert our staff of potential problems before they occur. The information provided by the intern helped to direct our plant maintenance efforts by our staff in the most efficient manner. We are very happy with the results of the Intern Program, and with what we have learned about IPM scouting," said George Pealer, owner of Millcreek Gardens (Ostrander, OH).

A scout from Ohio State University examines the roots of a poinsettia plant in the greenhouse.

Sticky trap counts were made weekly to evaluate insect activity in the greenhouse.

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$15,627

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User-Friendly Decision Tools for Predicting Insect and Weed Phenology

Daniel A. Herms, Department of Entomology; John Cardina, Department of Horticulture and Crop Science; and David Lohnes, Department of Communications and Technology, OARDC, Ohio State University

Effective integrated pest management (IPM) requires accurate pest phenology and environmental data to optimize timing and intensity of management tactics, but this information is not readily accessible to growers. We generated degree-day and phenology data for key agronomic weeds and insect pests of nurseries, and linked these data with the flowering sequence of common ornamental indicator plants to generate a user-friendly, Web-based BioCalendar (http://www.oardc.ohio-state.edu/gdd) for timing pest management tactics.

From 2000 to 2002, we monitored phenological stages of 32 weed pests of agronomic and vegetable crops, 43 arthropod pests of ornamental nursery crops, and the flowering sequence of 94 common ornamental trees and shrubs. We also quantified cumulative degree days required for development of each phenological event. Although calendar dates of phenological events varied substantially over the 3-year period, the phenological sequence remained constant from year to year (minimum Spearman's r value = 0.96). Therefore, the easily monitored sequence of flowering plants can be used accurately as a BioCalendar to track degree-day accumulation and predict the phenology of insect and weed pests.

A phenology Web site has been developed for Ohio in which cumulative degree-day data accessible to growers in real-time is linked directly to this BioCalendar. Daily temperature data from the 12 OARDC research stations around Ohio are used to calculate cumulative degree days in real time for any location in the state.

Implementation of IPM strategies and tactics is often hindered by lack of access to data necessary to accurately time pest management decisions, especially for alternatives to pesticides, which must generally be timed precisely. This project helps overcome this key barrier to implementation of IPM by connecting pest phenology with degree-day data. The format is user-friendly and provides growers with a Web-accessible source of degree-day and phenology information for key weed and arthropod pests in the North Central region.

The BioCalendar and Web-based degree-day data base are complementary decision tools that can be used to predict accurately the phenology of weed and insect pests, time pest management decisions, and facilitate extension recommendations. Better timed management tactics result in more effective pest management and increased crop yields, while decreasing pesticide use and production costs. These outcomes ultimately will increase grower acceptance and implementation of IPM in the North Central region.

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$78,187

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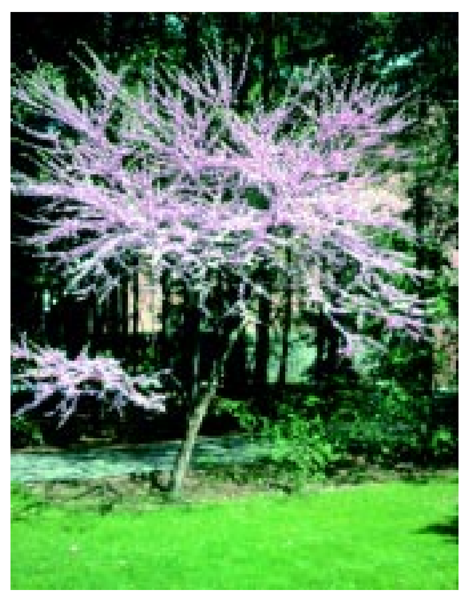

The first gypsy moth (Lymantria dispar) egg hatch always occurs when Eastern redbud (Cercis canadensis) is in full bloom.

Crop Rotations for Integrated Crop and Weed Management

Jerry Doll, Department of Agronomy; and Kevin Shelley, Nutrient and Pest Management Program, University of Wisconsin

The objective of this 6-year on-farm research and demonstration project is to help corn and soybean farmers in southern Wisconsin recognize potential agronomic, economic, and pest management benefits associated with a more diverse crop ecology. We have compared a soybean–corn rotation with an expanded rotation of soybean–winter wheat–corn in which medium red clover is frost-seeded into the wheat for a postharvest cover crop. Rotations have been compared on three host farms in south central Wisconsin in field-length, side-by-side strips with two or three replications of each rotation. Two of the farms have completed the 6 years, with the third farm finishing in 2003.

Observing weed pressure in each rotation has been the primary pest management focus. It was expected that adding a winter annual crop and legume forage cover crop to an otherwise continuous annual crop rotation would break the cycle of summer annual weeds. This approach would provide a cultural component to weed control in what is normally a chemically based control program.

Weed pressure in each rotation was evaluated by two methods. The first method involved germinating weeds in greenhouse flats from intensively collected soil samples in each of the field-length strips in each of years 2 through 6. The second method involved taking in-field weed counts in early June of the final year before postemergence herbicides were applied. Other expected benefits from the three-crop rotation included reduced presence of soybean disease pests such as soybean cyst nematode, brown stem rot, and white mold. Enhanced root and plant health of soybean and corn due to an additional crop in the rotation should translate into higher yields in these crops. With successful cultivation of winter wheat, average annual profit should rival that of the two-crop rotation.

Weeds observed in corn on June 8, 2002 , year 6 where the soybean/corn rotation was: 1997 (corn); 1998 (soybean); 1999 (corn); 2000 (soybean); 2001 (corn); and 2002 (corn).

Weeds observed in corn on June 8, 2002 , year 6 where the soybean/wheat/corn rotation was: 1997 (soybean); 1998 (wheat); 1999 (corn); 2000 (soybean); 2001 (wheat); and 2002 (corn).

Contrary to our expectation, weed pressure seemed to be higher in the wheat rotation as indicated by in-field weed counts in year 6 of the comparison. Superficially, this finding would argue against the efficacy of this rotation as part of an integrated approach to weed management; however, possible competition advantages afforded crops grown in the more diverse rotation also must be considered. Weed seedlings germinated in the greenhouse from the seed bank soil samples did not show a clear relationship with rotation and weed pressure declined during the 6-year period. Foliar symptoms of brown stem rot were noticeably higher in soybean grown in the soybean–corn rotation at one farm in 2000.

Economic results favored the three-crop rotation on two of the three farms in the comparison, due to the following: 1) slightly higher corn and soybean yields in this rotation, and 2) relatively high wheat yields. Teaching the agronomics for high-yield wheat was another component of the project.

Crop rotation is often mentioned by researchers and educators as a component in an integrated approach to managing pests. Measuring or demonstrating its efficacy is less common, particularly in actual production situations. This project has attempted to provide a learning opportunity about the concepts of ecological diversity and how they apply to crop rotations as a tool for managing pests by emphasizing the ecological contributions of winter wheat and red clover to the rotation in terms of its effects on pests and soybean and corn yields. Our results show that economics of wheat must be evaluated rotation-wide. Farmers hosting the comparisons and more than 100 farmers and agricultural professionals attending five field days have taken advantage of this opportunity. Others in Wisconsin have read articles published in the state's farm press. Additional educational outreach on final results is planned.

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$40,403

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Distribution, Characterization, Modes of Transmission, and Impact of Phytoplasma in Alfalfa in Wisconsin

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$100,000

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Although alfalfa breeders have been successful in breeding and releasing cultivars with resistance to many pathogens, overall alfalfa yields are progressively declining. A project was initiated to determine the frequency and affect of phytoplasma and viruses. A survey was conducted during September to November, 1998–1999, to determine the incidence of phytoplasma in alfalfa plantings. Leaves were obtained from fields in eight geographic regions of the southern half of Wisconsin. Leaf samples were processed by extraction of DNA, assayed by polymerase chain reaction (PCR) with two universal primer pairs. PCR products were characterized by restriction enzyme digests and comparison of restriction fragment length polymorphisms with patterns of known phytoplasmas. Phytoplasmas are widespread in alfalfa plantings in Wisconsin. Restriction digest work PCR products (amplified DNA) of the 12 positives revealed the presence of phytoplasmas belonging to the aster yellows grouping. This report is the first to indicate the presence of the aster yellows organism in alfalfa. The majority of alfalfa samples that are PCR positive for phytoplasma originated from plantings in their 3rd or 4th year. As expected, seed transmission of phytoplasma was not observed.

Alfalfa was sampled at three locations and leaves assayed for alfalfa mosaic virus (AMV), and tobacco streak virus (TSV). AMV and TSV were detected in commercial-sized fields and the incidence of AMV was high as expected, but a high incidence of TSV was found and was not expected (Fig. 1). Stable resistance to AMV has been difficult to achieve. Thus, resistance to insects that vector viruses may be a more successful option.

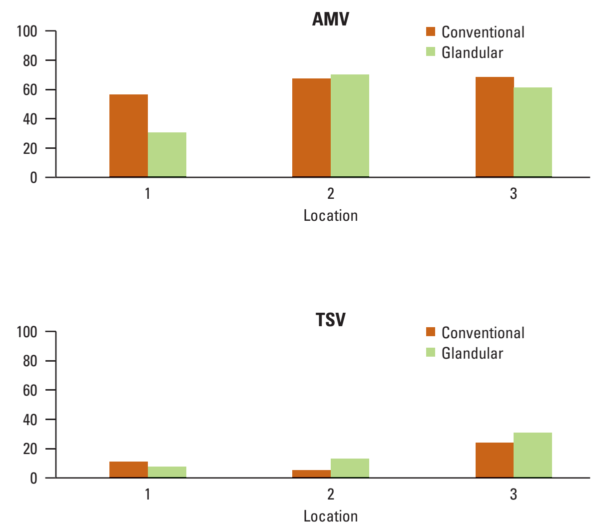

Fig. 1 • Incidence of alfalfa plants infected with AMV (A) and TSV (B) at three locations in Wisconsin. Conventional alfalfa cultivars were compared with glandular-haired cultivars resistant to potato leafhopper (Homoptera: Cicadellidae).

The effect of the leafhopper-resistant alfalfa cultivars on the incidence of viruses affecting alfalfa is not well known. Conventional and glandular-hair (leafhopper-resistant) cultivars were sampled for AMV and TSV at three locations in Wisconsin. Most of the sampled plants did not express virus-like symptoms. However, when symptoms were present they where characterized by mosaic mottling, yellowing along the veins, and yellow round spots. The average incidence of AMV across locations ranged from 43 to approximately 70%, and the incidence of TSV from 8 to 27%. Glandular hair cultivars were infected with either AMV or TSV at the same incidence as conventional cultivars (Fig. 1). Both phytoplasma and a previously undetected virus, TSV, are present in alfalfa and are worthy of further investigation as factors affecting alfalfa health and productivity.

Endophytic Acremonium-Like Fungi as Possible Agents Altering Soybean Health and Productivity

Craig R. Grau, Department of Plant Pathology, University of Wisconsin

Brown stem rot, caused by *Phialophora gregata*, and Sclerotinia stem rot, caused by *Sclerotinia sclerotiorum*, are yield-limiting diseases of soybean in the North Central states. The incidence and severity of both diseases frequently vary by location and year. Research was initiated to determine whether other fungi common to soybean stems modify the incidence and severity of each disease. Acremonium-like isolates were identified as *Plectosporium tabicinum* based on morphology and random amplified polymorphic DNA (RAPD) markers. Soybean plants challenged with *P. tabicinum* expressed no-to-mild symptoms and the presence of *P. tabicinum* modified the interaction phenotype between soybean and *Sclerotinia* and *P. gregata* in greenhouse studies but not in field studies. *P. tabicinum* was detected early in the growing season, but declined in isolation after reproductive growth stages were initiated. This result may provide a partial explanation for why suppression of each disease was not observed in the field. *Verticillium chlamydosporium* was also commonly recovered from field-grown soybean plants at several locations, but was not observed to have disease-suppressing ability in greenhouse trials. Thus, variation in symptom incidence and severity could not be explained by the presence or absence of *P. tabicinum* and *V. chlamydosporium*.

Brown stem rot symptoms aare affected by soybean variety and genotype of the pathogen.

Studies were refocused on genetic variability within field populations of *P. gregata*, the brown stem rot pathogen. Collaborative studies were established with Dr. Weidong Chen, former member of the Natural History Survey (University of Illinois, Champaign, IL). The midwestern population of *P. gregata* was found to differentiate into two genotypes (A and B) based on a molecular (RAPD) marker. This result has pathological relevance because genotype A of *P. gregata* causes greater symptom severity compared with isolates of genotype B. Genotype A is recovered at a higher frequency from susceptible soybean lines and the B genotype is recovered at a higher frequency from most, but not all soybean lines that express resistance to *P. gregata*. The frequency of pathogen genotypes were detected equally in brown stem rot-resistant cultivars derived from BSR101, the most common source of resistance used by the soybean industry. This finding strongly suggests that soybean breeders should consider using alternative sources of resistance that favor the mildly aggressive B genotype.

Response of cultivar "Corsoy 79" to *Phialophora gregata* genotypes A and B.

A pattern of strain frequency was also associated with different sources of resistance to the soybean cyst nematode (SCN). The B genotype was recovered most frequently from soybean cultivars derived from PI 88788, a commonly used source of SCN resistance, and the A genotype is recovered more frequently from SCN-resistant cultivars derived from the Peking source of SCN resistance. These data strongly suggest that variation in severity of brown stem rot relates to genetic diversity within populations of *P. gregata* and is further modified by genotype of soybean planted in a specific field. Soybean breeders now have guidance on which genetic form of *P. gregata* to use in screening for resistance and have evidence that alternative sources of brown stem rot resistance should be used in their breeding programs. Furthermore, soybean breeders have information that sources of SCN resistance differ in reaction to *P. gregata*.

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Phone: 217/333-6652
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megray@uiuc.edu

Indiana

http://www.entm.purdue.edu/entomology/ext/fieldcropsipm/index.html

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Alfalfa, Apple, Christmas Trees, Corn, Greenhouse, Livestock, Melons, Ornamentals, Potato, Soybean, Stored Products, Sweet Corn, Tomato, Turf, Urban, Wheat

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Fax: 765/494-2152
rich_edwards@entm.purdue.edu

Iowa

http://www.ipm.iastate.edu/ipm/

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Field Crops, Corn Soybeans, Alfalfa, Vegetables, Organic Agriculture, Fruits, School IPM, Livestock, Ornamental and Turf, Shade Tree, Household, Lawn and Garden

Dr. Jerry DeWitt
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Department of Entomology
109 Insectary Building
Ames, IA 50011-1010
Phone: 515/294-1101 and 515/294-1923
Fax: 515/294-8027
jdewitt@iastate.edu

Kansas

http://www.oznet.ksu.edu/pesticides-ipm/

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Alfalfa, Corn, Grain, Sorghum, Soybean, Sunflower, Wheat

Ms. Sharon Dobesh
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Fax: (785) 532-6258
sdobesh@oznet.ksu.edu

Michigan

http://www.msue.msu.edu/ipm/

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Field Crops, Fruit Crops, Vegetables, Lanscape and Nursery

Dr. Michael Brewer
Michigan State University
B 18 Food Safety & Toxicology Building
East Lansing, Michigan 48854-1302
Phone: (517) 353-5134
Fax: (517) 353-4995
brewerm@msu.edu

Minnesota

http://vegedge.umn.edu/

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Corn, Soybeans, Wheat, Barley, Sugar beets, Dry Edible Beans, Sunflower, Canola, Sweet Corn, Peas, Potatoes, Snap Beans, Pumpkins, Cucumbers

Dr. Kenneth R. Ostlie
University of Minnesota
Department of Entomology
1980 Folwell Avenue
St. Paul, MN 55108
Phone: 612/624-7436
Fax: 612/625-5299
ostli001@maroon.tc.umn.edu

Missouri

http://ipm.missouri.edu

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Corn, Soybean, Cotton, Forestry, and Urban

Dr. Fred Fishel
University of Missouri
212 Waters Hall
Columbia, MO 65211
Phone: 573/884-6361
Fax: 573/882-1467
fishelf@missouri.edu

Nebraska

http://entomology.unl.edu/

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Field Crops, Urban Pest Management, Vertebrate Pest Management

Dr. Robert J. Wright
University of Nebraska
202 Plant Industry Building
Lincoln, NE 68583-0816
Phone: 402/472-2123
Fax: 402/472-4687
rwright2@unl.edu

North Dakota

http://www.ag.ndsu.nodak.edu/aginfo/ndipm/

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Barley, Canola, Corn, Drybeans, Potato, Soybean, Sugarbeet, Sunflower, Turf, Wheat

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Ohio

http://www.ag.ohio-state.edu/~ipm

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Fruit, Vegetables, Field Crops, Nursery, Turf & Landscape, Schools

Dr. Joseph Kovach
Ohio State University
IPM Program
Selby Hall
Wooster, OH 44691
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Fax: 330-263-3841
kovach.49@osu.edu

South Dakota

http://plantsci.sdstate.edu

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Corn, Soybeans, Small Grains, Pulse Crops, Sunflower, Alfalfa and Special Emphasis on Pasture/Range and Invasive Species

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Plant Science Department
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Brookings, SD 57007
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Fax: 605/688-4602
deneke.darrell@ces.sdstate.edu

Wisconsin

http://ipcm.wisc.edu/

PRIMARY COMMODITIES/PROGRAM AREAS IN IPM:
Alfalfa, Cranberry, Field Corn, Fresh Market Vegetables, Potato, Soybean

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