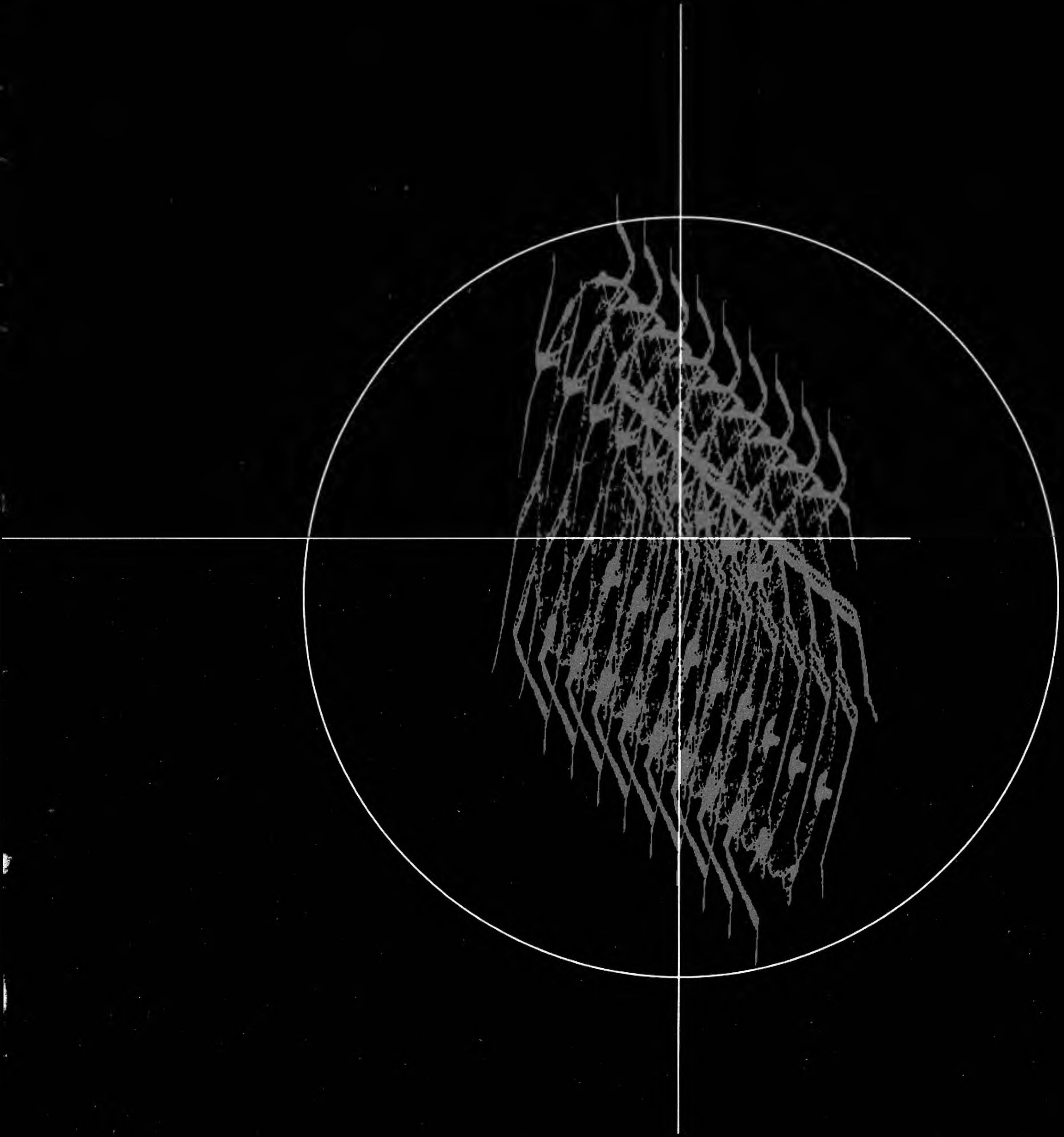
1995



Illinois Agricultural Pesticides Conference

January 4 and 5, 1995
University of Illinois
at Urbana-Champaign
College of Agriculture
Cooperative Extension Service
In cooperation with the
Illinois Natural History Survey

ILLINOIS APC

Illinois
Agricultural
Pesticides
Conference

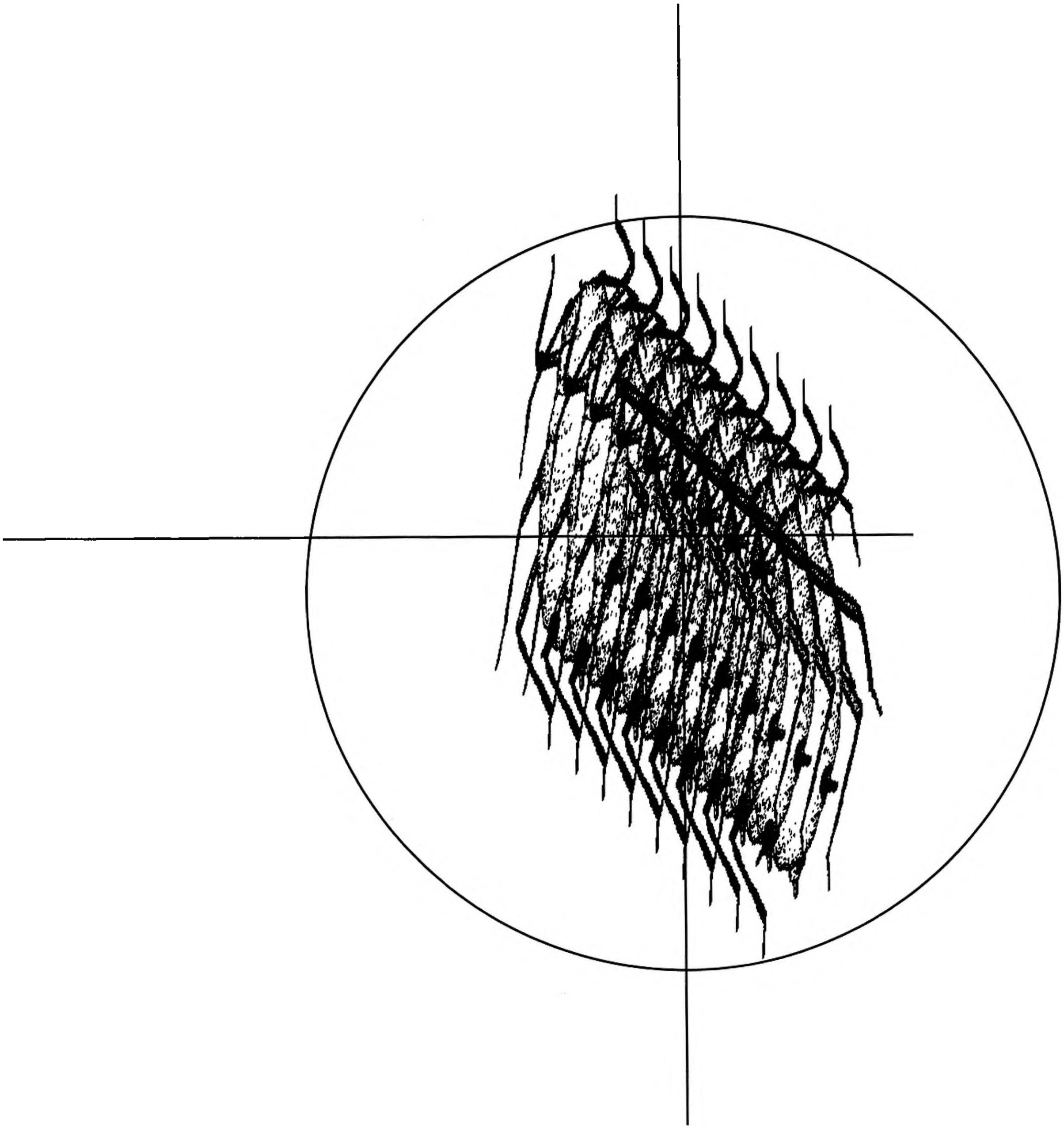
The Illinois Agricultural Pesticides Conference is an annual program presented for anyone in agriculture who uses or recommends the use of pesticides in a crop pest management program. The conference encourages the proper, timely, and wise use of pesticides within an integrated crop management system. The program is sponsored by the Cooperative Extension Service in the College of Agriculture at the University of Illinois at Urbana-Champaign and the Illinois Natural History Survey. We gratefully acknowledge the assistance of the Illinois Department of Agriculture, the Illinois Environmental Protection Agency, and the Illinois Fertilizer and Chemical Association in planning and staging the program.

This publication contains summaries of the presentations made at the Illinois Agricultural Pesticides Conference on the dates indicated on the front cover. Many of these summaries are research reports that provide the latest research information about agricultural pest control. Some of the chemicals discussed in the summaries are not registered for use by the public and thus are not intended as recommendations. The Illinois Agricultural Pest Management Handbook contains suggestions for using registered pesticides. The use of trade names does not imply or constitute an endorsement by the University of Illinois, nor does it imply discrimination against other products.

Statements made in the summaries within these proceedings are the responsibility of the author or the institution he or she represents. Reproduction and publication of these summaries are permitted only with the approval of the author.

Cooperative Extension Service
University of Illinois at Urbana-Champaign
Helping You Put Knowledge to Work

1995



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Acknowledgments

The compilation and publication of these proceedings require considerable coordination and cooperation among several units in the College of Agriculture at the University of Illinois. Without the dedication of the individuals involved in this effort and the cooperation of the many authors, the papers within these proceedings could never be published as a whole. The following is a list of the people responsible for the production of the Proceedings of the 1995 Illinois Agricultural Pesticides Conference.

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Entomology and Regulatory: Kevin Steffey
Plant Pathology: Walker Kirby
Weed Science: Ellery Knake

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Summaries of Presentations

1995 Illinois Agricultural Pesticides Conference

The Illinois Agricultural Pesticides Conference is an educational program sponsored by the following organizations:

Cooperative Extension Service
College of Agriculture
University of Illinois

Illinois Natural History Survey
Illinois Department of Agriculture
Illinois Fertilizer and Chemical Association

Members of the **planning committee** for the 1995 Illinois Agricultural Pesticides Conference were:

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Noel Troxclair
Extension Educator, IPM, Benton, IL
Illinois Cooperative Extension Service

Program — Wednesday, January 4
Illini Rooms

Wednesday Morning Session
Kevin Steffey Presiding

10:00 a.m. Welcoming Address: Reorganization of the College of Agriculture at the University of Illinois: What It Means To You, W. "Reg" Gomes

10:10 GPS for Site-Specific Farming, Carroll Goering

10:25 Herbicide Tolerant Crops: A Seed Industry View, Mark Winkle

10:40 Herbicide Tolerant Crops: A Herbicide Industry View, Donn Schmidt

10:55 Herbicide Tolerant Crops: An Academic View, David Simpson

11:10	Control of Sod and Weeds for Acres Coming Out of CRP, Marshal McGlamery
11:25	String Techniques for Evaluation of Spray Patterns, Dennis Gardisser
11:40	Spray Modifiers, John Nalewaja
12:00 noon	Illinois Generic State Management Plan for Pesticides in Groundwater, Warren Goetsch
12:15 p.m.	Township Ratings of Susceptibility: What Do These Ratings Mean? Don Keefer
12:30	Lunch

First Wednesday Afternoon Session

Loren Bode Presiding

1:30 p.m.	Biological Control of Insects in Field Crops: Expectations and Reality, Rob Wiedenmann
1:45	The Use of Bt-Corn to Control European Corn Borers: 1994 Results and Future Expectations, Ria Barrido and Kevin Steffey
2:05	Agricultural Pesticide Clean Sweep Program: 1994 Activities and Plans for 1995, Warren Goetsch
2:20	Agricultural Pesticide Container Recycling Program: 1994 Activities and Plans for 1995, Brad Beaver
2:35	New Techniques for Aerial Application of Pesticides, Dennis Gardisser
2:50	'94 Resprays and Implications for '95, Dan Childs
3:05	Break

New Developments from Industry

Dave Mowers Presiding

3:20 p.m.	Monsanto, Brett Bussler
3:32	Neogen, Chuck Bird
3:42	Miles, Joe Bruce
3:52	BASF, Mike McKeague
4:02	American Cyanamid, Dan Zinck
4:14	DuPont, Kevin Hahn
4:24	Zeneca, Dave Thomas
4:36	DowElanco, Joe Pafford
4:43	AgrEvo USA Company, John Baldwin
4:50	Gustafson, Ray Knake
4:57	FMC, Dan Hopper
5:04	Valent, Alan Kurtz
5:11	Rhone-Poulenc, Bill Striegel
5:18	Ciba, J.R. James
5:28	Sandoz, Gary Schmitz
5:40	Adjourn to Mixer

Mixer

Ballroom, Illini Union
5:40 p.m. to 7:00 p.m.

This mixer is sponsored by the Illinois Fertilizer and Chemical Association and is intended for you to meet the speakers, sponsors, and committee members in an informal atmosphere. If you have any questions for the speakers who made presentations today or if you just want to visit with friends, please stop by.

Program — Thursday, January 5

Illini Rooms

First Thursday Morning Session

Dennis Bowman Presiding

8:00 a.m.	New Herbicide Developments, Steve Hart
8:20	Races of Phytophthora Attacking Soybeans, Jack Paxton
8:35	USDA Recordkeeping Requirements; 1994 Results, Proposed Changes for 1995, and the Role of Commercial Applicators, Gerald Kirbach
8:50	Weed Species Shifts, Ellery Knake
9:05	Shifts in Weed Control Practices, Dennis Epplin
9:20	Survey of IPM Practices in Central Illinois, George Czapar
9:35	Status of Soybean Cyst Nematode Races in Illinois, Dale Edwards
9:50	Diagnosing Herbicide Injury, Aaron Hager
10:05	Break

Second Thursday Morning Session

Doug Rushing Presiding

10:20 a.m. Environmental Provisions of the Farm Bill, Jon Scholl

10:35 Pesticides and Food Safety: The Gods' Honest Truth Is It's Not That Simple, Rick Weinzierl

10:50 Stewardship of Crop Protection Products: What Will the EPA Require in the Future? Doug Rushing

11:05 Water Quality Update: The Results of Pesticide Monitoring in Illinois' Streams and Public Water Supplies, A.G. Taylor

11:20 Vegetative Filter Strip Establishment, Mike Plumer

11:35 White Mold of Soybeans: Management and Control, Craig Grau

12:00 noon Lunch

First Thursday Afternoon Session

Kevin Black Presiding

1:00 p.m. Electronics for Precise Application, Bob Wolf

1:15 Attractants for Adult Corn Rootworm Monitoring and Control, Lesley Deem-Dickson

1:30 Areawide Pest Management for Corn Rootworms: Fantasy or Realistic Expectations? Mike Gray

1:45 Effect of Rainfall on Soil-Applied Herbicide Performance, F.W. Simmons

2:00 Identification and Distribution of Pigweed Species, Loyd Wax

2:15 Agrichemical Facility Containment Program Update, Gerald Kirbach

2:30 How We Reduce Pesticide Drift and Its Impacts, Dick Stiltz

2:45 Break

Second Thursday Afternoon Session

Kevin Steffey Presiding

3:00 p.m. Sensors for Variable Rate Application of Agricultural Chemicals, John Hummel

3:15 Remote Sensing Project, Dennis Bowman

3:30 How Worker Protection Standards Will Affect Commercial Applicators in 1995, Tom Walker

3:45 The Advantages of Becoming a Certified Crops Advisor, Harold Reetz

4:00 Rootworm Problems in First-Year Corn: An Increasing Problem? Eli Levine

4:15 Adjourn

Pesticide Applicator Training for Field Crop and Demonstration and Research Pest Control Categories

Room 314, Illini Union
7:00 p.m. Thursday Evening

Concurrent training sessions for the field crop and research and demonstration pest control categories will be offered.

A person desiring to become certified as an applicator must first take and pass the General Standards examination before taking any of the applicator category examinations. However, there will be no training for the General Standards examination. Manuals and handout material will be available.

Pesticide Applicator Examinations

Room 314, Illini Union
8:00 a.m. - 12:00 noon, Friday, January 6

Written examinations for all commercial pesticide applicator pest control categories will be offered. General Standards examinations will also be available. A person may take as many examinations as he or she can complete during the allotted time. A passing score of 70 percent is required on both the General Standards and category examinations in order to become a certified applicator. Allow about an hour to take each examination. Exams can be started at any time between 8:00 and 11:00 a.m.

Program Participants

Baldwin, John. Field Development Representative, AgrEvo USA Company, Springfield, IL

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Zinck, Dan. Technical Service Representative, American Cyanimid Co., Canton, IL

Commercial Pest Training and Certification Clinics

Commercial Pesticide Applicator Training Clinics will be presented by University of Illinois Cooperative Extension Service personnel from December, 1994 until May, 1995. These training sessions are intended for custom applicators and others who apply pesticides for hire, for their employer, or to public property, and who must be certified before the 1995 season. Farmers and others who apply restricted use pesticides to property that they own or rent need to attend Private Pesticide Applicator Clinics, which will be organized by local extension offices.

Most of the clinics are scheduled for two days. Training for general standards will be given during the first morning; general standards testing will be held that afternoon for operators. Field crop applicators should attend category training, which begins during the afternoon of the first day and concludes during the morning of the second day. Information needed to pass the pesticide tests will be covered; specialists will also discuss new developments to help keep pesticide applicators up-to-date. Applicators may take both the general standards and category tests during the afternoon of the second day. Calculators can be used during the testing sessions.

The Illinois Department of Agriculture certifies and licenses individuals who use pesticides in outdoor environments and in the production of agricultural commodities. In accordance with the Americans with Disabilities Act, any attendee who requires a reasonable accommodation should notify the Illinois Department of Agriculture of their needs at least two weeks prior to any pesticide clinic or testing session. Questions regarding testing, certification, and licensing should be directed to the Illinois Department of Agriculture personnel in Springfield at (217) 785-2427 or Des Plaines at (708) 294-4343.

Schedule of Pesticide Training and Certification Clinics

The following information pertains to clinics in Illinois, excluding those held in northeastern Illinois. There is a $15.00 per clinic registration fee payable by preregistration or at the door. One fee covers both days of two-day clinics. Preregistration and registration may be paid by cash, VISA, MasterCard, or check payable to the **University of Illinois**. State of Illinois vouchers or field orders cannot be accepted as payment. Clinic registration and preregistration fees apply to the cost of training and *do not* cover state license fees.

Space is available on a first come-first served basis. Seating may be limited at some clinics. Call (217) 244-2123 day or night for information on available space at clinics. Send preregistration to: Office of Ag. Entomology, 172 Natural Resources Bldg., 607 E. Peabody Dr., Champaign, IL 61820.

First Day

7:30 a.m. – 8:00 a.m.	Clinic registration
8:00 a.m. – 1:30 p.m.	General Standards training
1:30 p.m. – 4:30 p.m.	General Standards testing only
1:30 p.m. – 4:30 p.m.	Category training begins (as listed below)

Second Day

8:00 a.m. – 12:00 p.m.	Category training continues (as listed below)
1:00 p.m. – 4:30 p.m.	Testing (all categories and General Standards)

Rights-of-way, Grain Facility, and Mosquito category training will be provided during the morning of the second day only, starting at 9:00 a.m. Seed Treatment category training will run from 8:00 to 9:00 a.m. on the second day. Ornamentals category training will be provided during the afternoon of the first day. Turfgrass category training will be offered during the morning of the second day. Field Crops category training will begin during the afternoon of the first day and be completed during the morning of the second day from 9:00 a.m. to noon.

All tests will be available at one-day clinics, as well as on the second day of two-day clinics, not just the tests for the categories covered in the training. Testing will end at 4:30 p.m. Training questions should be directed to Phil Nixon, University of Illinois, Champaign at (217) 333-6650.

DATE	CITY	TRAINING[1]	LOCATION
Dec 1-2	Champaign	G.S., ROW, D&R	Chancellor Inn, Rt. 45 & Kirby Ave.
Dec 7-8	Galesburg	G.S., F.C.	Regency Center, 2 mi. W of I-74 on U.S. 34 (Alpha Exit)
Dec 12-13	Champaign	G.S., F.C.	Chancellor Inn, Rt. 45 & Kirby Ave.
Dec 20-21	Mt. Vernon	G.S., ROW, Seed, Gr., Aq.	Ramada Inn, I-57 & I-64
Jan 11-12	East Peoria	G.S., ROW, Seed, Aq.	Best Western East Light, I-74 & Rt. 116 W
Jan 18-19	Ottawa	G.S., Seed, Gr., F.C.	Pitstick Pavilion, 4 mi. N of I-80 on Rt. 23
Jan 26-27	Springfield	G.S., ROW, Seed, Gr., Mos.	Prairie Capital Conv. Cen., 9th & Jefferson St.
Feb 8-9	Springfield	G.S., T&O	Prairie Capital Conv. Cen., 9th & Jefferson St.
Feb 16-17	Mt. Vernon	G.S., F.C.	Ramada Inn, I-57 & I-64
Feb 21-22	Collinsville	G.S., T&O, ROW, Mos.	Gateway Center, Rt. 157 & I-70
Feb 27-28	Freeport	G.S., T&O, ROW	Highland Comm. Coll. Student/Conf. Center Rm. 201
Mar 8-9	Jacksonville	G.S., F.C.	Holiday Inn, Rt. 104
Mar 15-16	Mt. Vernon	G.S., T&O, Mos.	Ramada Inn, I-57 & I-64
Mar 21-22	East Peoria	G.S., T&O	Best Western East Light, I-74 & Rt. 116 W
Mar 23-24	Champaign	G.S., T&O	Chancellor Inn, Rt. 45 & Kirby Ave.
Apr 4-5	Moline	G.S., T&O, ROW	Holiday Inn, I-74 & Airport Exit (Rt. 6)
Apr 26	Mt. Vernon	G.S.	Ramada Inn, I-57 & I-64
Apr 27	Springfield	G.S.	Coop. Extension Office, State Fairgrounds, (Gate 11)

[1] G.S. = General Standards; F.C. = Field Crops; T&O = Turf and Ornamentals; ROW = Rights-of-Way; Mos. = Mosquito; Aq. = Aquatic Weeds; Gr. = Grain Facility and Private Applicator - Fumigation; D&R = Demonstration and Research; Seed = Seed Treatment. You must already have a Private Applicator's License to take the Private Applicator-Fumigation test.

Northeastern Illinois Pesticide Clinics

A $15.00 per day prepaid registration fee is required at all locations. Refunds and transfers between clinics are not permitted. Registration fees should be sent to the Northern Illinois Horticulture Association, P.O. Box 204, Gurnee, IL 60031, except for the March 2 clinic (call 815/338-3737 to preregister). Clinic registration and/or preregistration fees apply to the cost of training and *do not* cover state license fees.

Due to limited seating at most locations, registration fees must be received by the Friday before the desired clinic date. Send a self-addressed stamped envelope if you wish to receive a confirmation of your registration. Your check will be returned if the clinic that you designate is full. Receipts will be available at the door. For answers to questions concerning these clinics, call (708) 356-5265 from 1:30 to 4:00 p.m. on Mondays and Fridays preceding the clinics.

For two-day clinics, general standards training and testing will be conducted on the first day, and turf, ornamentals, and other category training, as well as testing in all categories, will be conducted on the second day. All tests will be available on May 31. Each clinic begins at 8:00 a.m., with testing from 1:00 to 4:00 p.m. No tests may be started after 3:00 p.m.

DATE	CITY	TRAINING[1]	LOCATION
Feb 7-8	Mundelein	G.S., T&O	Holiday Inn, Rt. 45
Feb 22-23	Matteson	G.S., T&O, ROW, Mos.	Holiday Inn, I-57 & Rt. 30
Mar 2	Crystal Lake	G.S.	Holiday Inn, Rt. 31 S. of Rt. 14. Call 815-338-3737 to preregister
Mar 7-8	Willowbrook	G.S., T&O	Holiday Inn, Rt. 83 & I-55
Mar 14-15	Mundelein	G.S., T&O	Holiday Inn, Rt. 45
Mar 21-22	Glen Ellyn	G.S., T&O	Holiday Inn, Rt. 38 & Finley Rd.
Apr 5-6	Alsip	G.S., T&O	Holiday Inn, I-294 & Cicero Ave.
Apr 11-12	Mundelein	G.S., T&O	Holiday Inn, Rt. 45
Apr 25-26	Elk Grove Village	G.S., T&O	Park District, 1000 Wellington Ave., Exit I-355 at Biesterfield Rd. E
May 31	Glen Ellyn	G.S.	Holiday Inn, Rt. 38 & Finley Rd.

[1] G.S. = General Standards; T&O = Turf and Ornamentals; ROW = Rights-of-Way; Mos. = Mosquito.

Pesticide Applicator Study Materials

General Standards Manual	$ 4.00
General Standards Manual	$5.00
General Standards Workbook	$2.00
Aerial Applicator Manual	$5.00
Aquatic Weed Control	$8.00
Dealer Pest Control (inc. General Standards Manual)	$5.00
Demonstration & Research	$5.00
Field Crops Manual	$8.00
Field Crops Workbook	$2.00
Forest Pest Control	$5.00
Fruit Crops Pest Control	$5.00
Grain Facility Pest Control	$8.00
Livestock Pest Control	$2.00
Livestock Pest Control	$ 3.00
Mosquito Pest Control	$5.00
Ornamentals Manual	$8.00
Plant Management	$2.00
Private Applicator Manual	$5.00
Private Applicator Workbook	$2.00
Rights-of-Way Manual	$8.00
Rights-of-Way Workbook	$2.00
Seed Treatment Manual	$2.00
Soil Fumigation	$2.00
Turfgrass Manual	$8.00
Turf & Ornamentals Workbook	$2.00
Vegetable Pest Control	$5.00

These manuals and study materials may be ordered from: **Agricultural Publications, 69 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801, Ph. 217-333-2007.** Make checks payable to the **University of Illinois**. All prices are subject to change without notice. (Workshops Offered)

Workshops Offered in 1995

Twenty-first Annual Illinois Crop Protection Workshop

Extension specialists and research personnel with the University of Illinois, College of Agriculture, and the Illinois Natural History Survey will offer a Crop Protection Workshop from February 28 to March 1, 1995, at the Chancellor Hotel and Convention Center, Champaign, Illinois. Advance registration is required.

The objectives of the workshop are to give in-depth training in diagnosing pest problems; troubleshooting in the field; and identifying insect, weed, and disease pests, as well as life cycles, thresholds, plant nutrient deficiencies, and other factors that affect crop production decisions.

Specialists in entomology, weed science, agronomy, plant pathology, and agricultural engineering from the University of Illinois, Illinois Natural History Survey, Purdue University, University of Missouri, Iowa State University, and the University of Wisconsin will conduct training sessions on the above topics. Out-of-state speakers will also give general session presentations on subjects of current interest.

The registration fee for the workshop is $95, which includes the cost of the workshop and two lunches, but does not include lodging. Further information about the workshop may be obtained at the registration desk at the Illinois Agricultural Pesticides Conference or from Michael Gray, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820; (217) 333-6651.

Field Crop Pest Management Short Course

A pest management short course for field crops will be offered in 1995. This course is being offered to accommodate persons who will monitor field crops for pest problems. The courses will be taught by extension specialists in weed science, agronomy, entomology, and plant pathology from the University of Illinois and the Illinois Natural History Survey. The short course will be offered twice: March 13-14 and 15-16, 1995.

Further information about the short course may be obtained at the registration desk at the Illinois Agricultural Pesticides Conference or from Aaron Hager, University of Illinois, Department of Agronomy, 1202 South Goodwin, Urbana, IL 61801; (217) 333-4424.

Which Workshop Is For You?

Each year a number of people inquire about the difference between the Crop Protection Workshop and the Pest Management Short Course.

The Crop Protection Workshop is intended for those individuals concerned with current research that affects pest management. Topics presented represent subject matter that will provide the basis for future pest management decisions. Farmers, consultants, agribusiness people, seed industry personnel, and extension educators represent the largest portion of the 300 people in attendance.

The Field Crop Pest Management Short Course is intended for those who wish to learn the what, how, where, and when of field crop scouting. The lab sessions are approximately four hours for each pest management discipline and cover the identification and scouting procedures for weeds, insects, and plant diseases. Farmers and field scouts employed by private consultants comprise the largest segment of the audience. Other participants include those who want a quick refresher course just before the growing season.

Both the Crop Protection Workshop and the Short Course have been approved by the Illinois Certified Crop Adviser Program for issuance of continuing education credits.

If you are still unsure about which workshop to attend, contact Michael Gray, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820; (217) 333-6651.

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GPS for Site-Specific Farming

C.E. Goering, M.D. Cahn, and J.W. Hummel

Although a lengthy presentation would be needed to fully describe the technology known as site-specific farming (or precision farming, variable-rate technology, farming by the foot, etc.), this presentation provides a brief description of the what, why, where, who, when, and weeds concerns of site-specific farming.

WHAT is site-specific farming?

Simply stated, it is matching seed, fertilizer, and other input rates to the inherent productivity of the soil. Lesser rates of seed and fertilizer are applied to less productive soils so that greater rates can be applied to richer soils. Soil productivity can vary within a field for many reasons, including spatial variation of soil texture, slope, depth of topsoil, etc.

WHY is site-specific farming worth considering?

There are both economical and environmental justifications for its use. If seeding and fertilizer application rates are matched to soil productivity, it is possible to produce the same crop yield as with uniform applications, but with savings of seed and fertilizer. When fertilizer rates are closely matched to the inherent productivity of the soil, these fertilizers, especially nitrates, are more likely to be used by the current crop and less likely to escape from the field with runoff water. Also, site-specific farming can automatically produce a record of the amount of fertilizer applied to each part of the field. Such records may become very valuable if future government regulations require farmers to document and/or justify fertilizer use.

WHERE in the field are the least and most productive soils?

Farmers can often locate these areas using personal knowledge, but it is hoped that research will provide a more scientific answer to this question. Ideally, spatially-variable target yields will be predicted from measured soil properties using yet-to-be-developed theoretical relationships. An alternate approach could be to equip the combine for yield mapping and use the maps to indicate spatial variations in soil productivity. Once target yields are established, agronomists are able to calculate the fertilizer amounts needed to produce those yields and fertilizer application maps can be prepared.

There is another part of the **WHERE** question, and that is determining where the applicator is in the field at any time. A number of navigation systems have been tested, but the Global Positioning System (GPS) developed for the U.S. military is the most promising. GPS includes 21 to 25 satellites launched into orbit by the U.S. government. A suitable receiver locked on 4 or more of these satellites can determine latitude, longitude, and altitude. For site-specific farming, only the latitude and longitude are needed. The satellites broadcast two types of signals, the P signal restricted to military use and the C/A signal available for commercial use. To prevent an adversary from using the C/A system, the U.S. government uses **selective availability** to degrade the C/A signal's accuracy to about 100 yards. Such accuracy is completely inadequate for site-specific farming, but suitable accuracy can be achieved by use of Differential GPS (DGPS).

Two GPS receivers are used with DGPS; a **base station** with a known location is used to determine the GPS correction, which is broadcast to the **roving** GPS receiver. Positioning accuracies of 3 to 5 yards are typical using DGPS. The cost of GPS systems has fallen while their accuracy has improved, and manufacturers of some newer DGPS systems claim accuracies within a few inches, although these claims have not been validated.

It may not be necessary for GPS users to install their own base stations. Some commercial organizations have installed networks of base stations and used a side band of commercial radio stations to broadcast the GPS corrections. GPS users can access these corrections for a fee, typically about $600 per year. Use of these corrections saves more than the cost of a GPS base station—it also eliminates the need to purchase an FCC-licensed radio transmitter to transmit the corrections from the GPS base station to the rover.

The DGPS can be used in site-specific farming in several ways. When soil samples are taken, DGPS can pinpoint the location of each sample. When fertilizers are applied using variable-rate spreaders, the DGPS can pinpoint the spreader location on the application map, allowing the application rate to be set on-the-go. A DGPS can also be used on combines equipped for yield mapping. Finally, the DGPS can assist a farmer who wishes to record observations about, for example, weed infestations in a field.

WHO have been and are currently involved in site-specific farming?

The basic idea is not new. In the 1920s, scientists at the University of Illinois Agricultural Experiment Station recommended preparation of maps of pH levels within fields; the maps were used to make spatially-variable applications of lime. Farmers scooping lime out of horse-drawn wagons could easily vary the application rate as indicated by the map. The technique became impractical, however, and fell into disuse when high-speed tractors to pull spreaders became available.

The development of powerful, low-cost personal computers, the DGPS, and electronic controllers has renewed interest in site-specific farming. Ag-Chem[1] and Cenex/Land O'Lakes, through their ownership of Soil Teq, now produce fertilizer application trucks capable of variable-rate applications. In Central Illinois, Illini FS is using these trucks to make variable-rate applications of P and K on more than 150,000 acres. Deere and Company recently formed their Precision Farming Group to plan the development of equipment needed for variable-rate applications. Deere collaborated with Top-Soil Testing Service and Applications Mapping Company, companies that were already involved in soil testing and in developing software for map preparation. The AgLeader Company currently produces a grain flow measurement system for use in yield mapping. Numerous other companies are developing equipment and/or software for site-specific farming. Research teams at several universities, including the University of Illinois, are developing sensors for measuring key soil properties on-the-go. Sensors have already been developed for soil organic matter and soil moisture.

WHEN should farmers consider site-specific farming?

Some caution is advised, because equipment cost and capabilities are changing rapidly, and the profitability of the technology has not been fully demonstrated. The profitability of site-specific farming depends on the extent of within-field variability of soil productivity, because there would be no benefit if a field were completely uniform. Thus, equipping a combine for yield mapping, or custom-hiring such a combine, is a recommended starting point when considering site-specific farming. The yield maps could be used to assess within-field variability. If soil-sampling is done, these samples should be recorded on a grid instead of pooling them for each field. Analysis of these recorded samples provides another assessment of within-field variability. Also, mapping software can be used to convert the analyses of the soil samples into maps. A final consideration is the quality of the fertilizer applicator. The recording capabilities and the typically high-quality controllers developed for variable-rate applicators can improve farm operations and record keeping.

Thus even if fertilizers are not applied using variable rates, an applicator with this capability is recommended, whenever the present applicator is due for replacement.

WEEDS can also be treated site-specifically

One approach under consideration is the use of a special helmet worn by a weed scout. The helmet is coupled to a DGPS so that, as the wearer scans the perimeter of a weed patch, the DGPS signal is automatically recorded. One software manufacturer is building a marking capability into the yield sensor data system. Using this system, the combine operator could mark data for weed infestation and identify the weed species present. The resulting weed maps could then be used to control preemergent herbicide applications the following spring. Work is also underway on sensors that can recognize weeds and control the application of postemergent herbicides. However, at this time, site-specific application of herbicides is not nearly as advanced as site-specific application of fertilizers.

In summary, site-specific farming is an old idea that is being revived by new electronic develop-

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[1] Trade names are used solely for the purpose of providing specific information. Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture or the University of Illinois and does not imply the approval of the named product to the exclusion of other products that may be suitable.

ments. The most important of these is the DGPS, which can accurately determine the positions within a field. Site-specific farming may provide economical and environmental benefits, but more development is needed before the cost/benefit relationship can be fully evaluated. Yield mapping and grid soil sampling are good entry points into site-specific farming, because they assist in assessing variability within a farmer's own fields. Although the current focus of site-specific farming is on fertilizer application, future developments may also assist in applying herbicides only where needed to control weed infestations.

Herbicide Tolerant Crops: A Seed Industry View

Mark E. Winkle

Within the next several years, growers will have several herbicide tolerant options for soybeans, corn, and cotton. Information provided by the manufacturers suggests that herbicide tolerant crops may be available as early as 1996. Therefore, it is critical that the members of the agricultural community consider each technology and how it might either solve existing problems or simply provide a new management tool for controlling a pest. From a seed industry perspective, these are some of the questions regarding herbicide tolerance:

- Will any herbicide tolerant option affect either the growth or yield potential of the crop?
- If a growth or yield effect is observed, is it significant enough to limit effective penetration into the market?
- Can the herbicide tolerant genes be combined into the same germplasm? If so, are there any interactive effects that alter plant growth or yield potential?
- Would the farmer prefer to have a plant with several herbicide tolerant options?
- What are the inventory management issues related to carrying at least two versions of the same crop hybrid/variety?
- Is it necessary for a seed company to include every herbicide tolerant technology in its product line?
- What are the developmental costs and timelines for each tolerant crop?
- How can volunteer plants be controlled during the next growing season?

Soybean Market

Roundup Ready and STS (sulfonylurea tolerant soybean) are the key herbicide tolerant technologies that will be available in the soybean market. Both options provide excellent herbicide tolerance and broad-spectrum annual weed control options. Because they have different modes of action, they offer an excellent opportunity to minimize weed resistance by alternating between the two options every 2 or 3 years. This is particularly true for STS technology because the sulfonylurea and imidazolinone families are both inhibitors of acetolactate synthase (ALS).

Corn Market

The corn market has several technologies that will be available between 1996 and 1999. Currently available are IR (imidazolinone resistant) and IT (imidazolinone tolerant) corn, which provide protection from Pursuit herbicide. Herbicide tolerance options that are being evaluated by both chemical and seed companies are sethoxydim (Poast herbicide by BASF), glufosinate (Ignite herbicide by Hoechst), and glyphosate (Roundup herbicide by Monsanto). At present, the herbicide tolerant genes are providing commercially acceptable tolerance for their specific herbicides. If future research continues to be positive, the corn grower will have several herbicide tolerant corn options for postemergence control of the annual weed spectrum.

The Future Looks Bright

The addition of herbicide tolerant options for both soybeans and corn, along with existing preemergence and postemergence herbicides, will provide several options for growers to use in their weed management programs. The key to successfully introducing new herbicide tolerant genes into the market will involve not only addressing those questions listed earlier but also asking new questions that may not seem obvious at present but are equally important for the correct development of each new technology.

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Herbicide Tolerant Crops: A Herbicide Industry View

Donn K. Schmidt

Herbicide resistant corn, soybeans, sugarbeets, wheat, and cotton are either in development or commercially available. Resistance to herbicides in crops has been developed by one of the following methods: selecting for naturally-occurring variants, inducing variation with a mutagen followed by selection, or genetic engineering. The terms "resistant" and "tolerant" are often used interchangeably; however, resistance is commonly used to indicate a higher level of tolerance to a herbicide.

Interest in the development of herbicide resistant crops is increasing in the agricultural chemical industry. Currently, the time required to develop and register a pesticide is 8 to 10 years, and the estimated cost is 35 to 50 million dollars. On the average, only 1 in 30,000 compounds that are screened actually appear in the market place, and this trend is expected to increase in the future. New products must not only have a broad spectrum of activity, but also must be effective at lower use rates. In an effort to ensure that a pesticide will not present health or environmental concerns, development compounds are subjected to over 120 separate tests. These tests are used to evaluate and assess the effect of these compounds on humans, wildlife, and the environment. The trend toward reduced pesticide load and the desire for lower amounts of active ingredients are predicted to increase.

The new generation of low-use-rate, highly effective, broad-spectrum herbicides fit the profile of products being demanded by the industry. The inherent tolerance of herbicide resistant crops adds a greater margin of crop safety. The use of resistant crops in combination with this new generation of environmentally safe and low-use-rate herbicides provides expanded flexibility for producers weed management programs.

Herbicide resistant crops are being developed by basic herbicide manufacturers and then joint ventures with traditional crop breeders. Examples of herbicide tolerant crops currently under development or already available for Illinois are listed in Table 1.

Introduction and use of these herbicide resistant crops may increase the level of management currently required of producers and pesticide dealers. Because resistant crops do not differ in appearance, the possibility exists for misapplication of a pesticide to non-resistant crops. Herbicide resistant crops may also exhibit differential responses to herbicides within the same chemical family. Additional education and training will be required when using herbicide resistant crop technology. This will require a coordinated effort involving the agrichemical industry and state or local extension personnel to ensure systematic transfer of critical technology to the grower. This challenge is not unique to herbicide resistant crops; rather, it has often been the case when new technology is introduced.

Finally, if the same herbicide could be used alone and always applied in the same manner for a number of consecutive years, a weed species shift or resistance could develop. This is also true when herbicides from a single family or mode of action dominate the choices for weed control programs across crops. American Cyanamid has adopted the following management strategies in an effort to avoid or delay the development of herbicide resistant weeds:

- Always read and follow label recommendations.
- Utilize University recommendations for commercial weed control.
- Practice crop rotation.
- Utilize tank mixes or sequential applications of herbicides that have different modes of action but have overlapping weed spectrums.
- Combine tillage with herbicide treatments where practical.

Resistant crops allow the use of herbicides that offer improved environmental advantages and provide more effective and broader-spectrum weed control with greater margins of crop tolerance than older herbicide technology. Although the use of resistant crops may involve increased management levels, this can be easily provided with proper training, education, and experience.

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TWPoast Plus is a trademark of BASF Corporation
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TWRoundup is a trademark of Monsanto Company
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Table 1. Herbicide tolerant crops under development

CROP	HERBICIDE	MANUFACTURER
Corn	Pursuit	American Cyanamid
	Poast Plus	BASF Corporation
	Buctril	Rhone-Poulenc Ag Company
Soybeans	Roundup	Monsanto Company
	Synchrony	E.I. du Pont de Nemours

Herbicide Tolerant Crops: An Academic View

David M. Simpson and Marshal D. McGlamery

What are Herbicide Resistant Crops?

Crop tolerance to a herbicide allows the herbicide to selectively control weeds while causing minimal injury to the crop. Tolerance of crops to herbicides is a primary constraint on the use of herbicides in crops and is species dependent. For example, corn demonstrates high tolerance to atrazine, 2,4-D, and dicamba, whereas soybean has very low tolerance to these herbicides. Soybean has tolerance to Pursuit, Scepter, and ACCase herbicides, but corn does not. This type of crop tolerance can be referred to as natural herbicide tolerance.

The genetic modification of crops can increase a crop's natural tolerance to a herbicide. Based on the degree to which crop tolerance has been altered, the genetically modified crop is referred to as herbicide tolerant or herbicide resistant. For this discussion, the term *herbicide resistant crop* will be used to refer to any crop for which natural herbicide tolerance has been increased using genetic techniques.

Why the Sudden Interest in Herbicide Resistant Crops?

The development of herbicide resistant crops has been aided by advances in herbicide physiology that have identified which plant biochemical and physiological functions are affected by herbicides. In many cases, scientists have been able to identify the enzyme responsible for the metabolism of the herbicide or the specific enzyme inhibited by a herbicide. Natural crop tolerance is often due to a plant's ability to metabolize the herbicide to non-phytotoxic forms. By studying weeds that have developed resistance to a herbicide, research has demonstrated that changes in the enzyme to which a herbicide binds can alter a plant's tolerance to that herbicide. Atrazine resistant weeds have developed a Q_β protein that is not inhibited by atrazine. Weed resistance to herbicides that inhibit the ALS (acetolactate synthase) enzyme has resulted from the presence of an ALS enzyme that is not inhibited by these herbicides. It has thus been proposed that crop tolerance could be altered by altering herbicide metabolism or the herbicide binding site on the inhibited enzyme.

Advances in genetic techniques have given us the tools by which herbicide tolerance can be altered. As in the case of weeds, there is a potential for finding individual crop plants within a population that have increased tolerance to a herbicide. To date this has not been an efficient means of developing resistant crops because of the large number of plants that must be tested in order to find that one tolerant individual. Seed mutagenesis has been used to cause mutations that may convey herbicide resistance, but it also requires screening of large populations. Tissue culture offers a more efficient method of identifying herbicide resistant plants. In tissue culture, thousands of plant cells can be rapidly tested for resistance to a herbicide. Plants can then be regenerated from these individual cells. This rapid advancement in biotechnology has provided the tools to transfer specific and well-characterized traits across the broadest evolutionary boundaries. Thus the genes responsible for the natural herbicide tolerance in a plant or organism can potentially be transferred to crops with little herbicide tolerance.

Examples of Herbicide Resistant Crops

Although attempts have been made over the years to develop herbicide resistant crops, it is only in the last 5 years that we have seen commercialization of herbicide resistant crops. ICI/Zenaca seed company developed imidazolinone tolerant (IT) corn by identifying an inbred line with high tolerance to Scepter and introducing this trait into commercially acceptable hybrids. Imidazolinone resistant (IR) corn was developed by utilizing cell culture to identify cells resistant to Scepter and then regenerating plants. Sulfonylurea tolerant soybean (STS soybean) was developed by mutating seeds with chemical mutagenic agents and selecting for tolerance to Glean. The sulfonylurea tolerant trait is a semidominant trait that can be transferred easily to commercial lines. Roundup tolerant soybeans were developed by inserting a gene into soybean cells from a bacteria that codes for a glyphosate resistant EPSP enzyme. Soybean plants were regenerated from these resistant cells and the trait was introduced into commercial lines. Roundup tolerant corn was developed by inserting a gene into corn cells from a bacteria that codes for an enzyme that metabolizes Roundup. Classical breeding techniques, cell culture, or genetic engineering have also been used to develop bromoxynil resistant cotton, tomato and tobacco; sulfonylurea tolerant sugarbeets; triazine resistant canola; and sulfonylurea resistant tobacco. Research will be continued to develop resistance to new herbicides and in many more crop species.

Why Develop Herbicide Resistant Crops?

Herbicide resistant crops are being developed for a variety of reasons. It has become more difficult and more costly to develop new herbicides that have crop selectivity, broad-spectrum weed control, and low toxicological traits, as well as being competitive with existing products. Herbicide resistant crops could expand the number of crops in which current products can be used. IT and IR corn will allow Pursuit to be used in both corn and soybean. Roundup resistant soybean and corn will expand the use of Roundup from nonselective preplant applications to selective postemergence applications. Minor and specialty crops that have limited herbicide options would benefit by the introduction of herbicide resistance genes. Herbicide resistant crops could allow the use of herbicides that have lower application rates, shorter persistence in the soil, and more favorable toxicological properties than some current herbicides. Improved crop safety is another reason that herbicide resistant crops are being developed. An example of this is the STS soybean, which eliminates soybean injury caused by Classic and Pinnacle applications. Resistant crops will minimize problems with herbicide carryover for rotational crops. Resistant crops could also be used as a weed resistance management tool if the resistance trait allows the use of a herbicide with a different mode of action than those widely used in the production area. For instance, Roundup tolerant soybean can provide another mode of action in markets dominated by the use of ALS-inhibiting herbicides.

Are There Drawbacks to Using Herbicide Resistant Crops?

As with any new technology, there are potential problems and limitations associated with resistant crops. One such problem is the possible application of a herbicide to fields with a sensitive variety. This could result from the producer or seed distributor mixing bags of herbicide resistant seed with bags of susceptible seed at planting. It could also result from poor communications between the farmer and the custom applicator about which fields have resistant varieties. If these problems occur, there will be questions of liability to be addressed. Preventing such misapplications will require keeping accurate records on the varieties planted and clearly marking the fields that have herbicide resistant varieties.

Herbicide resistant crops may not meet the expectations of the farmer. Herbicide resistant crops do not affect the weed control spectrum of a herbicide. Thus a herbicide's strengths and weaknesses will not be altered. For example, farmers familiar with Roundup's activity on plants from preplant knockdown applications may expect excellent control with a single postemergence application of Roundup. However, the lack of residual activity may require multiple applications to control multiple weed flushes.

Herbicide resistant crops could make control of volunteer crop plants difficult. For instance, volunteer Roundup resistant corn would not be controlled by Roundup in Roundup tolerant soybean. Volunteer sethoxydim tolerant corn would not be controlled in soybean with applications of Poast. Imazethapyr and imazaquin would not control volunteer IR and IT corn in soybean. The potential development of corn varieties with more than one herbicide resistant trait could increase the problem of controlling volunteer corn.

Herbicide resistant crops could increase the potential for the development of herbicide resistant weeds. There is also a high potential for weeds to develop resistance to herbicides that have a single site of action and long soil persistence, especially if multiple applications are used continuously for several years. Most herbicide resistant crops are being developed for herbicides with a single site of action, which may allow the use of these herbicides in all the crops in a rotation. The development of IT and IR corn will allow Pursuit to be used continuously in corn and soybean. This will increase the potential for the development of Pursuit resistant weeds. There are documented cases of weed resistance to Glean, another ALS-inhibiting herbicide, after 5 years of continuous use. Weeds that have developed resistance to a specific herbicide may also be resistant to other herbicides with the same mode of action. This could result in weed resistance to other ALS herbicides used in soybean. Although there have been no reported cases of Roundup resistance during 20 years of use, the intense selection pressure from multiple applications every year might result in the development of Roundup resistant weeds.

How Should Herbicide Resistant Crops Be Used?

Herbicide resistant crops have the potential to significantly alter options for weed control, in both major and minor crops, by expanding the number of herbicides available for use by the farmer. Without the constraints of crop tolerance, the use of herbicides with low application rates, short persistence in the soil, and favorable toxicological properties could potentially be expanded. But like any technology, we must recognize that this technology has limitations and potential problems. Herbicide resistant crops will require increased management to avoid potential problems such as weed resistance and misapplications.

Control of Sod and Weeds for Acres Coming Out of CRP

M.D. McGlamery

Conservation Reserve Program (CRP) contracts will begin to expire in 1995 unless the contract growers take the 1-year permissible extension. CRP, which was established under the 1985 Farm Bill, allowed certain lands to be taken out of production for a 10-year period. The farmer was required to establish a permanent cover on the land. If the land was planted to sod, the farmer was to mow the area by August 15th to maintain weed control.

A renewal of the CRP program is dependent upon the 1995 Farm Bill and will likely be targeted at "environmentally sensitive" lands to minimize erosion or protect aquatic areas. It has been estimated that up to 67 percent of the CRP acreage in the Corn Belt will be returned to crops unless there is another program. Conservation and environmental groups want to retain some of the program acreage for various reasons.

Most of the CRP land in Illinois (see Tables 1 and 2) was planted with grass sods, some of which had a legume component. The legume component has possibly disappeared over the 10 years. Several questions need to be answered before a control program for the sod can be attempted.

What species are present on the land? What is the grass species? This may vary from Kentucky bluegrass, which is relatively easy to control, to orchardgrass or reed canarygrass, which are more difficult to control. Is there still a viable legume component? If so, is it necessary to also control it? Have perennial weeds become established in the area that need to be controlled before returning to crop production?

Most perennials are easier to control in the fall than in the spring because of better translocation of herbicides to the roots as phloem-mobile herbicides move with the food produced in photosynthesis. In early fall, perennials move food into roots to overwinter and produce new vegetation next year. In the spring, food moves up from root reserves to feed new vegetation and herbicides often provide only "top-kill" because of lack of downward translocation. Thus, a fall application of a translocated herbicide such as Roundup, Banvel, Clarity, or 2,4-D provides better control of perennials than a spring application.

It is essential to have "active growth" and adequate plant foliage for herbicide retention and uptake, regardless of when herbicides are applied. Mowing in late summer, 4 to 6 weeks prior to fall herbicide application, will remove old growth and permit 6 to 8 inches of new regrowth. If perennial broadleaf weeds or legumes are also present, fall applications allow higher rates of Banvel or 2,4-D than applications in the spring prior to crop production. Fall application facilitates easier and earlier planting the following spring. Effective spring applications must be delayed until after 6 to 12

Table 1. Acres in Conservation Reserve Program in Illinois

		NUMBER OF COUNTIES WITH (ACRES)	
Signup	Acres	500 to 1,000	> 1,000
1	17,240	5	2
2	27,002	3	10
3	46,773	11	12
4	186,176	20	52
5	53,553	17	14
6	65,095	17	29
7	68,815	26	26
8	81,902	22	29
9	86,910	18	34
10	28,404	9	5
11	79,428	20	25
12	80,852	18	25
Total Acres	821,135		
Total Bids	19,921		
Ave. Size	41.22 Acres		

inches of new growth, thus forcing late planting of corn or soybeans.

Table 2. Illinois counties with high acreages under Conservation Reserve Program

TOTAL ACRES	NUMBER	COUNTIES WITH HIGH TOTAL ACRES
> 30,000	5	Franklin, Hamilton, Jefferson, Pike, Wayne
20 to 30,000	4	Fayette, Jo Davies, Marion, Union
10 to 20,000	18	Numerous
5 to 10,000	29	Numerous
2.5 to 5,000	17	Numerous
2.5 to 1,000	14	Numerous
< 1,000	11	Numerous

Roundup is presently the most cost-effective herbicide for controlling perennial grass sods. The rate needed to control perennial sods varies with the species as well as the time and method of application. Roundup rates are lower if applied alone at lower volumes of water plus nonionic surfactant than when applied with residual herbicide mixtures or at higher volumes. Adding ammonium sulfate may also increase Roundup activity. Rates for fall application are lower than for spring application. If applied in the spring, rates are sometimes lower if corn is planted and atrazine is used as a sequential, residual treatment.

Recommendations for low-volume broadcast application, sometimes called Low Rate Technology (LRT) are: water volumes per acre of 3 to 10 gallons for ground application or 3 to 5 gallons for aerial application and addition of nonionic surfactant of more than 70 percent active ingredient at 0.5 percent by volume (2 quarts per 100 gallons of spray). Ammonium sulfate at 17 pounds per 100 gallons of spray may increase herbicide activity under certain conditions. This should not be mixed with soil residual herbicides or applied in liquid fertilizer carriers at low LRT Roundup rates.

Recommended Roundup rates for control of grass sods vary from 2 to 4 pints per acre. If alfalfa, clover, or dandelions also need to be controlled, it is advisable to add 2,4-D or Banvel to improve control. Several research studies have been conducted on the control of perennial grass and legume species using Gramoxone Extra (paraquat) with and without a triazine herbicide such as AAtrex or Atrazine (atrazine), Bladex (cyanazine), or Extrazine II (3:1 cyanazine:atrazine) when applied in the spring.

Several Midwest weed extension specialists conferred on the effectiveness of the above treatments on several perennial grass species, clover, alfalfa, and dandelions. Table 3 gives the consensus of their "expert" opinions.

Will Assure II, Poast Plus, Fusilade DX, or Select control perennial "bunch type" sod grasses as well as

Table 3. Control of perennial grass and legume sods with Roundup or Gramoxone Extra

	ROUNDUP (QT/A[1])		ROUNDUP				GRAMOXONE[2]	
	Applied during		Fall Applied		Spring Applied		Spring Applied	
Sod Species	Fall	Spring	1qt/A	2qt/A	1qt/A	2qt/A	alone	+triazine
Timothy	1.0	2.0	9	10	7	8[3]	5	8[3]
Bluegrass	1.0	1.5	9	10	8	9	7	9
Fall fescue	1.0	2.0[4]	7	8	6	7	5	7+
Quackgrass	1.5	2.0	9+	10	8+	10	5	7
Orchardgrass	1.5	2.0[4]	7	8	5	6	3	7
Smooth brome	1.5	2-3[4]	8	10	6	8	5	7
Rye or wheat	—	0.5-1	—	—	10	10	7	8+
Red clover	2.0	2.0	6	8	5	7	7	8+
+ 1/0 pt 2,4-D	1.5	2.0	9	10	8	9	8	9
+ 0.5 pt Banvel	1.0	1.0	10	10	9	10	8	9
Alfalfa	2.0	2.0	6	8	4	6	3	4
+ 1.0 pt 2,4-D	1.5	1.5	8	9	7	8	7	8
+ 0.5 pt Banvel	1.0	1.0	9	10	8	9	8	9
Dandelion	2.0	2.0	8	9	5	7	4	7
+ 1.0 pt 2,4-D	1.0	1.0	9	10	9	9	8	8

[1] Roundup LRT = 3 - 10 gal/A water + 0.5% NIS. Can add AMS @ 17 lb/100 gallon

[2] Gramoxone + triazine = Gramoxone Extra + atrazine (preferred), Bladex or Extrazine II Rate/A: 2-3 pints Gramoxone plus triazine rate allowed for the soil.

[3] 10 = Excellent, 9 = Very Good, 8 = Good, 7 = Fair, 6 = Poor, 5 = Unacceptable

[4] Possibly can reduce spring Roundup rate if corn is planted and atrazine is used as a sequential treatment.

they control rhizomatous perennials such as quackgrass, johnsongrass, and wirestem muhly? Studies conducted on "young" (less than one or two years old) perennial forage sods indicate that grass species vary in their susceptibility, with Kentucky bluegrass being the most susceptible and reed canarygrass the least susceptible, but the herbicides also vary in their control, with Assure II and Fusilade DX in general providing the best control.

If the land is not highly erodible, it may be permissible to use tillage to kill the sod. This is reminiscent of the meadow-corn rotation of the past. Fall tillage to "break the sod" followed by spring tillage to prepare a seedbed and control seedlings is critical. No matter how the sod is controlled, it will be necessary to have a residual or postemergence herbicide program planned to control seedlings and weeds that emerge following planting. The major decision is how to control the sod cover.

String Techniques for Evaluation of Spray Patterns

Dennis R. Gardisser

The string collection system was developed at Oklahoma State University in the early 1980s. This system can determine the deposition of sprays from dynamic applications in real world situations. Because of its flexibility and ease of use, this collection system can be used in a variety of ways, including spray pattern measurement (from both ground and aerial applications), field deposition, canopy penetration (from typical field crops, forestry, orchards, and vineyards), and drift measurement. The string collector is a 1 mm diameter 100 percent cotton string. Because the tracer is a fluorescent dye, and bleaches have fluorescent capability, the string must be special-ordered, specifying that no bleaches be used in weaving it. Manufacturers will accept only quantity orders because in addition to not using any bleach, they must clean their equipment from previous manufacturing runs to be sure that no bleach spots can be picked up at random on the string. The tracer used for analysis is usually a Rhodamine dye mix with approximately 200 ppm of dye in the carrier.

The string is analyzed by feeding the sprayed portions through a Turner fluorometer equipped with a specially designed chamber that has a mirror and optic system to enhance feedback of how much fluorescence has been deposited at each location along the string. The fluorometer is connected to a computer to provide easy control and data storage. The accompanying software has been written to record the pertinent identifying data, parameters of the test, and string measurements. This data can be quickly printed and used as a record of the test and a guide for improvement.

Pattern Measurement

The string system is most often used to determine pattern characteristics from either an aircraft or a ground sprayer. The sprayer is operated over the string at a 90° angle. The sprayer is generally operated directly into the wind to avoid distortions caused by crosswind. Patterns may also be taken with intentional crosswinds to determine the wind effect. The ground sprayer or aircraft is operated over the string in the normal fashion: speed, height, pressure, etc. similar to what would be expected during normal spray operations. After each pass over the system, the string is wound onto a spool. As one string test is being wound up, new string is pulled out of a tensioning device in preparation for the next analysis run. Usually three repetitions are done for each scenario to confirm the pattern shape.

The string analysis provides information about where nozzles should be placed on aircraft to obtain a uniform pattern shape. Ground operated spray units may also exhibit aerodynamic problems, requiring nozzle setup to be different from what might be expected. Pattern analyses also help to determine the optimum swath width for a particular spray operation. The use of a computer with this system allows the analyst to pictorially show the uniformity across a field using a multiple pass simulation.

Field Deposition

The field deposition program uses the same analysis system, but has a software package that will accept a long string. Usually a string is stretched out over 5 to 10 swaths across a typical field application area. Fluorescent dye is added to the spray mixture and the application is made in the normal fashion. The actual wind direction and intensity are recorded to assist the analysis. Generally pattern analysis is done into the wind, but this technique allows the operator to see exactly how uniform his application might be all the way across a field.

Canopy Penetration

The canopy penetration is done with strings (as many as 5 layers deep) placed at different levels in the plant canopy. With many applications, it is desirable to hit a specific portion of the plant, and this may be documented using this technique. This technique has been used extensively in forestry and orchard applications. With orchard spraying, the string can be placed at different locations within the tree canopy and evaluations made to see how completely the whole tree is being covered.

Drift Measurement

The string technique has been used as a quick way to determine the presence of drift downstream. The string is usually held vertical by some sort of tower and at some distance downstream from the application swath. Several towers may be used at different locations downstream to quantify how far the material is moving. Typically the drift towers are equipped with a tensioning and wind-up unit at the bottom of the tower and a set of pulleys on the top. With this arrangement, exposed string can be quickly wound up and several tests conducted while the weather conditions remain constant. This allows operators to compare nozzle types, application speeds and heights, effect of drift control agent, and other application parameters.

Conclusion

The string spray collection system allows the quick measurement of deposition under a variety of actual field conditions. The actual number of ways that it may be used is limited only by the analyst's imagination.

Spray Modifiers

John D. Nalewaja

Adjuvants for Herbicides

Postemergence herbicide effectiveness is dependent upon spray droplet retention and herbicide absorption by weed foliage. Adjuvants and spray quality influence postemergence herbicide efficacy. Adjuvants generally are not important for preemergence herbicide efficacy because retention and absorption by foliage are not important. The recent increased availability of postemergence herbicides for weed control in corn and soybean has increased the interest in adjuvants.

Spray additives consist of oils, surfactants, and fertilizers. The most effective additive varies with different herbicides and the need for an additive varies with environment, weeds present, and herbicide. Additives should be used only when indicated on the herbicide label because they may increase injury to crops or reduce weed control.

Oils generally are used at 1 percent v/v (1 gal/100 gal of spray solution) or at 1 to 2 pt/A, depending upon herbicide and oil. Oil additives increase herbicide absorption and spray retention. Oil adjuvants are petroleum, vegetable, or methylated vegetable oils, plus an emulsifier for dispersion in water spray carriers. The emulsifier, the oil class (petroleum, vegetable, etc.), and the specific type of oil in a class all influence effectiveness of a given oil adjuvant. Methylated vegetable oils have been especially effective with Poast and Accent, but generally are equal to or better than the other oil classes with all herbicides. However, Cobra is more effective when applied with petroleum oil than with methylated vegetable oil. Vegetable oils usually are equal to petroleum oils, except that they are less effective with Assure. The above comparison may differ depending upon the specific adjuvant product.

Surfactants are used at 0.12 to 0.5 percent v/v (1 to 4 pt/100 gal of spray solution). Surfactant rate depends upon the amount of active ingredient in the surfactant and other factors such as species and herbicides. The main function of a surfactant is to increase the plant spray retention, but surfactants also assist in herbicide absorption. When a range of surfactant rates is given, the high rate is for use with low rates of the herbicide, drought stress, tolerant weeds, or when the surfactant contains a low percentage (less than 50 percent) active ingredient. Surfactants vary widely in their chemical composition and in their effect on spray retention and herbicide absorption. Effectiveness of a given surfactant will also depend upon the herbicide and its formulation. Information on surfactant effectiveness with a herbicide requires field testing and cannot be predicted from surface tension or droplet spread on a wax surface.

Fertilizers containing ammonium nitrogen have increased the effectiveness of barban, acifluorfen, glyphosate, bentazon, nicosulfuron, imazethapyr, and sethoxydim. Fertilizer applied with herbicides may reduce weed control or cause crop injury. Fertilizers should be used with herbicides only as indicated on the label or where experience has proven acceptability.

Ammonium sulfate at 17 lb per 100 gal spray volume (2 percent) has enhanced weed control with glyphosate. Enhancement of glyphosate is most pronounced when spray water contains relatively large quantities of certain ions, such as calcium, sodium, and magnesium. Ammonium sulfate may contain contaminants that do not dissolve and then may plug nozzles. Ammonium sulfate should be dissolved in a small amount of water and filtered to prevent nozzle plugging. Commercial solutions of ammonium sulfate are available. Ammonium sulfate at 2 percent is adequate to overcome severe salt antagonism. Ammonium sulfate at 0.5 percent has adequately overcome antagonism of glyphosate from 300 ppm calcium. Ammonium ions also are involved in herbicide absorption and have enhanced phytotoxicity of many herbicides in the absence of salts in the spray carrier. The enhancement of herbicides by nitrogen compounds appears most pronounced with certain species such as velvetleaf and sunflower.

Ammonium sulfate enhances phytotoxicity and overcomes antagonism from salts of sethoxydim, glyphosate, and 2,4-D amine. The 28 percent nitrogen is effective for enhancing weed control from many postemergence herbicides and overcoming sodium but not calcium antagonism of glyphosate. Sodium bicarbonate antagonism of sethoxydim is overcome by 28 percent nitrogen, ammonium nitrate, or ammonium sulfate.

Ammonium sulfate or 28 percent nitrogen does not preclude the need for a surfactant. Many adjuvants are available to enhance herbicide action, but information on their effectiveness is limited. The precise salt concentration in water that causes a visible loss in weed control is difficult to establish because weed control is influenced by many other factors as well. Thus comparisons of adjuvants should be made using marginal control levels to determine the effectiveness of adjuvants for specific herbicides, sprays, water, and weeds. Effective adjuvants may allow use of herbicides at reduced rates or provide more consistent results with adverse conditions. However, use of rates less than the label recommendation exempts herbicide manufacturers from liability for nonperformance.

Spray Carrier Water Quality

Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Clay inactivates paraquat and glyphosate, organic matter inactivates many herbicides, and minerals of various types can inactivate 2,4-D amine, MCPA amine, Poast (sethoxydim), glyphosate, and Banvel (dicamba).

In many parts of the United States, water is high in sodium bicarbonate, which reduces the effectiveness of 2,4-D and MCPA amines (not esters), sethoxydim, glyphosate, and dicamba. Water samples with 1600 ppm sodium bicarbonate have been observed, but antagonism of the above herbicides was noticeable at or above 300 ppm. The antagonism is related to the salt concentration. At low salt levels, loss in weed control may not be noticeable under normal environmental conditions. However, the antagonism from low salt levels will cause inadequate weed control when weed control is marginal because of drought or partially susceptible weeds.

High salt levels in spray water can reduce weed control in nearly all situations. Calcium and, to a lesser degree, magnesium are antagonistic to 2,4-D and MCPA amine, dicamba, and glyphosate. Calcium antagonism may become noticeable at 150 ppm. Sulfate ions in the solution can reduce the antagonism from calcium and magnesium, but the sulfate concentration must be three times the calcium concentration to overcome antagonism. The sulfate that occurs naturally in water can be disregarded. The amount of ammonium sulfate needed to overcome antagonistic ions can be determined as follows: ammonium sulfate (pounds per 100 gallons) = 0.005 sodium [ppm] + 0.002 potassium [ppm] + 0.009 calcium [ppm] + 0.014 magnesium [ppm].

An analysis of spray water sources will provide a guide for determining possible effects on herbicide efficacy. Ammonium sulfate, at 2 percent as indicated on many labels (17 lb/100 gallons spray), will overcome the antagonism from the highest calcium and/or sodium concentrations in North Dakota waters for glyphosate, sethoxydim, 2,4-D amine, MCPA amine, and dicamba. However, ammonium sulfate at 1 percent is adequate for most North Dakota waters. Iron also is antagonistic to many herbicides, but usually is not abundant in North Dakota water.

Water often contains a combination of sodium, calcium, and magnesium, and these cations generally are additive in the antagonism of herbicides. Many adjuvants are marketed to modify spray water pH, but low pH does not appear essential to the action of most herbicides. Ammonium sulfate, granular or liquid, and 28 percent liquid nitrogen fertilizer help overcome antagonistic salts in spray carrier water. The 28 percent nitrogen fertilizer overcomes mineral antagonism of most herbicides, but not glyphosate. Research results with amounts of 28 percent nitrogen fertilizer are limited, but 4 gallons/100 gallons of spray has generally been adequate. The ammonium sulfate and 28 percent nitrogen adjuvants have enhanced herbicide control of certain weeds, even in water without salts. This is especially true for glyphosate, sulfonylureas (Harmony Extra, Express, Ally, Pinnacle), Blazer (acifluorfen), and bentazon. However, ammonium sulfate, 28 percent nitrogen, or other adjuvants should be used with caution because their benefit often is limited to specific herbicides or weeds and they may be antagonistic to other herbicides or weeds.

Illinois Generic State Management Plan for Pesticides in Groundwater

W. D. Goetsch

Introduction

The purpose of the "Illinois Generic State Management Plan for Pesticides in Groundwater" is to describe the framework in which the State of Illinois intends to address risks of groundwater contamination by pesticide chemicals, in response to the U.S. Environmental Protection Agency's (USEPA) *Pesticides and Groundwater Strategy*. The USEPA's strategy, which was under development for several years, became final in 1991. The adopted approach is one of continued nationwide regulation of pesticide use and disposal, augmented by strong state roles in the local management of pesticide use to protect groundwater. This state participation is to come from the development of individual state management plans (SMPs), which consider local variations in use and vulnerability.

The incentive for states to prepare these plans comes from the federal pesticide registration process. The future use of registered pesticides that have been identified by the USEPA as hazardous to groundwater will depend on the presence and adequacy of a state's management plan. In some situations, the USEPA may require a state-specific label or supplemental labeling with SMP-prescribed, pesticide management measures. In other cases, the USEPA may need to take steps, including statewide cancellations, to control the use of a pesticide that poses a significant groundwater threat, if there is no adequate SMP in place to prevent or reduce the threat of unacceptable contamination. The possibility of special state management measures in lieu of USEPA cancellation has thus been the driving force behind the plan's development.

In the *Pesticides and Groundwater Strategy*, the USEPA mandated that states assume a major role in determining whether the use of a pesticide compound presents a hazard to groundwater, and that they should also have the flexibility to design protection programs that will be specifically effective in protecting this resource. The State of Illinois is in the process of developing a generic state management plan for pesticides in groundwater. The components included in this generic program should be viewed as principles or concepts to be incorporated in compound-specific SMPs as they are required in future years. Also, this plan provides guidance about preventative measures that, if followed, may allow Illinois to address possible groundwater problems associated with pesticides even before the USEPA determines that a compound-specific plan is warranted.

The Illinois Generic SMP Development Process

The draft of the Illinois generic state management plan is being developed by a pesticide subcommittee of the Interagency Coordinating Committee on Groundwater (ICCG). The pesticide subcommittee of the ICCG is currently made up of the following members of both state and federal agencies:

- Illinois Department of Agriculture, chair
- Illinois Environmental Protection Agency
- Illinois Department of Energy & Natural Resources
  - Illinois State Water Survey
  - Illinois State Geological Survey
  - Illinois State Natural History Survey
- Illinois Department of Public Health
- United States Department of Agriculture University of Illinois Cooperative Extension Service
- Soil Conservation Service

A draft of this generic SMP was released for public comment in late May, 1994. The Illinois Department of Agriculture, as the chair of the subcommittee, received comments about the draft from 78 individuals and organizations through August 1, 1994. The subcommittee is currently reviewing these comments and considering adjustments to the draft where possible. A preliminary review of the comments suggested that the initial draft: 1) included too heavy a regulatory tone, 2) needed a stronger voluntary component, 3) should include a much stronger role for the agrichemical industry, 4) should include a stronger monitoring component, and 5) should be modified by limiting the use of sensitivity scores to assessment, planning, and education, not regulation. The second draft of this generic plan should be completed before the end of the calendar year. The USEPA has suggested that it will publish (by May 1995, in the Federal Register) a proposed rule that will identify the pesticides for which a compound-specific management plan will be required. Based on that publication date, the following is a projected timeline:

February, 1996—Final rule published and becomes effective

May, 1996—States required to notify USEPA of intent to develop compound-specific SMPs

February, 1997—States required to develop compound-specific SMPs and submit them to USEPA for review

August, 1997—USEPA reviews and approves SMPs

December, 1997—States implement SMPs

Conclusion

The components currently being considered for inclusion in the generic state management plan are not all inclusive and may require adjustment or refinement over time, depending upon the specific compound under study. They are based on the premise that the people of the State of Illinois are willing to support the development, implementation, and enforcement of compound-specific state management plans that may limit the use of certain compounds to certain areas of the state in order to prevent or reduce groundwater contamination. The components are based on compromises between an ideal basis for assessment and planning and what is practical using available resources. It is understood that possible use limitations resulting from a compound-specific management plan may potentially place some areas of the state at a competitive disadvantage. However, in the long term, the potential economic implications resulting from unchecked groundwater contamination in areas particularly sensitive to it will place the entire state at an even more severe economic disadvantage for generations to come.

Township Ratings of Susceptibility: What Do These Ratings Mean?

Donald A. Keefer

Introduction

In their Pesticides and Groundwater Strategy, the U.S. Environmental Protection Agency (USEPA) encourages the state-level development of management plans to address the presence of pesticides in groundwater. With this strategy each state would have the responsibility to develop a groundwater protection program that addresses its specific pesticide-use and groundwater-resource needs. In Illinois, the Illinois Department of Agriculture (IDOA) is the state liaison agency for the development and implementation of compound-specific management plans. The IDOA is working with the Illinois Environmental Protection Agency (IEPA) and the Pesticide Subcommittee to the Interagency Coordinating Committee on Groundwater in this effort. Together, these agencies have created a generic management plan for pesticides in groundwater in Illinois—a plan that provides the components and general framework that are expected to be included in future compound-specific management plans (IDOA 1994). To effectively meet the goal of statewide groundwater protection from contamination by pesticides, the generic management plan was designed, in part, around a statewide map of aquifer sensitivity to contamination from pesticides. This map will be used for predicting both water quality in shallow aquifers and the sensitivity of aquifers to contamination from pesticide leaching. If this map is not useful as a water-quality predictor, the overall effectiveness of the management plan will be limited. Accordingly, the intended application of the map demanded that it not seriously underpredict pesticide leaching potential for the various soil/aquifer settings found in Illinois.

The generic plan recognizes that pesticide regulation would ideally be applied to individual farm fields. Evaluation at this level of detail would minimize the under-regulation or over-regulation of pesticide use. Limitations in resources, however, require the use of some larger land area as a basic regulatory unit. The initial draft of the generic plan called for the use of townships as the basic regulatory units in Illinois (IDOA 1994). A township, as defined by the Public Land Survey System, is an approximately 36 square mile area of land. (Townships are delineated on U.S. Geological Survey topographic maps at a 1:24,000 scale, and on many other maps at a larger scale.)

The statewide evaluation and scoring of townships was made using the map entitled "Aquifer Sensitivity to Contamination from Pesticide Leaching" (Keefer, in review). The map was developed by the Illinois State Geological Survey (ISGS), under contract with IDOA, for use with the state management plan. It was intended to be used as a tool for predicting shallow-aquifer water quality with respect to pesticides. This paper describes the philosophy used to generate the aquifer sensitivity map, and the use of this map in the state management plan for predicting aquifer water quality at state- and township-scale land areas. A detailed discussion of the method used to develop this map is presented in Appendix B of the generic plan (IDOA 1994).

Background

In 1991, a statewide evaluation of aquifer sensitivity to contamination from agricultural chemicals was conducted for Illinois (McKenna and Keefer 1991). This evaluation attempted to predict water quality on the basis of the geologic setting of land areas. The map developed by McKenna and Keefer (1991), entitled "Potential for Agricultural Chemical Contamination of Aquifers in Illinois," classified geologic setting into four groups, using only information on the upper 50 feet of geologic deposits. These four groups were defined as: aquifer materials within 5 feet of land surface, aquifer materials between 5 and 20 feet of land surface, aquifer materials between 20 and 50 feet of land surface, and no aquifer materials within 50 feet of land surface. These groups were ranked in terms of their interpreted sensitivity to contamination. At that time no suitable information was available for the statewide distribution of soil characteristics relevant to pesticide leaching.

Following the publication of this map, a sampling study of rural, private water supply wells was conducted (Schock et al. 1992). One of the main goals of this sampling study was to determine whether these four aquifer sensitivity map units were valid predictors of aquifer water quality. The results from this sampling study suggested that depth to uppermost aquifer could be used to help predict shallow-aquifer water quality. However, a statistical analysis of the data supported the delineation of only three of the four originally defined depth-to-aquifer units. In ranked order, these three units were: aquifer material within 20 feet of land surface, aquifer material between 20 and 50 feet of land surface, and no aquifer material within 50 feet of land surface.

Since the publication of the aquifer sensitivity map (McKenna and Keefer 1991), the U.S. Soil Conservation Service (SCS) released a computerized map and database of Illinois soil associations (SCS 1991). This statewide map was compiled from the 102 individual county soil-association maps that were produced for county-level, detailed soil surveys. Existing inconsistencies in association definitions, and discrepancies in map-unit boundaries across county borders were resolved in the process of compiling the Illinois map. The information in the corresponding database included many important parameters for predicting pesticide movement through the soil.

Method Selection

A review of available data found that the SCS soils data, depth-to-aquifer data, and findings of Schock et al. (1992) were the only suitable resources available for this new map. Next, a method was needed for combining these data to assist in predicting shallow-aquifer water quality with respect to pesticides. Three different approaches were considered for this project: 1) computerized solute transport modeling, 2) interpretive hydrogeologic mapping, and 3) the combination of solute transport model results with mapped information for recommending best management practices at the farm level.

Computer Solute Transport Models

Computer models of pesticide fate and transport generally evaluate pesticide movement at the field scale using detailed information on soil and pesticide characteristics. All but a few of these models assume that the soil is a non-fractured material with known, or assumed, pesticide transport characteristics. Unfortunately, most soils in Illinois are heavily fractured and, like other soils, exhibit a generally unknown variability in their pesticide transport characteristics. These differences between the model equations and actual soil conditions usually result in transport models underpredicting the depth of pesticide movement. These models also tend to predict a more simplified distribution of pesticides throughout the subsurface environment. Another major limitation to using transport models in a state management plan is that they are unable to predict pesticide movement on a statewide scale.

Recently, a few models have been written that begin to address the transport of pesticides through preferential flow paths (macropores). These models are still in the early development stage, but show promise of providing some predictive ability for this complicated transport problem.

Interpretive Hydrogeologic Mapping

Interpretive hydrogeologic mapping involves the combining and re-interpretation of maps of soils, geologic deposits, land use, etc., to produce land suitability maps for various purposes. Interpretive maps can be custom designed around anticipated uses of the final map and the relevant data layers that are available. They are generally not constrained to follow a given mathematical equation. Interpretive maps can even be designed to address complicated scenarios, such as pesticide movement through Illinois soils, which mathematical equations currently cannot.

This method also has several limitations. Interpretive maps must be developed by someone who is familiar with the processes to be modeled, the accuracy limitations of each data layer, and the restrictions that each combination technique possesses. The scale of the source maps limits the appropriate scale of the final interpretive maps. Final maps may be generated at any scale equal to or smaller (more generalized) than the source data. Lastly, the accuracy of each source map must be carried through to the final product(s).

Hybrid Modeling Approach

The SCS has used a hybrid approach to addressing pesticide transport. They have combined statistical descriptions of transport-model output with the flexibility and accuracy of site-specific soil surveys and geologic maps to produce a tool for recommending best management practices for individual farm fields. The use of site-specific information improves on the scale-dependent generalizations inherent in statewide interpretive mapping of aquifer sensitivity.

Unfortunately, this method is still limited in that it relies heavily on transport predictions from equations that cannot account for either the nature of soil properties found in Illinois soils, or the impact of these properties on pesticide transport.

When transport modeling improves to the extent that the preferential and non-preferential movement of pesticides at a farm-field level can be predicted with a useful degree of accuracy, this hybrid approach may become the most useful one in any pesticide management plan. Until then, the limitations of this method are likely to result in consistent underpredictions of pesticide movement.

In selecting a method for predicting aquifer sensitivity to contamination from pesticide leaching, the advantages of interpretive mapping were found to outweigh the advantages of transport models. In addition, the predictive limitations caused by insufficient transport equations eliminated the consideration of a hybrid (interpretive mapping/transport modeling) approach. Interpretive mapping was found to allow for a statewide screening of aquifer sensitivity, while providing a method that can be applied to more detailed, farm-level data. In addition, interpretive mapping is, at this time, the only method that can be used to easily update aquifer sensitivity predictions based on new data from monitoring-well samples. This ensures that the predictive uses of the map will not suffer from permanent underpredictions of pesticide contamination of groundwater—a result that would make reliable regulation impossible.

Map Generation

The interpretive map was generated in two steps: 1) generation of an interpretive map ranking the predicted pesticide leaching behavior of soil associations, and 2) the combination of this soil-pesticide leaching map with a depth-to-aquifer map to generate a map of predicted aquifer sensitivity.

Mapping the Soil-Pesticide Leaching Index

Pesticide movement through soils is affected by many soil, atmospheric, and agronomic factors, including: the amount of organic matter in each soil layer, the hydraulic conductivity (also called permeability) of each soil layer, the hydraulic gradient (difference in water pressure between two points) in a soil, the matrix porosity of the soil, the amount and nature of macropores throughout the soil, the rainfall rate, air temperature, wind speed, crop grown, tillage practices, type and quantity of pesticide applied, method of pesticide application, etc. Generally, only a small number of these factors can be considered in any pesticide transport modeling effort. The present map can use only the soil factors that contribute to pesticide movement. The non-soil factors (i.e., atmospheric and agronomic factors) either have a non-predictable impact on pesticide movement, or no suitable source of information exists that allows incorporation into the interpretive mapping model.

Although all of the listed soil factors are involved in pesticide transport, three of these factors are very important in predicting the movement of water and pesticides through a soil profile: hydraulic conductivity, hydraulic gradient, and percent organic matter. The SCS soil-association database contains information on the hydraulic conductivity (of the soil matrix and macroporosity combined) and organic matter for each soil layer. Information on the hydraulic gradient in a soil is used to help evaluate the amount of water moving through the soil. However, values for hydraulic gradient are not mappable, because this property is very dynamic over time.

Given that data on hydraulic gradient are not available, another soil parameter was found that is useful in estimating the relative amount of water movement through a soil profile—drainage class. A drainage class rating is assigned to each soil based on the presence and depth of reduced iron staining. Drainage class is generally considered to be a relative measure of the duration and depth to which the soil is saturated or nearly saturated. If a soil is excessively well drained, this implies that the soil profile is very rarely saturated or nearly saturated. If a soil is very poorly drained, this implies that the soil is saturated or nearly saturated within the upper soil horizon for a significant amount of time. For this map, this notion of drainage class was extended to infer that any excessively well drained soil was likely to have a larger quantity of water move through its profile than was a very poorly drained profile, excluding the presence of any artificial drainage systems.

Following this assumption, drainage class, hydraulic conductivity, and percent organic matter were selected as the main discriminating criteria for the interpretive mapping. Information on the percent organic matter and hydraulic conductivity were provided for each horizon in a soil profile, whereas soil drainage class was assigned to an entire profile. To make the use of these data easier and less prone to interpretive error, a measurement index was created for each factor. For example, the hydraulic conductivity of each soil horizon was combined with the corresponding horizon thickness to derive a "Travel Time Index." This index was used as a relative measure of the time it would take water to move through the entire soil profile. An Organic Matter Index and Drainage Class Index were also created (Table 1). Following the assignment of these three

Table 1. Assignment of initial soil-pesticide leaching index

SOIL-PESTICIDE LEACHING INDEX	TRAVEL-TIME INDEX	DRAINAGE CLASS INDEX	SOIL ORGANIC MATTER INDEX
Excessive	Very Fast or Fast	Excessive	Very Low
Somewhat Excessive	Very Fast or Fast	Excessive	Moderate or Low
	Very Fast or Fast	Well	Very Low
	Moderate	Excessive	Very Low
High	Very Fast or Fast	Well or Moderate	Moderate or Low
	Moderate	Excessive or Well	Moderate or Low
	Moderate	Moderate or Poor	Very Low
Moderate	Very Fast or Fast	Excessive or Well	High
	Very Fast or Fast	Very Poor	Very Low
	Moderate	Moderate to Poor	Low
	Slow or Very Slow	Excessive to Moderate	Very Low
Somewhat Limited	Very Fast or Fast	Moderate	High
	Very Fast or Fast	Moderate or Poor	Moderate
	Very Fast or Fast	Poor	Low
	Moderate	Excessive or well	High
	Moderate	Excessive or Well	Moderate
	Slow or Very Slow	Moderate or Poor	Low
	Slow or Very Slow	Excessive to Moderate	Very Low
Limited	Very Fast or Fast	Poor	High or Moderate
	Moderate	Moderate or Poor	High
	Slow or Very Slow	Excessive to Moderate	High or Moderate
	Slow or Very Slow	Poor or Very Poor	Low
Very Limited	Very Fast to Very Slow	Excessive to Very Poor	Very High
	Very Fast to Moderate	Very Poor	High to Very Low
	Slow or Very Slow	Poor or Very Poor	High or Moderate

component indices, an initial Soil-Pesticide Leaching Index was assigned (Table 1).

While assigning this index, it was recognized that tile-drained soils should be considered. In a tile-drained soil, much of the shallow groundwater is removed by the tile. Accordingly, the potential for these soils to allow pesticides to leach to depth is significantly reduced. Soils listed as having a drainage class of somewhat poorly to very poorly drained, with travel time index values of moderate to excessive, were assumed to be suitable for subsurface drainage tile installation. It was further assumed that any of these "drainable" soils were probably already tile drained to some degree.

The final Soil-Pesticide Leaching Index was determined by incorporating information from two additional soil factors into the initial Index. These factors were: 1) presence of a thin soil profile, and 2) presence of slopes greater than 15 percent. It was determined that, if present, either of these two factors would lead to a reduction in the leaching characteristics of a soil. A thin soil profile was characterized by soils classified as Entisols or Inceptisols. The thinner solum, common to these soils, was viewed as restricting the depth of pesticide transport through soil macropores. This was then assumed to reduce the risk of pesticide contamination of deeper groundwater. The presence of slopes greater than 15 percent was viewed as contributing to increased runoff, and correspondingly reduced infiltration. A reduction in infiltration was then viewed as a reduced potential for leaching, due to a reduction in water flux. If either one of these factors were present for a soil, the initial Soil-Pesticide Index was reduced by one level. This adjustment was made only once for each soil, so an Entisol on a slope of 25 percent would be adjusted down only one level from the assigned initial leaching index.

Mapping Aquifer Sensitivity to Contamination From Pesticide Leaching

The map entitled "Aquifer Sensitivity to Contamination from Pesticide Leaching" was generated by combining the map entitled "Soil-Pesticide Leaching Index for Illinois" with a map illustrating the depth to the uppermost aquifer. The depth-to-uppermost-aquifer map was generated from a statewide map of geologic deposits within 50 feet of land surface (Berg and Kempton 1988) and was divided into the three depth units indicated as relevant by Schock et al. (1992) (i.e., within 20 feet of land surface, between 20 and 50 feet of land surface, and not within 50 feet of land surface). The data from the two source maps were combined according to the method described in Table 2. This method was intended to produce a map that combined information on soil leaching characteristics and observed aquifer sensitivities, to provide an improved prediction of aquifer sensitivity to contamination. This final map resulted in five map units, each of which represents a distinct soil and aquifer setting.

Interpretation and Uses of the Aquifer Sensitivity Map

Interpretations and Validations

The aquifer sensitivity map is a map of soil-geologic settings, which have been grouped and ranked according to their predicted tendency to allow pesticide movement to the uppermost mapped aquifer. Several considerations must be understood to correctly interpret and use this map. First, the source maps used (i.e., soil-association map and depth-to-aquifer map) are statewide maps, whose map units are generalizations of known conditions. Generalizations not withstanding, these maps provide very useful information about the distribution of soils and geologic deposits throughout the state. In addition, these maps are the only statewide sources of this information.

Next, the assumptions made in the utilization of a depth-to-aquifer map need to be considered. Basically, the subsurface hydrology of any location has been generalized, such that all deposits are assumed to be uniform in hydraulic conductivity, and classifiable as either an aquifer or a non-aquifer. In reality, hydraulic conductivity is usually a highly variable parameter, and deposits can range in almost a continuum from aquifer to non-aquifer. Again, the need and intended uses of this map make these generalizations necessary and appropriate. The results of Schock et al. (1992) have demonstrated the potential utility of this type of generalization if only coarse levels of stratification are necessary.

Lastly, this map is the first effort in integrating soil and geologic information into a relevant and usable predictive map. It is not to be viewed as the final evaluation of the issue. This map was developed in response to federal pressure to address groundwater quality on a statewide level. As has been shown in this paper, the application of interpretive mapping to this issue results in a very useful regulatory tool. However, the aquifer sensitivity strata represented by the five map units are not directly based on any monitoring results. They have not been validated by observations of pesticide concentrations.

The IDOA and ISGS have already begun discussing the need to validate these map predictions. However, care must be taken in any effort to validate the aquifer sensitivity map. Specifically, three questions must be addressed:

- Does the soil and geologic setting at the sampled well match that indicated on the map?
- Does the available information allow an evaluation of the aquifer sensitivity ranking?
- Does available information support the assumption that aquifer sensitivity is a useful predictor of water quality, or do the external factors also need to be considered to successfully predict water quality?

A complete discussion of these questions is outside the scope of this paper; however, it should be recognized that these three issues must all be addressed for any monitoring data to be successfully interpreted and used with the state management plan. In addition, these questions make it clear that map validation must be put in the appropriate context. Is the source data being verified/validated? Is the aquifer sensitivity model being validated? Is aquifer sensitivity as a useful predictor of water quality being validated? Accordingly, any monitoring data must be collected with enough site-specific information to enable the analytical results to address one or more of these questions.

Calculation and Use of a Township Score

Assuming that these considerations are met, the management plan is designed to use monitoring data and the aquifer sensitivity map to regulate compound application rates, if necessary. At the time of this writing, the township is to be the basic regulatory unit for this part of the state management plan. The scale for both the soil and geologic maps used in this study is 1:250,000. This scale is determined to be large enough to allow the evaluation of individual townships, but too small for the evaluation of much smaller land areas. To regulate pesticide use on a township basis, the mapped aquifer sensitivity of each township was generalized using a weighted averaging technique. Importance weights were assigned to each map unit, with higher sensitivities having a larger weight. This weight was multiplied by the ratio of the area of that map unit to the total area of the selected township. The resulting values from each map unit were then summed to reach the township score, which was used to represent the township-level aquifer sensitivity. A detailed discussion of the generation of township scores is presented in the generic plan.

Table 2. Assignment of aquifer sensitivity level

AQUIFER SENSITIVITY	SOIL-PESTICIDE LEACHING INDEX	DEPTH TO UPPERMOST AQUIFER
Excessive	Moderate to Excessive	< 20 feet
High	Somewhat Limited to Very Limited	< 20 feet
	Moderate to Excessive	20 to 50 feet
Moderate	Somewhat Limited to Limited	20 to 50 feet
Limited	Very Limited	20 to 50 feet
	High to Excessive	Not within 50 feet
Very limited	Moderate to Very Limited	Not within 50 feet

The generic plan suggests that monitoring results will be utilized to evaluate the presence of pesticides in groundwater. If a pesticide is detected at a concentration above a specified action limit, the aquifer sensitivity map will be used to conduct more regional monitoring. If monitoring results suggest that some level of restricted use is necessary for the compound, the township scores (T.S.) will be used as the basis for use restriction stratification. For example, as discussed in the generic plan (IDOA 1994), townships with a score above a given value X (i.e., T.S. > X) might have a compound registration canceled. Those with a score between X and Y (i.e., X > T.S. < Y) might have the registration changed to one half of normal label application rates, and townships with a score less than Y (i.e., T.S. < Y) might have no restriction placed on the compound registration. This example illustrates the advantage of the township score; it allows for a consistent evaluation of the entire state in addressing the local protection of groundwater resources. This example also illustrates how a 36 square mile area will be generalized and regulated using a single aquifer sensitivity score. Some areas in each township are likely to be under-regulated and some areas are likely to be over-regulated.

The concern about over-regulation due to the township score prompted a discussion regarding a variance procedure. At the time of this writing, no variance procedure has been established. However, if enabled, any variance will necessarily regulate a land area that is significantly smaller than 36 square miles.

It has already been noted that the source maps used to develop the aquifer sensitivity map are not reliable for use at a level much smaller than a township. Accordingly, if a variance were developed, it would need to rely on more detailed information. Any procedure would also need to utilize the existing method for evaluating aquifer sensitivity, or the resulting evaluation and comparison to monitoring data would be meaningless when compared to township scores. Lastly, to make the administrative review of the petitions manageable, the area of consideration would need to be uniform for each petition.

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Biological Control of Insects in Field Crops: Expectations and Reality

Robert N. Wiedenmann

A discussion of biological control should respond to the following questions: 1) What is biological control? 2) Why consider biological control as a means of pest control? 3) Can biological control be implemented against some or all insect pests?, and 4) What will need to change to make biological control an alternative to chemically based pest-control strategies? I will attempt to answer these questions and offer the expectation that biological control can be a rational alternative in many crop-pest situations and can be compatible with certain current farming practices, even though it will not always work in every situation. This discussion will be limited to the biological control of insects.

What Is Biological Control?

All organisms—even insect pests—have natural enemies that limit the size of their populations, and thus provide a natural check on their population growth. This sort of biotic check is termed "natural control." Natural control occurs all the time, in the presence of natural predators, pathogens, and parasites of the target organism. We usually notice natural control only by its absence: when natural control is lost, the unchecked growth of an organism often leads to it becoming a pest. The loss of natural control in an agricultural habitat can occur due to agronomic practices that are unfavorable to the ability of natural enemies to maintain populations and provide their characteristic level of control.

Natural control is critical in all habitats, but especially in agricultural ones. Natural control can be differentiated from biological control using definitions. A simple definition of biological control is the suppression or prevention of a pest outbreak using purposeful manipulation of natural enemies. The words "purposeful manipulation" differentiate biological control intervention from natural control. Another definition that is easy to remember has been put forth by Frank Gilstrap of Texas A&M University. He defines biological control as "three sets of three": the prevention, reduction, or delay of a pest population... by predators, parasites, or pathogens... using conservation, augmentation, or importation.

Prevention of a pest population outbreak requires early intervention, before an insect actually reaches an economic level at which it becomes a pest. Reduction is the type of biological control with which we are most familiar: intervening after a pest outbreak has occurred, to decrease the pest population. Delay of a pest population increase is accomplished when the target population reaches high levels only after a critical period has passed; thus, by definition, it doesn't become a "pest" population.

The second set of "three"—the key players—are the natural enemies themselves, which include predators, pathogens, and parasites (also called parasitoids, because they kill their hosts and, thus, differ from true parasites). Predators are common and well known—examples include ground beetles and ladybird beetles; assassin, pirate, damsel, and stink bugs; lacewings; larvae of some flies; ants and some wasps. Parasites are primarily wasps (Hymenoptera) and flies (Diptera). Perhaps a million species of parasitic insects have been described; countless more await description. Pathogens include insect-specific fungi, bacteria, viruses, and protozoa.

The third of the "three" is the set of methods of biological control. Conservation is the manipulation of the habitat or agronomic practices to favor the persistence or effectiveness of natural enemies, such as leaving fence-rows for overwintering sites for predators, or altering insecticide applications to avoid killing native natural enemies. Conservation biological control takes advantage of naturally-occurring natural enemies, but it differs from natural control because the grower still manipulates the system intentionally to reap benefits from those natural enemies.

Augmentation means adding to the natural enemies that are already present, either by adding more of those already present, or adding some that do not presently occur. Many predaceous and parasitic insects are available for sale, either over the counter or by mail, for augmentative use. Augmentation methods include inoculation, in which small numbers of a natural enemy are released early in the season, and allowed to build up (but not necessarily to establish permanently), and inundation, in which large numbers of a natural enemy are released to overwhelm the pest and provide remedial effect.

Importation involves bringing an exotic natural enemy from another country, through quarantine, and releasing it against the target pest. Importation (also known as classical biological control) is usually used against exotic pests that arrived here without their co-evolved natural enemies. Because of the requirements of permits and quarantine to ensure safety, importation is done by university or governmental scientists. Importation biological control has been very effective around the world, including against several pests in the Midwest.

Why Consider Biological Control?

Several reasons exist for using biological control as an alternative to reliance on chemical-based insect control. Over-reliance on insecticides can lead to pesticide resistance and emergence of secondary pests, in addition to environmental and occupational hazards, such as the contamination of ground water by agricultural chemicals. Incidents of poisoning by insecticides are fewer in number in recent years, but they still occur. Perhaps the more serious consequences are the effects on the pests themselves. Several hundred species of insect pests are now resistant to one or more chemical compounds as a result of total reliance on pesticides. The increase in the number of resistant species has occurred almost exponentially, so the development of resistance will continue at an ever more rapid rate. Also, with reliance on pesticides comes the harmful effect on nontarget species that usually do not cause problems, but can become pests themselves because of the disruption of natural control.

There is no question that alternatives to reliance on pesticides are necessary, even if, paradoxically, the result is keeping certain pesticides available and effective. The question is whether biological control is the alternative that should be pursued. Biological control has proven safe, and is getting even safer as a result of increased regulation. Biological control has proven effective—hundreds of examples of partial or complete success exist, and the successes are not only in places such as California or Florida. Biological control has been used effectively against alfalfa weevil and cereal leaf beetle in the Midwest, as visible examples. Finally, biological control is cost-effective, providing substantial benefits for a small investment.

With all of the successes, safety, and favorable cost:benefit ratios, should biological control be used to the complete exclusion of pesticides? Even the most fervent supporter of biological control would not propose that biological control should be the only strategy used. Integrated pest management (IPM) was envisioned as a management based on several tactics—cultural control, biological control, and chemical control—but historically, IPM has relied on chemical control as the first, and sometimes only, tactic employed. Unfortunately, biological control, despite its success, has been used as a method of last resort, rather than as a first attempt. Biological control can work, but it needs to be incorporated into an IPM framework that is truly integrative.

Can Biological Control be Used Against All Pests?

The next important question will be: can biological control be implemented against all pests, or at least against pests important to agriculturists here in the Midwest? Again, even though biological control should be the first tactic attempted, it will not always be effective, in every habitat, against every pest, for every commodity or setting. For that matter, other pest-control tactics will not always be applicable in every setting either. However, many pests respond to biological control methods. Some of the potential uses are demonstrated by partial results of a recent survey. Entomologists throughout the Midwest (most of whom were not practitioners of biological control) were asked to rate pests of a variety of systems, as to their importance and their potential for the successful use of biological control. A selected list of pests considered to be potentially successful targets is shown in Table 1. The pests listed are all in the Midwest, and they belong to several insect orders and a variety of agronomic systems.

What Changes Will Be Necessary to Use Biological Control?

Whether those targets listed in Table 1—or other potential targets—will be successfully reduced using biological control depends upon the answer to my final question: How can biological control be used against these pests, and what will need to change for biological control to be an alternative to chemical control? This is where expectation and reality collide. For how many pest-crop situations can we fit biological control into the current production system, versus changing the system to accommodate biological control? Clearly, the acceptability and possibility for the use of biological control will be greater in those cases where major changes are not required. Many opportunities already exist for biological control to be implemented with simple changes. Examples include altered chemical use, either in more selective timing to avoid killing natural enemies, or simply letting the natural enemies do their job. Augmentation is being used successfully in some settings. For example, European corn borer is now being controlled at the same level as was done previously with insecticides—and at the same cost—by releasing *Trichogramma* wasps (D. Orr & D. Landis, Michigan State University, personal communication). Indeed, several pests listed in Table 1 are potential targets precisely because major changes are not needed in order to implement biological control. However, some of the changes that will be required for successful biological control may be more difficult, such as a major agronomic systems-level change, rather than a simple tinkering with some of the details.

Perhaps one of the simplest—yet most difficult—challenges is the required change in attitude. It is necessary to believe that pests can be controlled biologically, that expectations need to be reasonable, and that solutions may not always come easily. Biological control will not be an off-the-shelf technology, at least not often. There will be some instances when augmentation can be achieved using commercially available natural enemies, but those cases will be few, the effectiveness of those natural enemies will vary (or will be unknown), and the general applicability of those species will require a broad host range, which is not always compatible with minimizing the impact on nontargets. So, in the absence of off-the-shelf natural enemies, biological control will need to be specific for each pest, which will require research on the basic biology of the pest and the natural enemy. So how does the expectation reconcile with reality? Opportunities exist now for using biological control in Midwest agronomic settings and can offer real alternatives in many cases. In other cases, the opportunities will be available soon. But biological control is not now and will never be a panacea, so we must be realistic about our expectations, to avoid overselling the opportunities that are not yet here, but also to avoid selling short those opportunities that may soon be available.

Table 1. Suggested targets for biological control in the Midwest, based on importance and potential for success.

List generated by a survey conducted by NCR-125, the North Central Regional Committee for biological control of arthropod pests. Listed are pest species, the habitat or system in which they occur, and potential approaches: either conservation (C), augmentation (A), or importation (I).

POTENTIAL TARGET PEST	HABITAT OR SYSTEM	APPROACHES
Two-spotted spider mite	Greenhouse	A, C
European corn borer	Field crops	A, C, I
Indian meal moth	Stored grain	A, C, I
Alfalfa weevil	Field crops	C
European red mite	Fruit crops	A, C
House fly	Medical/Veterinary	A, C
Sweetpotato whitefly	Greenhouse	A, I
Imported cabbage worm	Vegetables	A, C, I
Scale insects	Woody ornamentals	C, I

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I thank Frank Gilstrap for allowing me to use his definition of biological control, and I thank Doug Landis and the NCR-125 Committee for allowing use of the data in Table 1.

The Use of Bt-Corn to Control European Corn Borers: 1994 Results and Future Expectations

Ria Barrido and Kevin Steffey

Throughout the past 10 years, European corn borers, *Ostrinia nubilalis*, have caused significant yield losses in Illinois and elsewhere in the north central states. The extremely large densities of corn borers that occurred in 1989 and 1991 generated a lot of interest in the economics of corn borer damage and the importance of timely and effective management. Corn growers and people who advise them are acutely aware of the impact that corn borers can have on corn production. Consequently, the level of interest in alternative management tactics has increased.

Presently, farmers control European corn borers by applying either chemical or microbial insecticides after the borers' densities have reached or exceeded economic thresholds. DiPel, a microbial insecticide that contains insecticidal proteins from a bacterium, is effective for control of first-generation European corn borers. Although the use of DiPel for corn borer control has increased in recent years, conventional chemical insecticides are still used on far more acres.

For decades, scientists have investigated the potential for developing corn varieties that are resistant to European corn borers. However, although some hybrids have resistance to first-generation borers and some exhibit slight resistance or tolerance to second-generation borers, most corn hybrids are susceptible to corn borer injury. Recent advances in agricultural biotechnology may offer a new approach for corn borer control, an approach that combines the advantages of plant resistance and microbial insecticides. The development of transgenic field crops shows promise, especially in light of the public's growing concern about the impact of chemical pesticides on the environment (Barton et al. 1987; Benedict et al. 1993). For example, corn can be genetically modified to express an insecticidal gene from a bacterium, *Bacillus thuringiensis* (Bt), the same bacterium utilized in the formulation of the microbial insecticide DiPel and similar products.

In this paper we present the results from our first field trial focused on the efficacy of transgenic corn (Bt-corn) for control of first- and second-generation European corn borers. The trial was conducted at the Monsanto Research Farm near Monmouth, Illinois.

Corn Borers and Bt

First through third instars of first-generation larvae feed on the leaves in the whorls of the plants. Early instars of the second generation feed on the tender leaf-collar tissue and on pollen that has accumulated in the leaf axils. Fourth and fifth instars of both generations burrow into the corn plant and feed inside the stalk. Tunneling injury causes physiological yield losses and broken stalks. Larvae of the second generation also tunnel inside ear shanks, often causing the ears to drop off.

Bacillus thuringiensis is a gram-positive bacterium that produces a crystal protein during sporulation. When ingested by a susceptible host insect, this crystal protein is broken down into toxic subunits by enzymes in the insect midgut. The toxic subunits cause paralysis of the midgut, followed by bursting of the midgut epithelial cells, which eventually results in the death of the insect (Hoffe and Whitelay 1989; McGaughey and Whalon 1992).

Basic research has revealed that the presence of the Bt-toxin in transgenic corn is very effective for killing corn borer larvae feeding on the plant. Preliminary field tests have also been promising.

1994 Study, Monmouth, Illinois

Our study involved the comparison of two different corn hybrids. One hybrid was genetically modified to express a gene from *Bacillus thuringiensis* that encodes an insecticidal protein specific for the European corn borer. The other hybrid was genetically similar to the first hybrid, except that it did not contain the insecticidal Bt gene. The objectives of our study were:

- To determine the impact of natural and manual infestations of European corn borers on yield of Bt-corn and non-Bt-corn,
- To develop a relationship between insect injury and yield for Bt-corn and non-Bt-corn,
- To compare the yield of Bt-corn with the yield of non-Bt-corn protected from European corn borer injury with commercial insecticides, and
- To identify the effect of Bt-corn on other lepidopterans (caterpillars), as well as to observe any effects that Bt-corn may have on beneficial insects.

Materials and Methods

The plots were planted on May 12, 1994. Each plot was 4 rows by 30 feet, and the plots were arranged in a randomized complete block design. Each treatment was replicated 6 times. Additionally, one row of Bt-corn was planted between adjacent plots to minimize larval movement between plots and minimize insecticide drift. The 12 treatments employed in our experiment are presented in Table 1. The treatments consisted of various combinations of Bt- or non-Bt-corn; application of an insecticide or no insecticide applied; and manual infestations of corn borer larvae at times appropriate to simulate first, second, or both generations.

Pounce 3.2EC was applied weekly after anthesis (flowering) to treatments 5 and 6 to eliminate natural infestations of second-generation European corn borer larvae. Pounce 3.2EC was applied weekly until anthesis to treatments 7 and 8 to eliminate natural infestations of first-generation larvae. Pounce 3.2EC was applied weekly throughout the summer to treatments 9 and 10 to eliminate natural infestations of both generations of corn borers. In an attempt to simulate farmers' applications of insecticides after corn borer densities exceeded the economic threshold, DiPel 10G and Pounce 1.5G were applied to treatments 11 and 12, respectively, to control first- and second-generation European corn borer larvae.

When the plants reached the 8 to 10 leaf stage, we manually infested 40 plants in each of the center two rows of the appropriate treatments. Approximately 100 newly hatched European corn borer larvae were applied to the whorl of each plant. The second-generation infestation was performed at anthesis. Again, 40 plants in each of the center two rows of the appropriate plots were infested with approximately 100 larvae each.

We monitored the plots weekly to look for nontarget lepidopterans and beneficial insects, especially ladybugs, damsel bugs, minute pirate bugs, and lacewings. The objective of the weekly monitoring was to determine whether densities of these nontarget insects differed among treatments.

Nineteen days after the manual infestation of first-generation corn borers, we evaluated the amount of injury to the corn plants caused by the larvae. The evaluation was based upon the Guthrie scale:

1. No visible leaf injury or a small amount of fine shot-holes on a few leaves
2. Small amount of shot-hole injury on a few leaves
3. Shot-hole injury common on several leaves
4. Several leaves with shot holes and elongated lesions
5. Several leaves with elongated lesions
6. Several leaves with elongated lesions about 2.5 cm long
7. Long lesions common on about one-half of the leaves
8. Long lesions common on about two-thirds of the leaves
9. Most leaves with long lesions

Three weeks before harvest we recorded the number of broken stalks and dropped ears in each plot. In mid-October, just before harvest, we evaluated several types of injury to the corn plants caused by second-generation borers. We randomly

Table 1. Treatments in the Bt-corn trial conducted near Monmouth, Illinois, 1994

TREATMENT NO.	HYBRID	INSECTICIDE	MANUAL INFESTATION
1	Non-Bt	No insecticide	None
2	Bt	No insecticide	None
3	Non-Bt	No insecticide	1st and 2nd gen.[1]
4	Bt	No insecticide	1st and 2nd gen.
5	Non-Bt	Eliminate 2nd gen.	1st gen. only
6	Bt	Eliminate 2nd gen.	1st gen. only
7	Non-Bt	Eliminate 1st gen.	2nd gen. only
8	Bt	Eliminate 1st gen.	2nd gen. only
9	Non-Bt	Weekly Pounce 3.2EC	None throughout season
10	Bt	Weekly Pounce 32.EC	None throughout season
11	Non-Bt	DiPel 10G	1st and 2nd gen.
12	Non-Bt	Pounce 1.5G	1st and 2nd gen.

[1] Gen. = generation

selected 15 plants from the center two rows of each plot and recorded the following data:

- number of European corn borer entry holes
- number of inches of tunneling in the stalk
- number of inches of tunneling in the ear shank
- number of inches of damage in the ears.

After completing the second-generation injury evaluations, we hand-harvested the corn from the center two rows of each plot and recorded the total weight of the corn kernels, the percentage of moisture in the kernels, and the number of ears harvested from each plot.

Results

At this writing, the data have not been statistically analyzed. All of the data in Tables 2, 3, 4, and 5 are preliminary averages. Table 2 shows the results of the evaluation of the amount of injury caused by first-generation European corn borers. Table 3 shows the average number of broken tops in each treatment. Table 4 shows the average number of entry holes per stalk and the average amount of stalk injury. Table 5 shows average yields for all plots.

Discussion

Because statistical analyses have not been conducted at this writing, statistically significant differences among treatments have not been determined. Consequently, the discussion of the data is based solely upon comparisons of numerical averages.

The preliminary data in Tables 2, 3, and 4 show that non-Bt-corn generally had more leaf injury (higher Guthrie ratings), broken tops, entry holes, and inches of stalk injury than Bt-corn. The only treatment containing non-Bt-corn that consistently produced results similar to those in the Bt-corn plots was the treatment that was sprayed weekly with Pounce 3.2EC to eliminate virtually all corn borers and other insect pests.

The data in Table 2 and Table 5 suggest that the Guthrie scale is not a suitable predictor of yield losses caused by first-generation European corn borer larvae. Average Guthrie ratings (Table 2) in each treatment do not reveal substantial differences among treatments; the leaves in almost all plots sustained little or no damage. However, the yield data in Table 5 suggest that first-generation corn borers probably contributed significantly to yield reductions. Perhaps another method of evaluating first-generation corn borer injury should be devised.

The data in Table 3 reveal that the numbers of broken tops in four non-Bt-corn treatments were considerably larger than the numbers of broken tops in the Bt-corn treatments and the non-Bt-corn that was treated weekly with Pounce 3.2EC. Neither

Table 2. Average ratings[1] of first generation European corn borer injury to corn leaves, Monmouth, Illinois, 1994

HYBRID	INSECTICIDE	INFESTED WITH	AVERAGE GUTHRIE RATING
Bt	none	none	1.0
Bt	weekly Pounce 3.2EC	none	1.0
Bt	eliminate 2nd gen.[2]	1st gen.	1.0
Bt	eliminate 1st gen.[3]	2nd gen.	1.0
Non-Bt	weekly Pounce 3.2EC	none	1.0
Bt	none	1st and 2nd gen.	1.1
Non-Bt	eliminate 1st gen.	2nd gen.	1.3
Non-Bt	none	none	1.9
Non-Bt	eliminate 2nd gen.	1st gen.	2.0
Non-Bt	standard DiPel 10G	1st and 2nd gen.	2.4
Non-Bt	standard Pounce 1.5G	1st and 2nd gen.	2.5
Non-Bt	none	1st and 2nd gen.	2.9

[1] Ratings based upon the Guthrie scale. Values range from 1 through 9, where 1 = little or no leaf damage, and 9 = long lesions on most of the leaves. Refer to the text for more details.

[2] Second-generation corn borers were eliminated with weekly applications of Pounce 3.2EC after anthesis.

[3] First-generation corn borers were eliminated with weekly applications of Pounce 3.2EC until anthesis.

Table 3. Average number of broken tops caused by European corn borer larvae, Monmouth, Illinois, 1994

HYBRID	INSECTICIDE	INFESTED WITH	AVERAGE NUMBER OF BROKEN TOPS
Bt	weekly Pounce 3.2EC	none	0.8
Bt	eliminate 1st gen.[1]	2nd gen.	0.8
Bt	none	none	1.0
Bt	none	1st and 2nd gen.	1.2
Non-Bt	weekly Pounce 32.EC	none	1.3
Non-Bt	none	none	1.3
Non-Bt	eliminate 2nd gen.[2]	1st gen.	1.7
Bt	eliminate 2nd gen.	1st gen.	2.0
Non-Bt	standard Pounce 1.5G	1st and 2nd gen.	9.0
Non-Bt	none	1st and 2nd gen.	17.0
Non-Bt	eliminate 1st gen.	2nd gen.	18.8
Non-Bt	standard DiPel 10G	1st and 2nd gen.	20.1

[1] First-generation corn borers were eliminated with weekly applications of Pounce 3.2EC until anthesis.

[2] Second-generation corn borers were eliminated with weekly applications of Pounce 3.2EC after anthesis.

Pounce 1.5G nor DiPel 10G provided sufficient control of second-generation corn borers to prevent broken tops. When the first generation was eliminated and non-Bt-corn was manually infested with "second-generation" larvae, the average number of broken tops per plot was 18.8. However, the yield data in Table 5 suggest that broken tops did not contribute significantly to yield reductions.

The average number of inches of injury per stalk was much less than 1.0 in the five Bt-corn treatments and in the non-Bt-corn plots treated weekly with Pounce 3.2EC. In fact, four of the Bt-corn treatments had virtually no stalk injury. Standard treatments of Pounce 1.5G and DiPel 10G did not prevent entry holes or stalk tunneling.

Yield data are shown in Table 5. Two non-Bt-corn plots that were treated to eliminate first-generation corn borers had approximately the same yield as all five of the Bt-corn treatments. The data suggest a possible correlation between the absence of first-generation corn borers and a higher yield. All Bt-corn treatments produced higher yields than non-Bt-corn treated with standard chemical (Pounce 1.5G) or microbial (DiPel 10G) insecticides, non-Bt-corn treated to eliminate second-generation borers, and untreated non-Bt-corn. The two treatments with the highest yields were non-Bt-corn to which insecticides were applied to eliminate first-generation corn borers and the non-Bt-corn treated weekly with Pounce. The other non-Bt-corn plots had lower yields than the Bt-corn plots, perhaps as a result of the damage caused by infestations of one or both generations of corn borers.

Data obtained from our weekly scouting trips showed no apparent differences among plots. When present, other lepidopterans and beneficial insects seemed to be evenly distributed throughout the plots. There also were no apparent differences in weediness or the level of infection of plant pathogens among the plots. Bt-corn plots were as weedy as non-Bt-corn plots.

Conclusions and Future Expectations

Our study was only one of 11 similar trials that were conducted by university personnel and consultants in the Midwest. Trials similar to ours were conducted in Iowa, Kansas, Missouri, and Nebraska. At this writing, all researchers have not yet shared their results; however, informal conversations indicate that results at the various locations are comparable.

Table 4. **Average corn injury caused by second generation European corn borers, Monmouth, Illinois, 1994**

HYBRID	INSECTICIDE	INFESTED WITH	AVERAGE NUMBER OF ENTRY HOLES	AVERAGE AMOUNT OF STALK INJURY (INCHES)
Bt	weekly Pounce 3.2EC	none	0.0	0.0
Bt	eliminate 2nd gen.[1]	1st gen.	0.0	0.0
Bt	none	1st and 2nd gen.	0.0	0.0
Bt	eliminate 1st gen.[2]	2nd gen.	0.1	0.0
Bt	none	none	0.1	0.1
Non-Bt	weekly Pounce 3.2EC	none	0.1	0.1
Non-Bt	eliminate 2nd gen.	1st gen.	1.0	1.0
Non-Bt	standard Pounce 1.5G	1st and 2nd gen.	1.6	1.4
Non-Bt	eliminate 1st gen.	2nd gen.	1.8	2.2
Non-Bt	none	1st and 2nd gen.	2.4	2.6
Non-Bt	standard DiPel 10G	1st and 2nd gen.	2.2	3.0
Non-Bt	none	none	2.2	3.0

[1] Second-generation corn borers were eliminated with weekly applications of Pounce 3.2EC after anthesis.

[2] First-generation corn borers were eliminated with weekly applications of Pounce 3.2EC until anthesis.

Table 5. **Average corn yields, Monmouth, Illinois, 1994**

HYBRID	INSECTICIDE	INFESTED WITH	AVERAGE YIELD (BUSHELS PER ACRE)
Non-Bt	eliminate 1st gen.[1]	2nd gen.	193.4
Non-Bt	weekly Pounce 3.2EC	none	192.4
Bt	none	none	192.3
Bt	eliminate 1st gen.	2nd gen.	191.4
Bt	none	1st and 2nd gen.	190.4
Bt	eliminate 2nd gen.[2]	1st gen.	189.5
Bt	weekly Pounce 3.2EC	none	188.5
Non-Bt	standard Pounce 1.5G	1st and 2nd gen.	180.8
Non-Bt	none	1st and 2nd gen.	179.1
Non-Bt	eliminate 2nd gen.	1st gen.	178.2
Non-Bt	standard DiPel 10G	1st and 2nd gen.	170.3
Non-Bt	none	none	169.2

[1] First-generation corn borers were eliminated with weekly applications of Pounce 3.2EC until anthesis.

[2] Second-generation corn borers were eliminated with weekly applications of Pounce 3.2EC after anthesis.

The use of Bt-corn for control of European corn borers seems to be a promising technology. The level of control in efficacy trials has been excellent, and yields do not seem to be compromised. As long as the gene transfer technology can be utilized in hybrids that produce good yields, and the cost for the seed is reasonable, transgenic hybrids that control corn borers will be accepted readily by growers. However, a couple of concerns about the use of Bt-corn are worthy of discussion.

Certain consumer groups have not accepted the idea of genetically modified agricultural products. Plant resistance to insects or diseases has been derived by genetic manipulation through conventional crop breeding techniques for decades, and this is perfectly acceptable to both growers and the general public. However, the general public seems to have greater difficulty accepting the idea that a plant's genetic structure can be altered to express an insecticidal gene from a bacterium. The public's concern about genetic biotechnology must be taken seriously and addressed sympathetically.

From a scientific standpoint, the primary concern about the widespread use of Bt-corn is the development of resistance to Bt in populations of European corn borers. Continual exposure to a single gene resistance mechanism, such as the Bt toxin in corn, might select for resistance in corn borer populations. This occurrence, of course, depends on many factors, not the least of which is the percentage of acres that will be devoted to the production of Bt-corn. Consequently, the potential for the development of resistance to Bt in corn borers must be addressed by considering certain resistance management strategies.

One such strategy is interplanting mixtures of resistant and susceptible plant types. If Bt-corn plants were interplanted with non-Bt-corn plants, Bt-susceptible corn borers would mate with Bt-resistant corn borers, thereby reducing the potential for the development of resistance. However, deployment of this strategy in a single field would require determination of the appropriate mixture of Bt-corn seeds and non-Bt-corn seeds. Fortunately, this strategy would be enhanced by the presence of entire fields being planted to non-Bt-corn. It is unlikely that every corn grower will invest in Bt-corn or that every hybrid on the market will be genetically altered to express the Bt toxin. Additionally, European corn borers have an extremely wide host range. They have been found feeding on more than 200 kinds of plants, including weeds and cultivated crops such as cotton, peppers, popcorn, potatoes, snap beans, sorghum, soybeans, and sweet corn. Corn borers that feed and develop on these crops that do not produce the Bt toxin also might mate with Bt-resistant corn borers.

The development of Bt-corn and resistance management strategies should occur simultaneously. The more prepared we are for the introduction and implementation of this new technology, the more capable we will be of addressing problems that might develop. This new technology, as with any other pest management strategy, should be used in a completely integrated pest management program that also includes the use of cultural, mechanical, and biological control tactics. Bt-corn should not be used as a "silver bullet" against one of our most destructive insect pests. History has taught us some harsh lessons in agriculture. We should learn from some of our past mistakes so that we don't make similar mistakes in the future.

Acknowledgment

We express our sincere appreciation to the individuals working at the Monsanto Research Farm near Monmouth, Illinois, who provided assistance throughout the growing season.

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Agricultural Pesticide Clean Sweep Program: 1994 Activities and Plans for 1995

W. D. Goetsch

Introduction

In 1989, amendments to the Illinois Pesticide Act mandated the Illinois Department of Agriculture to conduct pilot collections of unwanted pesticides from Illinois farmers. Two collection projects were held in Macon and Henry counties by the Department, in cooperation with the local Cooperative Extension Service offices, Farm Bureaus, Soil and Water Conservation Districts, retail agrichemical dealers, and the Monsanto Corporation. The results of these collections were summarized in a report that was presented to the legislature in May of 1992.

New Funding

As a result of the Great Flood of 1993, the Department was able to secure a grant from the United States Environmental Protection Agency to assist in the collection and disposal of flood-orphaned agricultural pesticides. Immediate post-flood cleanup activities did not exhaust the funding, so the USEPA agreed to allow more general "clean sweep collection activities" to be held in the federally declared flood disaster counties.

In cooperation with the local Farm Bureaus, Cooperative Extension Service offices, Soil and Water Conservation Districts, area agrichemical dealers, and, in one case, the county solid waste coordinator, the Department scheduled collections to be held in the following counties during the fall of 1994:

- Pulaski and Alexander Counties
- Randolph and Monroe Counties
- Pike and Scott Counties
- Rock Island and Mercer Counties
- Lake County

(At this writing, exact dates for the collections have not been established, but the target weeks are the last week of November and the first week of December.)

Organization of the 1994 Collections

The results of the original two pilot collections suggested that future collections should include only those agricultural pesticides that could no longer be used. These should include products with canceled or suspended registrations, damaged products, and unknown products. Those that simply were no longer wanted by the current holder, but could be used for the original pesticidal purpose, should not be collected for disposal, but instead transferred to someone for use. This would ensure the use of scarce public funding for products in need of disposal and allow for more area of the state to be covered. This approach also places a larger burden on the local coordinators because of the need for management of the "swap" program, which attempts to place the usable products with applicators.

Prior to the five 1994 collections, an introductory letter and an inventory form (Figure 1) were sent to potential participants. Forms were completed by the holders of the unwanted pesticides and returned to the local coordinator by a certain date. All completed forms were then transmitted to the Department where the proposed products were screened for collection status (canceled registration, damaged, usable, or unknown). Product lists were then developed for participation in either the collection program or the "swap" program.

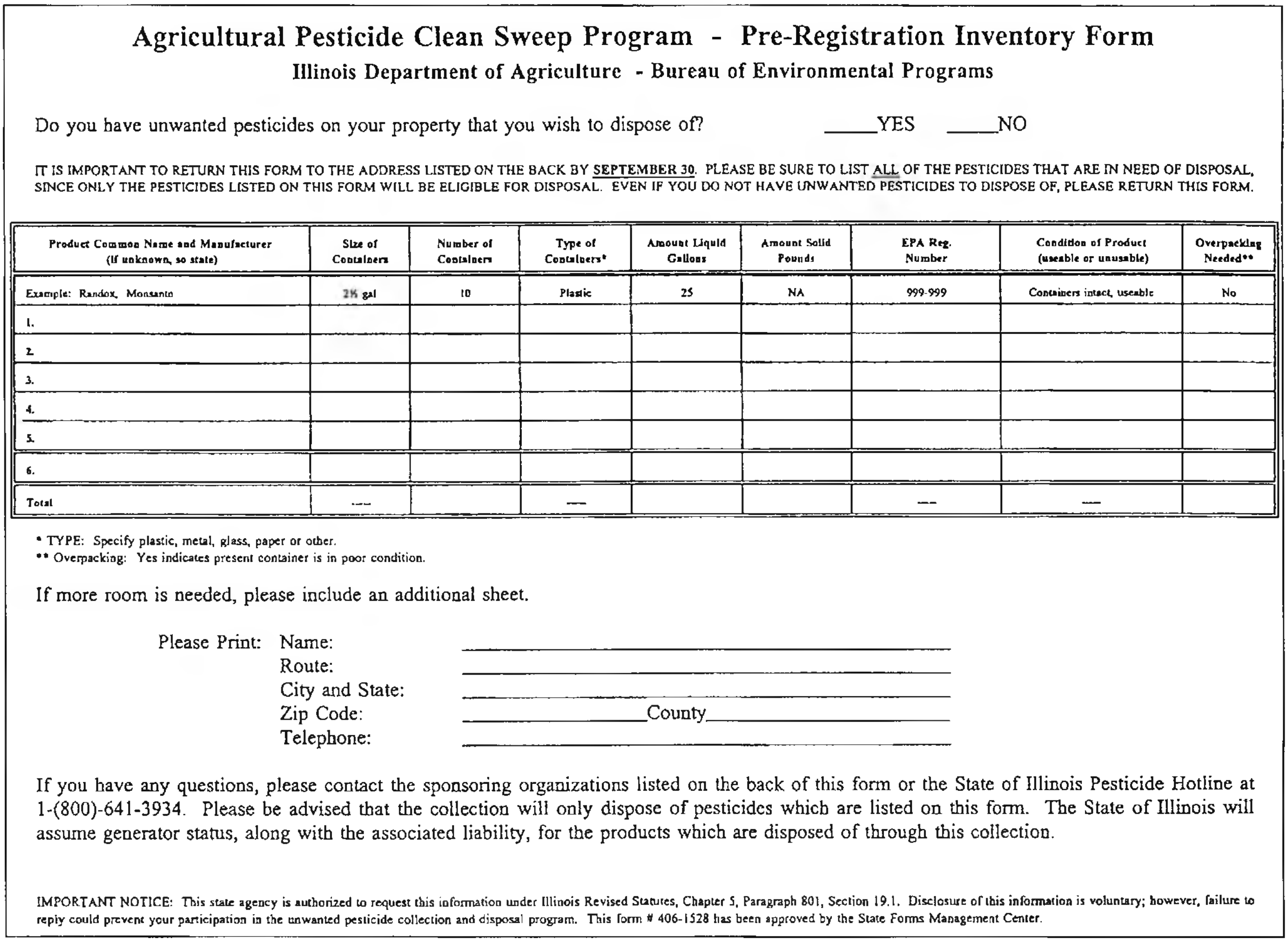
Each participant received a registration confirmation form indicating the date, location, and time of the collection, as well as the products that would be collected. Only products shown on the confirmation form were to be collected by the waste disposal contractor on the collection date. Other products proposed on the inventory form were classified as usable and were added to the "swap" list, which was transmitted to the local coordinator(s). The local coordinator(s), in cooperation with the local agrichemical dealers, then attempted to transmit the products on the "swap" list to the applicators who were able to use these products for their originally intended purpose according to label directions.

Plans for 1995

Early projections of waste volume and disposal costs, based on the inventory forms submitted from the nine counties participating in the 1994 collections, suggest that the existing funding may be sufficient to support two additional waves of collections in 1995. These would occur in the other 1993 federally declared disaster counties and would most probably be scheduled in late spring (immediately after planting) and early summer (immediately before harvest). If collections are completed successfully in these counties, approximately two-thirds of the counties in Illinois would remain candidates for future collections beyond 1995 if resources become available.

Summary

The pilot collections held in Macon (1990) and Henry (1991) counties demonstrated the need for the collection and disposal of unusable agricultural pesticides from many Illinois farms. These collections also demonstrated the high costs of disposal and the need to focus on products with canceled registrations, damaged products, and unknown products. In cooperation with various local county organizations and the agrichemical industry, the Illinois Department of Agriculture has initiated an expansion of these original collections to include federally declared flood disaster counties, assisted by funding from the USEPA. This expansion will take a dual approach, using both a "swap" program for usable products and collection/disposal for non-usable ones. Nine counties are participating in 1994 and it is hoped that this number may double in 1995.



Agricultural Pesticide Clean Sweep Program - Pre-Registration Inventory Form

Illinois Department of Agriculture - Bureau of Environmental Programs

Do you have unwanted pesticides on your property that you wish to dispose of? _____YES _____NO

IT IS IMPORTANT TO RETURN THIS FORM TO THE ADDRESS LISTED ON THE BACK BY SEPTEMBER 30. PLEASE BE SURE TO LIST ALL OF THE PESTICIDES THAT ARE IN NEED OF DISPOSAL, SINCE ONLY THE PESTICIDES LISTED ON THIS FORM WILL BE ELIGIBLE FOR DISPOSAL. EVEN IF YOU DO NOT HAVE UNWANTED PESTICIDES TO DISPOSE OF, PLEASE RETURN THIS FORM.

Product Common Name and Manufacturer (If unknown, so state)	Size of Containers	Number of Containers	Type of Containers*	Amount Liquid Gallons	Amount Solid Pounds	EPA Reg. Number	Condition of Product (useable or unusable)	Overpacking Needed**
Example: Randox, Monsanto	2½ gal	10	Plastic	25	NA	999-999	Containers intact, useable	No
1.								
2.								
3.								
4.								
5.								
6.								
Total	—		—			—	—	

* TYPE: Specify plastic, metal, glass, paper or other.
** Overpacking: Yes indicates present container is in poor condition.

If more room is needed, please include an additional sheet.

Please Print: Name: ____________________
Route: ____________________
City and State: ____________________
Zip Code: __________ County__________
Telephone: ____________________

If you have any questions, please contact the sponsoring organizations listed on the back of this form or the State of Illinois Pesticide Hotline at 1-(800)-641-3934. Please be advised that the collection will only dispose of pesticides which are listed on this form. The State of Illinois will assume generator status, along with the associated liability, for the products which are disposed of through this collection.

IMPORTANT NOTICE: This state agency is authorized to request this information under Illinois Revised Statutes, Chapter 5, Paragraph 801, Section 19.1. Disclosure of this information is voluntary; however, failure to reply could prevent your participation in the unwanted pesticide collection and disposal program. This form # 406-1528 has been approved by the State Forms Management Center.

Figure 1. Example of the preregistration inventory form used in the 1994 clean sweep projects.

Agricultural Pesticide Container Recycling Program: 1994 Activities and Plans for 1995

B. A. Beaver

Introduction

The Illinois Department of Agriculture, in cooperation with various local agrichemical facilities, the Illinois Fertilizer and Chemical Association, United Agri Products, Cole Grower, Grower Service, GROWMARK, and ACRC/Tri-Rinse, Inc., has completed another successful year recycling agrichemical containers throughout the state. Agrichemical users demonstrated their commitment to the program and to Illinois's environment this year by more than doubling the number of containers recycled last year.

The successful expansion of the program could not have come at a more opportune time. Beginning January 1, 1995, it will no longer be permissible to open-burn agrichemical containers at agrichemical facilities. The burning ban, pursuant to 8 Illinois Administrative Code Part 255, will greatly increase the need for alternative disposal methods, of which recycling should play a major role. Landfilling is one disposal option that is becoming ever more expensive due to diminishing landfill space and the reluctance of operators to accept agrichemical containers. Agrichemical facilities will still be allowed to burn in the field of application, but this option is limited due to the impracticality of transporting containers to the field when mixing is conducted at a permanent site and to the potential liability of starting roadside fires. Container reconfiguration to include disposable gel packs is another disposal option, but these packs are yet to be perfected. Concentrated products, to reduce container size, along with a reliance on bulk chemicals, are helping to ease the burden of container disposal, but recycling appears to be one of the most readily available, economically feasible, and environmentally compatible options.

Program Results

In 1994, 69 single day collections were held throughout the state. They were staggered in location to accommodate the majority of the agrichemical users in Illinois. The collections were held at volunteer agrichemical facilities. Four collections were held each day during the month of July and the first week of August. Morning and afternoon collections were held in both northern and southern Illinois.

A total of 128,700 agrichemical containers were accepted for recycling. This is more than double the 1993 total of 57,000 containers. Only 9,750 containers were rejected this year for improper or insufficient cleaning, which resulted in a 7 percent rejection rate, although some on-site washing was allowed. Assuming that a 2½-gallon container weighs approximately 0.75 lb and a 1-gallon container weighs 0.50 lb, this year's program resulted in the collection of an estimated 96,500 lbs of plastic. The number of participants was also increased from 224 in 1993 to 337 in 1994. Although this year's collection accounted for a large number of containers, it is still only a fraction of the number being manufactured each year.

The focus of the collection was on 1- and 2½-gallon HDPE (High Density Polyethylene) containers, although some 30-gallon and odd-sized containers were also collected. Each container was required to be properly triple-rinsed or power-washed before it was accepted for recycling. Each participant was also required to remove all lids, foil seals, and booklets from the containers. Lids were not accepted because they are made from a different kind of plastic, which currently cannot be recycled.

Illinois Department of Agriculture employees were at each site to inspect every container for possible pesticide residue. The inspection process is necessary because both state and federal laws require agrichemical containers to be properly cleaned before disposal. This process also ensures a clean and usable supply of recycled plastic.

After passing inspection, each container is granulated into small particles using an on-site granulator. This on-site granulation process facilitates transportation by reducing the overall volume of the containers. After granulation, plastic chips equivalent to 50 containers could be collected in a 2 ft by 1 ft pail. The plastic chips are stored in "super-sacs" that have a capacity for 1,100 lbs of plastic (approximately 1,500 containers). Filled super-sacs are then transported to another site for further processing.

Uses for Plastic

Currently, the majority of the plastic recycled in Illinois is being used as a fuel substitute in cement kilns. The "white coal," as it is called, provides a better btu value than coal. Although this process helps to conserve our natural coal resources, it is still the goal of the container recycling program to recycle the plastic collected in Illinois into agriculturally usable end products. Potential end products include fence posts, pallets, highway guardrails, new containers, hazardous waste drums, and plastic drainage tubing. Almost all of these items are in the prototype and developmental stages for use here in Illinois.

The feasibility of the manufacture of plastic drainage tubing from recycled plastic is currently under study by the Department. Tubing ranging in composition from 0 percent, 25 percent, 50 percent, to 100 percent recycled pesticide containers has been installed in a field drainage system and is being monitored for possible pesticide residues. Preliminary results look very promising with no apparent difference in residue levels found among those lateral lines made of virgin plastic and those lines made from 100 percent recycled plastic.

Advances in the marketing of recycled products have been slow in forthcoming. Delays can be attributed primarily to the fact that recycled plastic is more expensive than virgin plastic, but they can also be attributed to a general reluctance toward marketing a product made from agrichemical containers. Hopefully, this reluctance can be changed through continued efforts such as the evaluation of the effectiveness of the plastic drainage tubing manufactured from recycled plastic.

1995 Program

Continued expansion of the program is expected in 1995. We will begin to contact potential locations in December, thus permitting plenty of time to schedule the collection run(s) and publicize the event(s) properly. Dates and locations will be available as soon as these sites are selected.

1995's program will also include the first state-owned granulator, which is being purchased with the help of a grant from the Farmer's Home Administration. This granulator will provide increased flexibility as well as a replacement for either of the contractor-owned machines in the event of a mechanical failure. The granulator will be available for the development of permanent recycling center(s) as well as any necessary extra collections. Development of these permanent collection centers is still in the planning stage.

In this time of increased environmental awareness, Illinois agriculture has begun to show its commitment to the environment through its acceptance of the container recycling program. Agriculture can continue its commitment through the use of the 3 R's: reduce, re-use, and recycle. This can be achieved by reducing the amount of containers manufactured by using increased bulk chemical and dissolvable gel packs, by re-using refillable containers such as pressurized kegs, and by recycling the containers that are manufactured by participating in this program.

Table 1. Statistical summary for 1994 agrichemical container recycling program

Date	*Time*	*Site Location*	*Number Accepted*	*Number Rejected*	*Rejection Rate (%)*	*# of Participants*
07/06	A.M.	Bailey - Peavey Ag Center Edwards County	0	0	0.0	0
07/06	A.M.	Ward Crop Service McDonough County	1381	119	7.9	2
07/06	P.M.	Riden Farm Supply McDonough County	1353	58	4.0	3
07/06	P.M.	Wabash Valley Service Company White County	240	210	46.7	2
07/07	A.M.	Monmouth Grain and Dryer Warren County	2453	767	23.8	6
07/07	A.M.	George Smith Ag Service Wayne County	745	34	4.4	3
07/07	P.M.	Kearney Fertilizer Jefferson County	1061	26	2.4	1
07/07	P.M.	Inness Farm Supply Inc. Knox County	785	305	28.0	4
07/08	A.M.	Twin County Service Franklin County	110	1	0.9	2
07/08	A.M.	Spoon River FS Knox County	1814	68	3.6	7
07/08	P.M.	South Central FS, Inc. Fayette County	727	106	12.7	1
07/11	P.M.	Effingham Equity Clark County	1710	46	2.6	5
07/11	P.M.	Henry Co. Serv. - Alwood Serv. Henry County	1309	20	1.5	4
07/12	A.M.	Custom Crop Service Effingham County	1968	85	4.1	5
07/12	A.M.	Gateway Co-op Henry County	1434	168	10.5	6
07/12	P.M.	Planters Farm Center Effingham County	6392	98	1.5	4
07/12	P.M.	Stark Ag. Stark County	2252	341	13.2	8
07/13	A.M.	Woolsey Brothers FS, Inc. Fayette County	537	38	6.6	1
07/13	A.M.	Peoria County Service Peoria Service	1269	22	1.7	4

Date	Time	Site Location	Number Accepted	Number Rejected	Rejection Rate (%)	# of Participants
07/13	P.M.	South Central FS, Inc. Bond County	250	0	0.0	3
07/13	P.M.	Agland FS Tazewell County	3225	31	0.9	6
07/14	A.M.	Bockhorn Chemical Service Randolph County	1050	11	1.0	13
07/14	A.M.	Bell Enterprises, Inc. Tazewell County	1333	136	9.3	3
07/14	P.M.	Gateway FS Randolph County	1608	190	10.6	8
07/14	P.M.	Sun Ag, Inc. Woodford County	1099	71	6.1	8
07/15	A.M.	Flanagan Fertilizer Livingston County	1748	158	8.3	10
07/15	A.M.	Vigoro Industries Washington County	2695	23	0.8	2
07/15	P.M.	Bergmann - Taylor Madison County	1494	9	0.6	5
07/18	P.M.	Donovan Farmers Coop. Iroquois County	2043	8	0.4	2
07/18	P.M.	Richter Fertilizer Pike County	3610	92	2.5	2
07/19	A.M.	Green County Service Company Green County	4926	73	1.5	9
07/19	A.M.	Edwards Soil Service Inc. Livingston	2081	155	6.9	14
07/19	P.M.	Jersey County Farm Supply Jersey County	240	3	1.2	3
07/19	P.M.	New Ag Center Will County	2269	167	6.9	10
07/20	A.M.	Ty-Walk Liquid Inc. Kendall County	4986	317	6.0	3
07/20	A.M.	Area Ag Macoupin County	1195	143	10.7	3
07/20	P.M.	LaSalle County Farm Supply Co. LaSalle County	1391	49	3.4	2
07/20	P.M.	Montgomery Service Co. Montgomery County	2001	135	6.3	11
07/21	A.M.	Utica Elevator LaSalle County	1615	28	1.7	8

Date	Time	Site Location	Number Rejected	Number Accepted	Rejection Rate (%)	# of Participants
07/21	A.M.	Clayton Point Fertilizer Morgan County	8725	687	7.3	5
07/21	P.M.	G and J Fertilizer Company Putnam County	1357	376	21.7	6
07/21	P.M.	Herrin Ltd. Sangamon County	1888	35	1.8	2
07/22	A.M.	Michlig Agri-Center, Inc Bureau County	1380	29	2.1	6
07/22	A.M.	Christian County FS Christian County	1088	37	3.3	4
07/25	P.M.	Chem-Gro Hancock County	2511	16	0.6	8
07/25	P.M.	North Oil Company Lee County	1216	590	32.7	8
07/26	A.M.	Hintzsche Fertilizer DeKalb County	4251	442	9.4	11
07/26	A.M.	Schuyler - Brown FS Schuyler County	6656	0	0.0	5
07/26	P.M.	Northern FS Inc. Dekalb County	283	14	5.1	6
07/26	P.M.	Skiles Fertilizer Service, Inc. Fulton County	541	0	0.0	1
07/27	A.M.	Carrol Service Co. Carrol County	793	490	38.2	4
07/27	A.M.	Cass County Service Co. Cass County	3720	356	8.7	5
07/27	P.M.	Carrrol Service Co. Carrol County	40	2	4.8	1
07/27	P.M.	Mason County Service Co. Mason County	1466	0	0.0	4
07/28	A.M.	San Jose FS Inc. Logan County	1656	0	0.0	3
07/28	A.M.	Stephenson FS Stephenson County	322	97	23.2	2
07/28	P.M.	Warren Co-op JoDaviess County	2836	370	11.5	3
07/28	P.M.	Agland FS Inc. Logan County	3181	13	0.4	9
07/29	A.M.	Terra International, Inc. Champaign County	597	0	0.0	6

Date	***Time***	***Site Location***	***Number Accepted***	***Number Rejected***	***Rejection Rate (%)***	***# of Participants***
07/29	A.M.	Northern F.S. McHenry County	1691	452	21.1	10
08/01	A.M.	Weber Fertilizer, Inc. Iroquois County	1243	78	5.9	8
08/01	P.M.	Edwards Soil Service Livingston County	3700	23	0.6	5
08/02	A.M.	McLean County Service Co. McLean County	69	40	36.7	1
08/02	P.M.	Myers, Inc. McLean County	1899	62	3.2	4
08/03	A.M.	P.C. Ltd. Macon County	867	36	4.0	5
08/03	P.M.	P.C. Ltd. Moultrie County	561	27	4.6	3
08/04	A.M.	Terra International, Inc. Douglas County	3294	1012	23.5	3
08/04	P.M.	Sidell-Vermilion Service Co. Vermilion County	230	0	0.0	1
08/05	A.M.	Tri Central Cooperative Iroquois County	2316	166	6.7	5
Program Totals			***128,776***	***9761***	***7.0 %***	***337***

New Techniques for Aerial Application of Pesticides

Dennis R. Gardisser

The technology used to apply chemicals by air continues to improve. Almost all aircraft that are used for aerial applications today were designed and built specifically for this purpose. Several add-on systems enhance the efficiency of the basic airframes after they leave the factory where the airplane was built. These include spray monitors, electronic navigation and flagging systems, air conditioners and heaters, communication systems such as noise cancelling headsets with built-in stereos, hopper rinse systems, half boom shut-off systems, dry material spreaders, spray booms, and nozzles.

Aerial applicators have been continually pressured to improve their application efficiency and be better stewards of the environment by avoiding drift. Agricultural chemical prices continue to increase and agricultural crop profit margins continue to decrease. This causes good farm managers to scrutinize every aspect of their farming operation more closely. Pesticides represent one of the major costs in crop production, so their application efficiency, which affects efficacy, is monitored very closely. Aerial applicators are more visible than most ground applicators. Any drift off the target area will be met with strong opposition from individuals who wish to avoid any chemical on their land, as well as groups with environmental stewardship concerns.

Nozzles

Nozzle technology has not changed significantly over the last few years, but aerial applicators have changed the type of nozzle they select for use on their systems. Only a few years ago, the most common nozzle type was a cone or hollow cone type—usually a disc and core combination. Now the most commonly selected nozzle is one that produces a flat sheet of spray. This may be accomplished using a standard flat fan tip. These tips are mounted so that the spray is emitted parallel to the existing airstream and the sheet is parallel to the ground. The fan angle varies depending on the amount of drift control needed. Narrow angled nozzles provide better control because they place less shear on the spray as it is emitted and form a pattern that does not project a large amount of the spray laterally to be impacted by the high speed air moving around the nozzle.

One of the more popular aerial nozzles that produces a sheet of spray is the CP. This nozzle has become popular only in the last few years. The CP nozzle has four different orifice sizes and a plugged position, as well as three different spray deflector plates. Thus this nozzle can provide a range of different sizes over a wide range of application rates.

Spray Monitors

The actual number of aircraft in use has decreased over the last 10 years. The number of acres treated by aircraft has actually increased over the last 10 years. With fewer aircraft doing more work, the aircraft are obviously more productive, but the number and complexity of their tasks vary more than previously. Electronic monitors are being used to allow precise changes from one application rate to another. These systems may also be calibrated to help the operator determine differences in fluid viscosities.

Aerial applicators vigilantly try to maintain a constant ground speed as the wind direction and speed varies and their application direction changes. Measurement of actual ground speed was virtually impossible until recently. The Global Positioning System (GPS), which will allow accurate measurement of ground speed, can then be coupled to a spray monitor/rate controller to provide a more accurate application dosage. These control systems are currently under development.

DGPS (Differential Global Positioning System) Navigation and Electronic Flagging Systems

Turbine powered engines and DGPS have had the largest impact on aerial application of any developments in the last 10 years. The DGPS aerial applicators utilize a ground based tower that provides faster and more accurate position readings. Hardware and software for aircraft mounted GPS systems now allow the operator to mark and record the position of the aircraft during the application. The record may also indicate whether the aircraft is ferrying material or actually making an application.

Using these systems, the operator can select a swath width and use the guidance cues provided by the system to make more timely applications without coordinating activities with human flaggers. This also eliminates the worry about physical contamination to a person in the field. The cues, which are provided with startling accuracy, vary in form depending upon the manufacturer, but most are some type of light bar situated in the pilot's view field in combination with a screen type display in the cockpit. These systems are also accurate enough to provide some feedback on actual field size, which makes calibration checks much easier. Heads-up displays similar to those used by fighter aircraft are under development and are expected to be on the market soon.

Half Boom Systems

Aerial applicators are concerned about drift and environmental stewardship, and they are continually looking for ways to improve application efficiency and avoid off-target drift. Systems have been developed that allow the downwind half of the boom to be turned off during sensitive applications. This technology should allow the aerial applicator to work with narrower buffer areas with an extra margin of safety.

Dry Material Spreaders

Large volumes of fertilizers, seeds, and pesticides are applied aerially each year. The most common type of spreader on fixed wing aircraft is the venture or ram-air spreader. As instrument and measuring techniques have improved over the years, a better understanding of how to design and adjust spreaders has been achieved. Systems to quickly and accurately measure dry material deposition patterns from agricultural aircraft have been developed and utilized extensively.

Subtle but important changes in vane design have improved spread pattern uniformity and allowed easier adjustment of the spreaders. Engineers and operators have also learned that the correct spreader mounting angle improves the uniformity of the spread pattern, makes the aircraft fly better, and keeps the dry material from sandblasting the tailwheel and bottom of the fuselage.

There seems to have been an increase in the use of dry materials as carriers for pesticides. Dry materials provide a more predictable flight path because the particle size does not change because of evaporation. There are some concerns with handling exposure and the possibility of dust inhalation by the loading crew.

Temperature and Communication Systems

Pilots spend very long hours in the cockpit during the application season(s). Noise, dust, wind, and temperatures outside the human body's median comfort range can significantly increase the stress level that must be endured. Systems have been developed to help maintain the cockpit temperature at a desirable comfort level. This requires that the cockpit be enclosed and it may even incorporate some air-scrubbing device to remove dust and fumes.

Enclosed cockpits provide a more relaxed atmosphere in which to work, but they can still be noisy because of propeller and engine noise, given the amount of horsepower that is being developed. The noise cancelling headset, usually incorporated into the pilot's crash helmet, cancels loud or high energy noises and allows the pilot to be more relaxed. This also facilitates easier voice communications with other aircraft, loader crew, and base radios. Pilots can also focus their concentration on the application without noise distractions.

1994 Resprays and Implications for 1995

Daniel J. Childs

In China it may have been the year of the dog, but in Indiana, 1994 was the year of the weed. Weed control was unsatisfactory during the 1994 season, primarily due to untimely rains. In many areas of Indiana, periods of dry weather followed soil-applied herbicide treatments, which were then not activated in a timely manner. Cultivation was used in conventional systems to help kill weeds that escaped these soil treatments, but for narrow-row soybeans and no-till systems, cultivation was not an option. Thus, postemergence treatments were applied to these fields. In addition, rains returned to many of these once dry areas, keeping the fields wet. As a result, these postemergence treatments could not be applied until after many of the weed species had grown out of control. Weed control specialists received many inquiries asking how to kill oversized weeds in both corn and soybeans during the summer of 1994.

Some new herbicide products were introduced in 1994, but because of the untimely rains, evaluation of these products was difficult. Rain is needed soon after application for soil-applied herbicides to be effective, particularly when not incorporating. Many no-till growers are choosing to spray their soil-applied herbicides early to take advantage of spring rains, but herbicides applied at planting may not be effective if the needed rain is not forthcoming.

Postemergence treatments require correct identification of weeds and timing of application. Weeds that emerge during the first 5 to 6 weeks after planting have the greatest effect on crop yields. Therefore, treatments must be applied during this period. Weeds that emerge after 6 weeks generally do not cause significant yield loss.

With timely applications, many growers have been able to control weeds using less herbicide than the amount indicated on the label. This works only if the weed is identified correctly, the herbicide is very effective on that particular weed, the herbicide is sprayed when the weed is small and actively growing, and the crop can form a quick canopy. If any of these factors are lacking, controlling weeds with reduced rates of herbicides will fail, as was the case in several Indiana counties in 1994. These acres were then respired with more herbicide, so the initial advantage of lowering application costs was lost.

Even full-rate applications were ineffective in many areas of the state. A fall survey of custom applicators in Indiana indicated that an estimated 25 percent of the total corn and soybean acreage was respired due to poor herbicide performance.

Another potential problem with resprays or late postemergence applications is the risk that postemergence herbicides with residual activity may carry over to the next rotational crop and cause significant injury. With adequate rainfall after application and before the soil freezes, this risk is diminished. However, carnivore can be a problem in areas where rain is sparse. The previously mentioned survey of applicators revealed that an estimated 25 percent of the soybean acreage in southern Indiana was treated with a residual herbicide after July 1. This acreage will likely be rotated to corn in 1995. Management strategies will need to be designed that will reduce carnivore injury in these fields and limit the "additive" effects of corn herbicides that have similar modes of action to the soybean herbicides used the previous year.

New Developments from Industry

New Herbicide Developments

Steve E. Hart

Broadstrike and Battalion are two new herbicides for preemergence broadleaf weed control in corn. Broadstrike was introduced as a premix with Dual in 1994, and Battalion is expected to be introduced in 1996. These herbicides provide the Illinois corn growers with alternatives to atrazine for preemergence broadleaf weed control. Due to their extremely low-use rates, these herbicides may have less detrimental environmental impact than atrazine. Field trials were conducted in 1994 throughout Illinois to compare the broadleaf weed control of Broadstrike and Battalion with that of atrazine. Experimental locations were the Northern Illinois Agronomy Research Center near Dekalb (Drummer silty clay loam, O.M.= 5.0 percent, pH of 6.1), the Agronomy/Plant Pathology South Farm at Urbana (Drummer/Flanagan silty clay loam, O.M.= 1.5 percent, pH of 5.7), and the Brownstown Agronomy Research Center at Brownstown (Cisne silt loam, O.M.= 1.5 percent, pH of 6.7).

Herbicide treatments compared were Broadstrike/Dual and Battalion tank-mixed with Harness Plus and Bicep applied at the recommended rates depending on soil types. These treatments were compared in both conventional and no-till corn applied early preplant, preplant incorporated, and preemergence.

Overall preemergence herbicide performance at Dekalb was poor due to limited rainfall after application. In conventional tillage corn, all three herbicides failed to control velvetleaf 8 weeks after treatment. However, control with Broadstrike and Battalion was substantially higher than with atrazine. Broadleaf weed control in no-till with these treatments applied 2 weeks early preplant or preemergence was better than with conventional tillage, with the three herbicides providing roughly equal levels of giant ragweed, lambsquarters, and velvetleaf control. However, broadleaf weed pressure was light throughout the experiment because of a failure to control the heavy pressure of giant foxtail.

Overall weed control at Urbana was better than at Dekalb because of greater and more timely rainfall after herbicide application. Broadstrike performed well in no-till experiments when it was applied 2 or 4 weeks early preplant or preemergence, providing good control of velvetleaf, Pennsylvania smartweed, and lambsquarters. These levels of control were equal to those of atrazine and Battalion applied 2 weeks early preplant. In conventional tillage studies, all three treatments controlled smooth pigweed and cocklebur when they were applied preplant incorporated. However, Broadstrike failed to control tall morningglory. When these treatments were applied preemergence, Broadstrike and Battalion provided equal levels of broadleaf weed control and superior velvetleaf control compared to atrazine.

At both Dekalb and Urbana (locations with similar soil types), corn safety was excellent with Broadstrike and Battalion with no visible corn injury observed. As at Dekalb, rainfall after application at Brownstown was limited, thus reducing overall preemergence herbicide effectiveness. However, weed pressure was light, particularly in no-till experiments. In these no-till experiments, Battalion controlled lambsquarters and jimsonweed equally as well as atrazine, but Broadstrike did not. However, Battalion injury was observed on corn 8 weeks after treatment, which is cause for concern. In conventional tillage studies, the three herbicide treatments provided equal control of smooth pigweed and tall morningglory when they were applied preplant incorporated. They also provided equal control of smooth pigweed and Pennsylvania smartweed when they were applied preemergence. However, control of both velvetleaf and lambsquarters was greater with Broadstrike and Battalion. Given adequate rainfall, Broadstrike and Battalion apparently have the potential to provide good control of several troublesome weeds in Illinois. Experimental results suggest that these compounds may also have the potential to provide superior velvetleaf control. However, the weed control spectrum of Broadstrike, which seems to exclude tall morningglory and jimsonweed, does not appear to be as broad as that of atrazine. Battalion's spectrum of weed control appears greater but the observation of mid-season crop injury at Brownstown may be cause for concern.

Races of Phytophthora Attacking Soybeans

Jack Paxton

Phytophthora root and stem rot has been reported by soybean growers since 1955. Previously known as Phytophthora megasperma f.sp. sojae, this disease is now called Phytophthora sojae. It has been a problem in most of the United States, as well as in Argentina, Australia, Canada, Hungary, Italy, Japan, and the Soviet Union, so its distribution is worldwide.

Phytophthora root rot of soybeans is favored by cool, wet weather. Because flooding favors this disease , field drainage is very important in reducing it, and because of this, most of the soybean fields in Illinois have been tilled.

Thirty-seven races of Phytophthora sojae have been reported in the literature and many more have been discovered but have not yet been reported. The races of Phytophthora sojae are determined by the reaction of a large set of soybean cultivars to hypocotyl inoculation, but the isolate remains in question. The race can be determined only by which cultivars, in a set of cultivars chosen for their reaction to Phytophthora sojae, are susceptible or resistant to the given isolate. Race determination of isolates is therefore hindered by a large time and materials requirement to test isolates of the pathogen. Race determination is further constrained by the set of soybean cultivars chosen in the race screen. This means that for a given isolate, race determination could be meaningless because a new race would be given a race designation based on cultivar reactions that were not in the parentage of the host cultivar. Research is underway to develop molecular markers for Phytophthora sojae races that would be specific for Avirluence genes in this pathogen.

Metalaxyl is the only fungicide registered for protection of soybean plants from Phytophthora root rot. Resistance to this fungicide has been reported in other Phytophthora species and is a possibility with this pathogen. Biological control is another possibility for control of Phytophthora root rot of soybeans, but commercially acceptable control agents remain to be developed.

Because of the variability of this pathogen and its widespread occurrence, its control remains an important problem for plant pathologists.

USDA Recordkeeping Requirements: 1994 Results, Proposed Changes for 1995, and the Role of Commercial Applicators

G. C. Kirbach

Background

Effective May 1, 1993, the Agricultural Marketing Service, United States Department of Agriculture, amended the ***Food, Agriculture, Conservation, and Trade Act of 1990 (FACT Act)*** to implement regulations concerning recordkeeping requirements for certified applicators of federally restricted use pesticides (Section 1491). The purpose of the amendment to FACT was "to develop and maintain a comprehensive data base to provide accurate Federal restricted use pesticide data, which can be utilized by State and Federal agencies and for annual reporting to Congress by the U.S. Department of Agriculture and the Environmental Protection Agency on the use of agricultural and non-agricultural federally restricted use pesticides." The proposed regulations include a provision for protecting the identity of individual producers in surveys and reports. However, the rules do not include any requirement for reporting by certified applicators.

FACT Act

This paper reviews the provisions of the FACT Act, the results of the first survey performed by the Illinois Department of Agriculture, results of surveys in Idaho and Michigan, and the proposed amendments to the Act that have been published. The FACT Act "obligates" the Secretary of Agriculture, in consultation with the Administrator of EPA, to require recordkeeping regarding the use of restricted use pesticides. Section 1491(f) of the Act requires the USDA to survey certified applicator records and develop and maintain a comprehensive database to provide accurate federally restricted use pesticide (RUP) use data.

With increased awareness of pesticide safety, the public has become very concerned about the adverse effects of pesticides on food, worker safety, and the environment. The USDA has recognized that some of these concerns are based upon misinformation. The notoriety of the presence of pesticides in drinking water supplies has continued to direct the public focus on pesticide usage. The USDA believes that there are potential benefits from such recordkeeping requirements. Some of those benefits are: 1) Pesticide recordkeeping will provide factual data to help reduce consumer anxieties about food safety and environmental concerns; 2) these records should enable the farmer to track which treatments work, as well as experiment with and evaluate different application rates, products, techniques, and growing conditions that will allow for the effective and efficient monitoring of pesticide use; 3) pesticide recordkeeping is one of the major tools of Integrated Pest Management, including the monitoring, selection, integration, and implementation of control tactics; by selection of the most efficient combination of control tactics, pesticide use could be reduced; and 4) information from such records could assist the Environmental Protection Agency (USEPA) in the evaluation process and help in the re-registration process, which could potentially preserve registrations for minor use pesticides.

Private applicators are defined as anyone certified by USEPA or the State to use or supervise the use of a restricted use pesticide for the production of any agricultural commodity on property owned or rented by the applicator. Within 30 days after the application of **restricted use** pesticides, a private applicator must make a written record of the following:

- the brand name or product name of the restricted use pesticide and its EPA registration number
- the total amount of the product used, excluding water or other substances added
- the crop, commodity, stored product, or site to which the pesticide was applied
- the location of the application (this designation could be by county, range, township, and section; maps or written description; an

identification such as ASCS; or the legal property description)
- the month, day, and year of the application
- the name and **certification number** of the applicator or applicator's supervisor

All records must be maintained for a period of two years from the date of the pesticide application. The statute does not mandate the use of a required form, as long as the required data are included.

Proposed Changes for 1995

Early in the implementation phase of the program, a lawsuit was filed against the Secretary of Agriculture and the Administrator of the Environmental Protection Agency by the National Coalition Against the Misuse of Pesticides and Others. This lawsuit challenged "the substance of limited portions of the final regulations." Coupled with concerns involving specific interpretations by state agencies, this lawsuit moved USDA to review the rules, which resulted in the proposed revision of the regulations published April 6, 1994.

Under this proposal, several comments were received concerning "the release of the recorded information promptly for medical treatment." USDA originally defined a medical emergency as ***"injuries or illnesses which require immediate medical attention to prevent life-threatening or disabling conditions."*** Concern was raised about the need to react immediately to some exposures that did not fit the current definition. The new proposal would define a medical emergency as ***"a situation that requires immediate medical treatment or first aid."***

Another medical issue concerned the release of the pesticide information to a licensed health care professional. The published rule stated that information could be shared with a licensed health care professional as long as it pertained to the medical treatment. The proposed change would define a health care professional as a physician, nurse, emergency medical technician, or other qualified individual, certified by the State to provide medical treatment. This would exclude individuals who are certified to provide first aid or "CPR" by the American Red Cross. The revision also specifies that licensed health care professionals may release and utilize the information only under the following circumstances: 1) The submission of pesticide poisoning incident reports to appropriate s tate or federal agencies, or 2) where consideration of medical ethics may necessitate such utilization and release.

Finally, changes that would affect the remaining specific sections of the rules are as follows:

1) The recordkeeping requirements for "spot" treatments are to be recorded in the same manner as the other applications of federally restricted use pesticides. This would include field or area locations, as a means to assist in instances of potential exposure.

2) The proposed changes would reduce the maximum time period for recording after application from 30 days to 7 days. The 7 days is considered adequate without placing undue hardship on applicators during the peak production periods.

3) Finally, an applicator is required to release the information immediately upon request, even though an official record may not yet have been generated (i.e. less than 7 days). This release requirement is related to medical emergencies only.

Recordkeeping Requirements for Commercial Applicators

Commercial applicators who offer the service of maintaining records for private applicators and/or their customers will be required to maintain the same information as the private applicator. All records must be maintained for a period of two years. For all commercial applicators providing a recordkeeping service, the information must be recorded within 7 days of the application if the proposed changes go into effect. Industry has raised concern that this will present a burden to the commercial applicator during the "busy season." However, USDA has maintained that the 7-day proposed requirement would be mandated by statute. If the proposed changes are not passed, then the 30-day requirement would remain in effect. This time requirement would mandate that the commercial applicator would furnish a copy of the information to the person within the current 30-day time limit or 7 days as proposed.

Accessibility to records represented one of the more intensely contested issues of the rule. The statute reads ***"Records maintained under subsection (a) shall be made available to any Federal or State agency that deals with pesticide use or any health or environmental issue related to the use of pesticides, on the request of such agency. Each Federal Agency shall conduct surveys, but in no case may a government agency release data, including the location from which the data was derived, that would directly or indirectly reveal the identity of individual producers. State agency requests for access to records shall be through the lead State Agency so designated by the state (IDOA)."***

Access to the data will be provided in one of two ways. First, the National Agricultural Statistics Service of USDA will conduct voluntary pesticide use surveys for acquiring use data. This was performed by the Illinois Department of Agriculture under contract to USDA for the survey conducted last year. The results of this survey for recordkeeping and access are presented in Tables 1 and 2 respectively. Secondly, both USDA and state agencies will conduct compliance inspections. The compliance results for the Illinois survey are presented in Table 3. It is the intent of such inspections to be performed during "reasonable" time periods and to avoid peak production periods. Finally, there was the issue of who should receive a copy of the information from the commercial applicator. USDA's interpretation would mean that the copy should be provided to the person who contacts the commercial applicator. One major impact on all commercial applicators is the requirement that ***"all commercial applicators who make an application of a restricted use pesticide for an individual shall furnish a copy of the records maintained to the individual for whom the restricted use pesticide was applied within 30 days."***

Penalties

Penalties for failure to comply with this act shall be as follows for the current statute as well as the proposed revision:

1) Any certified applicator who violates the requirements shall be liable for a civil penalty of not more than $500.00 in the case of a first offense;

Table 1. USDA recordkeeping survey results

SURVEY RESULTS FOR APPLICATION	TOTAL %*
Applied by custom applicator	11.0
Did not use pesticides in '93 or '94	0.5
Did not know what to do	3.0
Refused to do the survey	2.5
Does not apply RUP	0.5

* The percent is based upon a total of 148 respondents that were randomly selected from a total of 30,000.

Table 2. Survey results for information access

MEDIA OR AGENCY SOURCE	PERCENT*
USDA Mailing	3.0
Illinois Dept. of Agriculture	24.0
Cooperative Extension Service	31.0
Other Sources	40.0
No Response	2.0

* Percent represents the total of 148 randomly selected respondents (Illinois).

Table 3. Survey results for compliance

COMPLIANCE COMPONENT MANDATED BY FACT	ILLINOIS[1] PERCENT COMPLIANCE	IDAHO[2] PERCENT COMPLIANCE	MICHIGAN[3] PERCENT COMPLIANCE
Brand/Product Name	88.0	100.0	81.0
EPA Registration Number	53.0	41.0	31.0
Amount Applied	77.0	81.0	62.0
Location of Application	86.0	94.0	81.0
Size/Area Application	87.0	78.0	62.0
Crop/Size	83.0	89.0	73.0
Date of Application	82.0	96.0	81.0
Name of Applicator	69.0	59.0	46.0
Certification Number	38.0	26.0	31.0

[1] Percent represents the percent total of 148 randomly selected respondents.

[2] Percent represents the percent total of 39 records checked.

[3] Percent represents the percent total of 21 records checked.

2) any certified applicator who violates the requirements shall be liable for a civil penalty of not less than $1000.00 for each subsequent offense, except that the penalty shall be less if the Administrator determines that the certified applicator made a good faith effort to comply with this part.

Conclusion

In summary, it is important to distinguish between compliance and the voluntary surveys. Surveys will be pursued to obtain accurate information on federally restricted use pesticide usage and then report the results to Congress. This will represent an overall effort for education and outreach. Compliance, on the other hand, will be measured as a regulatory effort. It is my opinion that the importance of recordkeeping is to provide accurate information, reduce concern over misinformation, and provide a tracking system to evaluate pest control programs objectively. A tracking system of this nature could be a viable tool for producers to refine production to their advantage through financial benefits, risk assessment, risk reduction, and sound stewardship based upon experience at their level. I believe that the producer's decision will be to approach this either as a beneficial tool or as a nuisance. After careful consideration, it is my opinion that the generation of these records could represent another resource to enhance agricultural production. For further information, please contact the Department at (217) 785-2427, TDD (217) 524-6858.

Weed Species Shifts

Ellery L. Knake and Aaron G. Hager

In recent years there have been some dramatic changes in tillage practices, introduction of new herbicides, and shifts in weed control practices. These and other modifications have influenced our weed complex. Some weed species have increased while others have decreased.

Tillage, such as moldboard plowing, tends to bury some of the small weed seeds. Even though some of the smaller seeds might germinate at a depth of a few inches, they may not have enough energy reserves to allow the seedlings to emerge. Leaving these small seeds near the surface, covered by enough crop residue to create a moist microclimate, can be conducive to germination. Thus, we often see an increase in fall panicum associated with no-till, especially where major reliance has been on atrazine. This may also help to explain some increase in eastern black nightshade in soybeans. Although the trend to no-till may also help to explain an increase in redroot and smooth pigweed, it may be less obvious for these species, because they are controlled so easily with many of the soil-applied herbicides regardless of the type of tillage.

The no-till trend has also prompted increased concern for winter annual weeds such as pepperweed, shepherd's-purse, and mustards, which appreciate not having their life cycle broken by tillage. However, if infestations are not too serious, the problem may "resolve itself" because the plants mature relatively early. Downy brome can present more of a challenge.

Some growers have found that 2,4-D can sometimes have an advantage over dicamba, especially where old alfalfa fields lose their vigor of youth and allow dandelions to proliferate. Culprits such as trumpet creeper, brambles, and even tree seedlings such as mulberry and boxelder move in as cold steel moves out.

Some large seeds such as cocklebur, when left on the soil surface, may not imbibe enough moisture for germination. Such factors as light, aeration, and nutrient relationships can also affect seed germination. Velvetleaf, for example, is favored by disturbing the soil with tillage. Red sorrel is favored by soils with low pH.

Weeds can also adversely affect other weeds. For example, a vigorous stand of giant foxtail may be accompanied by few other weeds, but a good stand of quackgrass can preclude the growth of foxtail.

It is somewhat surprising that the effect of insects and diseases on weeds has not been more dramatic or obvious. Perhaps we simply have not been keen enough observers. Those who remember the spines of horsenettle when shocking oats might say that this species has decreased. Horsenettle and potato are both of the Solanum genus. A beetle closely related to the Colorado potato beetle has been noted decimating horsenettle. More recently we have noted that some of the atrazine resistant pigweed seems to be more palatable to an insect.

Although such concepts, observations, and speculations may be interesting, especially to the academic community, some weed species shifts are presenting rather urgent, real-life challenges that require greater precision in the design of weed control programs.

Giant foxtail, an introduced species, has found a real home in Illinois and is our most significant annual grass weed. Fortunately we have good controls for it, with postemergence treatments sometimes outperforming preemergence treatments, or at least providing a good backup. In some areas the robust type of foxtail is quite evident. Although bristly foxtail has a foothold in a few areas, it does not seem to be spreading very rapidly. Perhaps its "sticky" nature, due to the retorse barbs on the awns, helps it to "stay put." The fact that yellow foxtail is a little less sensitive than giant foxtail to Accent and Assure II has prompted some rethinking in control strategy for a few fields.

Johnsongrass and shattercane are definitely taking a nose dive following the introduction of

Accent and Beacon. Pursuit, as well as the dinitroaniline (DNA) herbicides, have also played a role in addition to the postemergence grass killers for soybeans. Because of the genetic diversity of the sorghum species, potential for resistance could create a problem unless we take advantage of the variety of treatments available.

Although quackgrass was somewhat relieved when atrazine restrictions reduced rates, the joy was short-lived as the price of Roundup was reduced, and Accent and some other postemergence grass killers were introduced. Although wirestem muhly was once worrisome, especially in the northwestern part of the state, Roundup has been a first line of defense. Some of the postemergence grass killers for soybeans have also been effective.

Sorghum almum has also "met its match" with the introduction of Accent and Beacon. This offender has been primarily in northwestern Illinois since it was introduced years ago as Kangaroo grass forage for dairy cattle. Hopefully it will now be on the downgrade.

Crabgrass frequently becomes quite evident as being tolerant of Accent and Beacon. Fortunately, it is often controlled by an earlier preemergence treatment or does not grow vigorously enough to be of great concern, but there can be exceptions. Woolly cupgrass can be somewhat of a challenge. One of the main areas of infestation is in Livingston county. It has been there for many years and now is being found elsewhere in the state. Accent may provide some control if it is applied prayerfully. Similarly, wild proso millet is considered quite serious in Wisconsin and some has been observed in northern Illinois, possibly carried into the state on sweet corn harvesting equipment. However, it does not seem to be spreading to a very significant extent in Illinois.

Yellow nutsedge in corn or soybeans is favored by wet weather, but can be controlled quite easily with Basagran. Herbicides such as Lasso and Dual have also helped and the new Permit gives good control. An insect referred to as "bactra" may also be giving a little subtle help.

Horseweed (marestail) and prickly lettuce frequently increase soon after a shift to no-till. Although the burndown and residual of Canopy can give control, Pursuit needs the help of Roundup plus 2,4-D, which can also be considered for corn.

Hemp dogbane has been on the increase with reduced tillage because its roots are less disturbed. It remains somewhat of a challenge, although Roundup has been helpful, especially when applied with determination, such as with a wick or sponge applicator repeated in the opposite direction. Although fluroxypyr has given good control in research trials, the market has been considered too limited to justify registration. Common milkweed is in a somewhat similar category as dogbane.

Pokeweed is another culprit that is becoming more evident in no-till fields. Thus far, the conspicuous, large, succulent plants are usually only scattered, as if seeds were dispersed randomly by birds attracted to the berries. Although pigweed can be a very prolific seed producer with over 100,000 seeds per plant, many of the soil-applied herbicides hold it in check. Even those intended primarily for grass weeds, such as the DNA and acetamide herbicides, can give good control. However, a shift to more Bladex and less atrazine could favor pigweed. With Command on pigweed, little more than some strange coloration can be expected. Although the postemergence route sent up a yellow flag, adding Blazer to Basagran to give Galaxy detoured the pigweed. The popularity of Pursuit has also helped to hold some pigweeds in check but it is probably time to differentiate and be more precise.

Tall and common waterhemp are species of Amaranthus, the genus for pigweed. Waterhemp is more challenging than redroot or smooth pigweed, and breaks in control have likely contributed to its spread, especially in the area near Route 70.

Lambsquarters has increased to some extent. This may be associated to some degree with decreased use of Treflan, increased use of Pursuit, and some development of resistance to atrazine. Treflan can control lambsquarters if the rate is not skimpy, but this culprit is not quite as sensitive as pigweed. Prowl can also do well and for lambsquarters, Pursuit Plus soil-applied may be a better choice than Pursuit postemergence. The acetamides are somewhat variable. Lambsquarters is an Achilles' heal for Pursuit. Pinnacle, although not 100 percent, has helped plug a few holes in the dike and has counteracted some of the potential for increased lambsquarters. With lambsquarters, as well as pigweed, we will need to keep a step ahead of atrazine resistance.

Both lambsquarters and giant ragweed are early risers that without seedbed preparation can become a major challenge, especially for some of the postemergence herbicides for soybeans.

Velvetleaf remains one of the most significant broadleaves, especially in northern and central Illinois. On the negative side, the reduction in atrazine rates has allowed velvetleaf to increase. However, increasing the triazine rate by adding Bladex to atrazine for Extrazine II has helped. Command, even at a reduced rate, is quite effective. No-till has discouraged velvetleaf to some extent. The net effect is that velvetleaf remains a significant weed. Growers should keep an eye on Resource and also CIBA's CGA 248757 for offering significant flexibility for control of velvetleaf.

Pennsylvania smartweed is another significant consideration. However, it is very sensitive to atrazine, even at reduced rates. Although 2,4-D may only curl smartweed like a pig's tail, Banvel and Marksman almost "scare it to death." Loss of the triazines could prompt an increase in smartweed. Smartweed is also an early riser that can escape some burndowns unless they are complemented with atrazine. Swamp smartweed is a perennial usually confined to relatively small patches in low wet areas. The triazines and Banvel are not nearly as effective on swamp smartweed as on the annual Pennsylvania smartweed. However, Roundup can give some help.

Bur cucumber may be increasing in a few localized areas. Its vigorous growth and spiny nature justify prompt action where it is found. Although the triazines may help somewhat, the degree of residual is often too short to control the late germinators. Beacon and Accent may improve control.

Eastern black nightshade proliferated a few years ago and seems to be increasing again, although with the herbicides commonly used in corn, it is usually not a significant problem there. However, it can be a "hole in the armor" for the sulfonylurea herbicides, Classic and Pinnacle, and it can also escape Canopy. Although Beacon is also a sulfonylurea, it can give some control, but it is not used in soybeans. A major problem is that the berries are about the same size as soybeans and contain a sticky juice. One farmer reported that it was almost necessary to use a pick axe to get his soybeans out of the wagon. Fortunately, Pursuit can give very good control and be a first line of defense against nightshade.

Kochia is a very significant problem in some states further west, particularly since some atrazine resistant kochia has developed. Kochia has moved into Illinois and is becoming an increasing concern, partly because some of it appears to be resistant to atrazine. It first became evident along railroads, but it soon ignored boundary lines and moved into fields. Where atrazine resistance has developed, dicamba, Buctril, and pyridate (Tough) may offer some help. For soybeans, the DNA herbicides can help, and Canopy, Command, or Broadstrike can also be helpful. Most postemergence herbicides for soybeans have limited effectiveness on kochia, but may provide some help.

Hophornbeam copperleaf has been found primarily on alluvial soils near the Mississippi and Wabash rivers in southern Illinois. The leaves are somewhat heart-shaped with serrated edges. This offender is in the spurge family, and its seeds are in a three-seeded capsule with a single seed in each of the three compartments. It can be the predominant weed and quite dense in most of a field. In addition to Canopy, the diphenyl ether herbicides such as Blazer, Cobra, and Reflex can be of some help in soybeans, where copperleaf is much more common than in corn. We have also recently had several samples of toothed spurge ("wild poinsettia"), which has milky juice and a three-seeded capsule but the toothed leaves are relatively narrow. The toothed spurge appears to have a wider range in the state than does copperleaf. A little balloon vine, sicklepod, and hemp sesbania have moved from the south into southern Illinois, possibly with seed beans. There has also been increasing concern about spurred anoda and perhaps prickly sida.

Some serrated tussock seed was brought into Illinois in fescue seed imported from Argentina. Although some seed was sold before APHIS-USDA could control the situation, no firm evidence exists that the weed has gained a foothold in Illinois.

In summary, there have been relatively few new weeds introduced into Illinois in recent years. Potential for development of weeds resistant to certain herbicides justifies a watchful eye and increased consideration of herbicide rotations to avoid new problems. The major shift in weed species is probably associated with changes in tillage practices. The predominant use of certain new herbicides may also be permitting an increase in some species. However, with the diversity of herbicides still available, plus appropriate cultural practices, the majority of emerging weed problems can usually be controlled. But it may require a willingness to change the selection and use of weed control practices, which should not be a problem for most farmers who like to explore new ideas.

Shifts in Weed Control Practices

Dennis R. Epplin

The availability of new technology and the changing economic costs of all control measures cause shifts in weed control practices. Weed control is an ever changing science, and some would argue that it is an art. This presentation will focus on recent changes in weed control practices in southern Illinois. Some of the trends are unique to that geographic area, whereas others are almost universal across the corn belt.

Illinois extends about 400 miles north to south. The southern part of the state has a much longer growing season and accumulates at least 1,000 more growing degree days than the northern part. In addition to the longer growing season there, southern Illinois also has an "early greenup" of vegetation that usually occurs by April 1. Both of these factors have major implications for weed management.

The continuing shift to no-till has probably influenced weed control more than any other change in weed control measures. Along with equipment innovation, the introduction of triazine herbicides contributed significantly to George McKibben's early successes with no-till corn at the Dixon Springs Agricultural Center. Soon after these early successes, growers discovered that the expense associated with a knockdown herbicide could be avoided by utilizing triazines as early preplant treatments. Now it has become necessary to turn to new technology to reduce dependence on triazines in order to comply with environmental goals.

Full-season no-till soybeans are currently becoming quite popular. Advancements in no-till drill design allow better establishment, and narrow drill rows aid in quick crop canopy to reduce weed competition. Equally important has been the introduction of effective postemergence herbicides. Double-crop soybeans following wheat are somewhat unique to southern Illinois. Growers are now scouting to determine if a knockdown herbicide is necessary at planting. It may be possible to determine that a successful stand has been established before investing additional resources. Then a grower can identify specific weed problems and apply the appropriate postemergence treatments. Previously, the grower incurred the expense of a knockdown herbicide and preemergence grass and broadleaf herbicides before it was determined whether soybeans could be established.

Postemergence herbicide treatments have changed dramatically. Once considered primarily for rescue or salvage, postemergence applications are now used to target specific weed problems with less dependence on weather conditions. Many new postemergence herbicides, which are competitive in price with preemergence products, have recently been introduced for control of both broadleaf and grass weeds in corn and soybeans.

Although changes in control measures have helped to solve some weed problems, perennial weeds are increasing with no-till. Milkweed, hemp dogbane, bigroot morningglory, trumpetcreeper, and other perennial weeds are becoming a significant challenge. Proper timing of treatments is often difficult to achieve in corn and soybeans, and more effective herbicides are needed, especially for broadleaf weed control in soybeans.

Herbicide resistant weeds deserve mention. Although this is not a major problem at this time, its potential development dictates that both crops and herbicide modes of action should be rotated.

There is a trend toward more specialized spray equipment for both farmers and custom applicators. The low-pressure field sprayer is still the mainstay on the farm, but pick-up sprayers and ATV sprayers are now common. Custom applicators struggle with the many decisions associated with selecting truck, high clearance, and flotation equipment. There is a definite trend toward fewer grower-applied herbicides and more custom applications.

One of the oldest methods of weed management has been rediscovered. Cover crops are making a comeback. Cover crops can serve several purposes:

reduce soil erosion, suppress weeds, provide a mulch, trap excess nitrogen, fix nitrogen (legumes), and improve soil characteristics. Cover crops also have some potential disadvantages that should be considered. There are many cover crop possibilities, but the popular choices appear to be hairy vetch preceding corn and rye preceding soybeans.

Looking to the future, increased regulatory requirements will affect agriculture and have an impact upon weed control. Developing technology such as microprocessors, global positioning systems, variable-rate technology, and site-specific applications will be on the southern Illinois scene to a very limited extent during the 1995 growing season. The niche for herbicide resistant/tolerant crops is still being explored. Progressive growers and custom applicators will continue to adapt to the changing challenges of weed management by taking advantage of new technology as it develops.

Survey of IPM Practices in Central Illinois

George F. Czapar

Introduction

During the last 20 years, the role of Integrated Pest Management (IPM) in production agriculture has continued to grow. It is often included as a major component in discussions of food safety and water quality. In 1993, the Clinton Administration set a goal to develop and implement IPM programs on 75 percent of the total cropland in the U.S. by the year 2000 (Browner et al. 1993).

IPM means different things to different people, so the definition of IPM and how to measure its adoption have been discussed at great length. Cate and Hinkle (1993) reviewed some of the many definitions and meanings of IPM.

Sorensen (1994) related the following definition from the National Coalition on IPM: "IPM is a system that controls pests and contributes to long-term sustainability by combining the judicious use of biological, cultural, physical and chemical tools in a way that minimizes the risks of pesticides to human health and the environment." It is sometimes difficult to define IPM, but it is equally challenging to measure its adoption. In 1989, the National Academy of Sciences estimated the national usage of IPM as 20 percent and 14 percent of the corn and soybean acreage respectively. They defined IPM acres as those acres where basic scouting and economic threshold techniques were reportedly used (National Research Council, 1989).

Recently, Vandeman et al. (1994) reported that scouting for insects, weeds, and diseases is currently done on 65 percent of U.S. corn acreage and 69 percent of soybean acreage. Their report also estimated that economic thresholds are used to determine herbicide applications for 53 percent of U.S. corn acreage and 59 percent of soybean acreage.

A more detailed method of evaluating IPM adoption has been proposed by Hollingsworth et al. (1994). They developed an IPM certification program that includes a checklist of specific practices. These practices are assigned a point system, with higher values given to certain essential elements. This system allows the grower to choose the practices that are most appropriate for an individual farm or situation.

Survey of Central Illinois Farmers

In order to describe IPM practices in central Illinois and identify limitations to further adoption, a survey was mailed to 988 farmers in eight central Illinois counties. The Illinois Agricultural Statistics Service selected the mailing list and assisted with the survey design. Farmers were asked about IPM practices, including how they make pest management decisions, and how concerned they are about several environmental issues.

Of the farmers surveyed, 41 percent said that they scout fields on a weekly basis. An additional 35 percent said that they scout fields at least two or three times per growing season. Only 3 percent of the farmers said that they seldom or never scout their fields.

Regarding how pest management decisions are made, responses indicated significant differences between insect and weed management. Approximately 34 percent of those surveyed responded that they use economic threshold as a basis for insect control decisions, whereas 21 percent reported reliance on dealer recommendations.

For weed management, 45 percent base their weed control decisions on the previous year's weed problems, whereas 17 percent use dealer recommendations. Only 9 percent use economic thresholds as a basis for weed management decisions.

When farmers were asked to identify the major reasons for not using economic thresholds for weed management, their most frequent response was concern about weeds interfering with harvest. Landlord perception, weed seed production for the future, and general appearance of the field were also identified as limitations.

Answers to questions about environmental issues indicated that farmers are most concerned about the effects of pesticides on applicator health and about government regulations. In contrast, the development of herbicide resistant weeds was not identified as a major concern.

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Status of Soybean Cyst Nematode Races in Illinois

Dale I. Edwards

Introduction

Resistant soybean cultivars are excellent for use in crop rotation programs to control the soybean cyst nematode *Heterodera glycines* (SCN). However, the ineffectiveness of some resistant cultivars in reducing SCN losses has strongly indicated a wide physiological variation among SCN populations. This physiological variation was evident in the very early stages of breeding for SCN resistance (Ross 1962), and even today, presents a challenge for soybean breeders and nematologists (Schmitt and Shannon 1992).

To further complicate the issue, nematologists have disagreed on how to classify physiological differences among plant-parasitic nematodes (Sidhu and Webster 1981, Sturhan 1985), and even on how to apply the terminology to infraspecific forms. This disagreement prompted nematologists and soybean breeders to meet jointly at Beltsville, Maryland, in 1969, at a workshop designed to clarify the physiological variation among SCN forms. At this workshop, it was agreed that the term *races* be used to designate infraspecific forms of SCN (Golden et al. 1970) and races 1 to 4 were described (Table 1), based on the reaction on four soybean differentials (Pickett, Peking, PI 88788, and PI 90763) relative to that on the susceptible standard, which was designated the variety Lee. A reproduction rate of less than 10 percent (<10 percent) of the reproduction rate on Lee was considered as a "no" or negative reaction, and greater than or equal to 10 percent (≥10 percent) was described as a "yes" or positive reaction. Race 5 was added to the race determination scheme by a Japanese nematologist (Inagaki 1979). In 1981, isolates fitting the description for races 6, 8, and 9 were reported (Riggs et al. 1981), but they were not assigned a race number. Isolates fitting the criteria for race 6 were reported from Indiana (Faghihi et al. 1985), and in a survey from Florida, isolates fitting the criteria for races 9 and 14 were reported (Lehman and Dunn 1987). Race 7 was reported during the same year by Chinese scientists (Chen et al. 1987).

Sixteen races of SCN are theoretically possible when using the four soybean differentials, and in 1988, researchers from the University of Arkansas (Riggs and Schmitt 1988) expanded the race scheme to classify the remaining combination of races (Table 1). Using the expanded race concept, they officially identified races 6, 9, 10, 13, 14, 15, and 16. Although 16 possible combinations of races are possible with this race scheme, not all have been identified. The expansion of the race test to include up to 16 races provides the means to identify previously unclassi-

Table 1. **Race classification for soybean cyst nematode based on reactions to host differentials (Riggs and Schmitt, 1988)**

RACE	PICKETT	PEKING	PI88788	PI90763	LEE[1]
1	–[2]	–	+	–	+
2	+[3]	+	+	–	+
3	–	–	–	–	+
4	+	+	+	+	+
5	+	–	+	–	+
6	+	–	–	–	+
7	–	–	+	+	+
8	–	–	–	+	+
9	+	+	–	–	+
10	+	–	–	+	+
11	–	+	+	–	+
12	–	+	–	+	+
13	–	+	–	–	+
14	+	+	–	+	+
15	+	–	+	+	+
16	–	+	+	+	+

[1] The soybean cultivar, Essex, has also been used (MacDonald et al. 1980) as well as Williams-82 (Sikora and Noel 1991).

[2] – = Number of females and cysts recovered was <10% of the number on Lee soybean.

[3] + = Number of females and cysts recovered was ≥10% of the number on Lee soybean.

fied races and improve communication between nematologists and soybean breeders in breeding for resistance to SCN.

SCN Races in Illinois

In 1989 and 1990, 44 populations of SCN were collected from sites in 23 Illinois counties. Using the expanded race scheme (Riggs and Schmitt 1988), the 44 populations were separated into 5 distinct races (Table 2). Twenty-eight (64 percent) of the populations were identified as race 3 and were found in 18 of the 23 counties surveyed. These counties were distributed in all regions of the state. Twelve (27 percent) of the populations were identified as race 1 and these were found in 10 different counties in the north, central, and west-central regions of the state. Race 5 was found twice, once in Ford county and once in Iroquois county, in the east-central part of the state. One race 2 population was found in Marion county and one race 4 was found in Jefferson county. Races 6 to 16, as described in the expanded race scheme, were not identified in this study. Another important aspect of this study was the comparison between Williams-82 and the Lee cultivar as susceptible standards. The comparisons with the two cultivars resulted in the same race determination 92 percent of the time. Because the Lee variety has been difficult to obtain, Williams-82 may be a suitable alternative for race testing.

In 1991, a race study was conducted at Southern Illinois University, involving 30 populations of SCN from various locations in Jackson County, Illinois (personal communications, Jack Phillips and Robert Frank). In this study, 19 of the 30 populations were race 3, three were race 6, one was race 4, and one was race 9. Race 3 was found at about the same frequency as in the University of Illinois study (Sikora and Noel 1991). Races 6 and 9 were not identified in the University of Illinois study.

Table 2. Frequency of occurrence of *Heterodera glycines* (SCN) races in Illinois based on 44 field populations (Sikora and Noel 1991)

RACE	NUMBER OF OCCURRENCES	PERCENT OCCURRENCE
1	12	27
2	1	2
3	28	64
4	1	2
5	2	5

In conclusion, races 1 and 3 appear to be the most common and most widely distributed races in the state. Races 2, 4, 5, 6, and 9 have been identified but they are not as common or widely distributed as races 1 and 3. It is highly possible that other races classified in the expanded race scheme exist in Illinois, because SCN is widespread throughout the state. The expansion of the race scheme to identify 16 races will now help to detect additional races and enable the progress for breeding SCN-resistant soybean cultivars to continue as it has in the past.

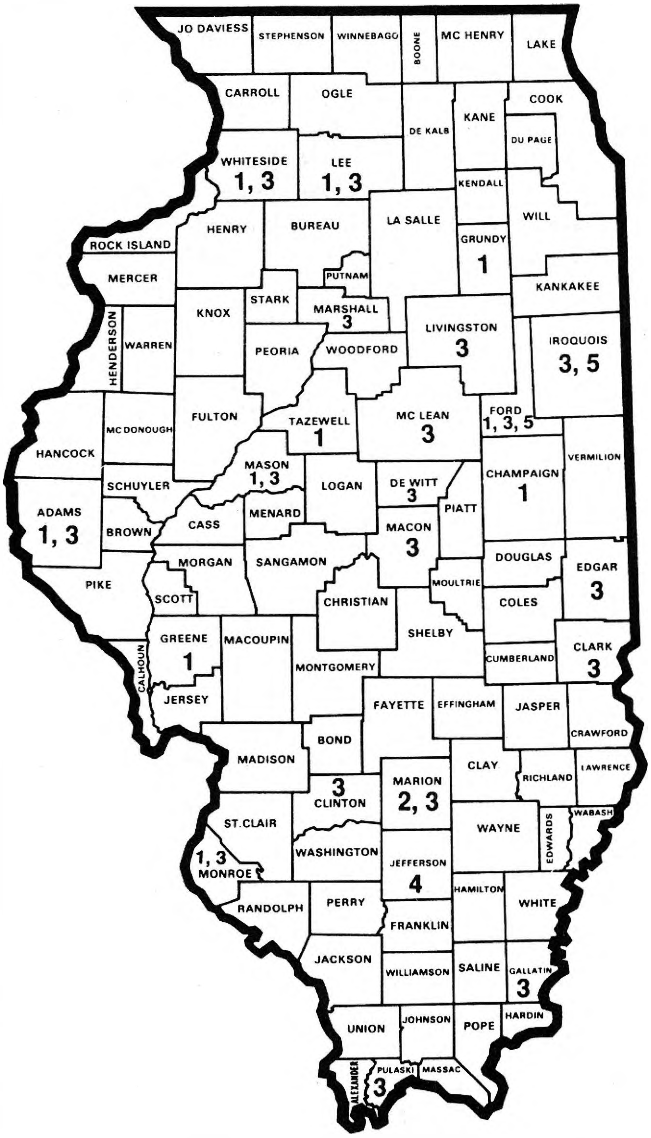

Figure 1. Distribution of *Heterodera glycines* (SCN) races in Illinois, 1989-1990 (Sikora and Noel 1991).

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Diagnosing Herbicide Injury

Aaron G. Hager

Chemical control of annual and perennial weed species is the most widely used method of weed control in Illinois crop production. It is most astonishing that weeds can be selectively controlled in a crop with little or no adverse effect on the crop itself. The science of chemical weed control is continually evolving. Early discoveries in chemical weed control, such as selective control of broadleaf but not grass weed species with 2,4-D, have been overshadowed by many of the more recent advances, such as selective, postemergence control of grass weeds in grass crops such as corn and wheat.

Ideally, herbicides should provide adequate control of the weeds present in a field for a sufficient period of time without adversely affecting the current or following crop. However, considering the extremely variable conditions under which herbicides are used, it is not uncommon to observe some type of crop injury following herbicide application. Crop injury may be caused by **direct applications** made during the current growing season, **drift** from applications to nearby fields, or **carryover** of herbicides applied to the field during previous growing seasons.

Correct diagnosis of the symptoms of herbicide injury is often complicated by factors unrelated to the herbicide (such as fertility deficiencies) that can produce similar, "look-alike" symptoms of injury. Environmental conditions prior to, during, and following herbicide application can considerably influence whether crop injury occurs. Genetic differences within the crop itself (such as corn hybrid differences in response to 2,4-D) can also be realted to crop injury. To complicate matters further, several factors influencing crop injury may interact to determine the degree of crop response. When several factors interact, diagnosis becomes increasingly difficult. Obtaining as much information as possible pertaining to a particular situation may be the single most important step in correctly diagnosing herbicide injury. What is the pattern of injury in the field? At what population was the crop planted? Has this problem occurred in the field during previous growing seasons? Were the fertility recommendations for this field followed? What treatments for insect or disease problems in this field have been applied this year? What were the environmental conditions at the time of the herbicide application? These are only a few of the questions that should be addressed when diagnosing crop injury. Contrary to popular opinion, the herbicide is not always the cause of crop injury.

Diagnosing herbicide injury requires some understanding of how a particular herbicide or herbicide family acts within the plant. Herbicide mode of action can be defined as the metabolic or physiological process(es) within the plant that is impaired or inhibited by the herbicide. Stated in simpler terms, mode of action is how the herbicide causes death of the plant. The site(s) of herbicide action is the physical location within the plant where the herbicide acts to exert its phytotoxic mode of action. Site of action and mode of action are phrases that are often used interchangeably but which do have distinctly different meanings and thus should be used discriminately. Herbicides are often classified according to their mode of action and herbicides with the same or similar mode of action generally produce similar injury symptoms. However, herbicides with distinctly different modes of action may also produce similar injury symptoms. For example, if soybean leaves appear chlorotic and necrotic within 24 to 48 hours following a postemergence herbicide application, the injury may have been caused by one of the cell membrane disrupter herbicides (protoporphyrinogen oxidase (PPO) inhibitors) or by a herbicide that interacts with photosynthesis.

Herbicide Selectivity

Herbicides that are used in a particular crop must have sufficient selectivity to provide an acceptable level of weed control without significantly damaging the crop. A given herbicide generally has the same target site in the crop plant as in the weed, and if the herbicide is able to reach its site of action within the crop, it can exert the same mode of action there that it exerts within the weed. When this occurs, visible crop injury symptoms are often observed. In other words, the crop plant is not completely "immune" to the herbicide because the herbicide is unable to differentiate between the crop and the weed.

Several physiological characteristics of herbicides can provide selectivity between the crop and the weed. These include differences in herbicide absorption, translocation, and metabolism .

Herbicide absorption can occur via roots or foliage or both, depending upon the herbicide. For root-absorbed herbicides, position of the herbicide in the soil, timing of application, and selective placement of the herbicide between crop rows can provide herbicide selectivity. Foliar absorption may be influenced by leaf properties (age, position, nature and amount of wax, pubescence, etc.), stage of plant growth, and spray additives.

Certain herbicides require translocation from their point of absorption to the site(s) of action. A reduced rate of herbicide translocation within the crop can provide selectivity. Differential herbicide translocation may be biotype or cultivar specific, and can also depend upon the ease with which the herbicide is loaded into the translocation system. Adsorption of the herbicide to plant proteins or cell walls and compartmentation in vacuoles may reduce the concentration of the free herbicide available for translocation.

Herbicide selectivity between the crop and the weed is often related to how rapidly and completely the herbicide is metabolized within the two plants. When a foreign compound (such as a herbicide) enters a plant, the plant immediately attempts to metabolize or somehow change the form of the foreign compound so that it does not harm the plant. Crop plants are generally able to metabolize a particular herbicide faster and more thoroughly than weed plants. Differential metabolism is the most widely encountered mechanism of selectivity. It is well-documented that weed sensitivity to a particular herbicide is largely determined by how rapidly the weed is able to metabolize the herbicide to non-toxic forms.

Extraneous factors that slow the crop's ability to metabolize the herbicide to non-toxic forms may increase the likelihood of crop injury. Corn is normally quite tolerant to the chloroacetamide herbicides (alachlor, metolachlor, acetochlor, dimethenamid). As the corn plant emerges from the soil, it absorbs the herbicide in a manner similar to that of the emerging weeds. If conditions are unfavorable for corn growth and development (cool temperatures, very moist soil), the crop is more likely to exhibit injury symptoms because it cannot metabolize the herbicide as rapidly as it normally could under more favorable growing conditions. When unfavorable growing conditions exist, the corn may lose a portion of its selectivity mechanism, which normally enables it to tolerate the herbicide. When conditions become more favorable for growth, the corn usually rapidly recovers from the injury with no significant loss of yield.

Herbicide Carryover

Herbicide residues from treatments applied during previous growing seasons may persist long enough to injure sensitive rotational crops. Many cases of herbicide carryover involve soil-applied herbicides, but some foliar-applied herbicides possess soil activity and may persist. Herbicide persistence in the soil is influenced by the factors that are responsible for herbicide dissipation.

Microbial activity is one of the most common means of herbicide dissipation. Various microbial populations of the soil can utilize the herbicide molecule as a source of energy for their growth. Microbial activity is governed to a large extent by soil temperature, moisture, pH, and oxygen. Degradation of herbicides by soil microbes generally proceeds most rapidly in warm, moist, well-aerated soils with a pH in the range for optimal crop growth. Extremes in these factors can slow the rate of microbial degradation, which may result in reduced herbicide dissipation.

Photolysis is the process by which herbicides are degraded by sunlight. This dissipation process is more important for herbicides that are not incorporated into the soil because the wavelengths of sunlight responsible for photolysis barely penetrate the soil surface. Whether or not a herbicide is subject to photolysis is dependent upon the chemical characteristics of the herbicide molecule. The greater the extent of herbicide photolysis, the less the amount of herbicide that will persist into the following season.

Soil pH is one of the most critical factors governing the degradation of certain herbicide families, in particular the sulfonylureas and triazines. Degradation of sulfonylurea herbicides is via the chemical process known as hydrolysis. The rate of the hydrolysis reaction is dependent upon pH; at low pH the process is much more rapid than it is at higher pH. Therefore, persistence of sulfonylurea herbicides is increased as the pH of the soil increases. The label of the herbicide Canopy, which contains the sulfonylurea herbicide chlorimuron (Classic), specifies rotational crop restrictions based on soil pH values.

Soil texture and organic matter influence the availability and persistence of many herbicides. Adsorption, the binding of molecules to the surfaces of clay and organic matter, is dependent upon both the type of clay comprising a particular soil and on the organic matter content of the soil. Herbicides that are adsorbed to clay or organic matter are unavailable for plant uptake, but are also less available for degradation. Interaction of the soil and herbicide leads to a distribution of the herbicide between that adsorbed to the soil components and that in solution and thus available for plant uptake. Adsorbed herbicide that is slowly released during the current or subsequent growing season may reach concentrations that could injure sensitive rotational crops.

Crop injury due to herbicide carryover may or may not follow specific patterns within a field, depending upon the herbicide family. For example, carryover of chlorimuron may be evident only in small areas of the field with high pH ("hot spots") or may occur across the entire field if the pH of the entire field is sufficiently high. Atrazine carryover into soybeans may be most evident on end-rows where the application rate may have been doubled during application. Symptoms can occur as distinct bands throughout the field, which may have resulted from a single nozzle applying too much herbicide the previous season.

Herbicide Drift and Volatilization

Movement of a herbicide out of the treatment area may result in injury to sensitive plants. Sensitive plants may be in a nearby corn or soybean field or may be ornamental plants growing in a residential area. The movement of the herbicide out of the target area may produce adverse effects. Herbicide movement can result from the actual physical movement of the spray particles as they are discharged from the spray nozzle (drift) or from a physical change of the herbicide from the liquid to the vapor state (volatilization). Not all herbicides are prone to volatilization, because the potential for volatilization is largely determined by the vapor pressure and formulation of the herbicide. All herbicides, however, may be subject to drift if applications are made when wind speeds are excessive and droplet size is small.

Factors that influence the amount of herbicide drift that occurs during the application include those associated with the application equipment and those associated with the prevailing environmental conditions. Spray droplet size, volume, and spray pressure are the equipment factors that have the largest influence on herbicide drift. Droplet size is determined primarily by nozzle type, whereas spray volume and pressure range are adjusted by the applicator according to suggestions on the respective herbicide label. Low carrier volume and high spray pressure favor small droplets and off-site movement of the herbicide by drift. Wind speed and relative humidity, environmental factors that influence drift, cannot be controlled by the applicator. Herbicide applications (especially postemergence) should not be made when wind speeds favor off-target movement. Many herbicide labels specify that applications should not be made when wind speed is in excess of a certain limit. For example, according to the Banvel label, applicators should "avoid making applications when spray particles may be carried by air currents to areas where sensitive crops and plants are growing. Do not spray near sensitive plants if wind is gusty or in excess of 5 MPH and moving in the direction of adjacent sensitive crops." Even though applicators cannot control the prevailing environmental conditions that influence drift, they can make the decision to spray or not based on the current conditions. Thus, applicators do have a direct influence on herbicide drift.

Volatilization is controlled by the vapor pressure of the herbicide, environmental conditions such as temperature and soil moisture, and to some extent by the formulation of the herbicide. As the vapor pressure of a herbicide increases, the potential to volatilize also increases. In general, volatility tends to increase as atmospheric temperature and soil moisture increase. Once the herbicide has changed to the vapor form, it can be carried out of the target area by wind currents. Some herbicides known to volatilize include 2,4-D ester, clomazone (Command), and EPTC (Eradicane). Banvel (dicamba) may hydrolyze to a free acid form, which can volatilize. To reduce volatilization, herbicides are often mechanically incorporated into the soil or formulated as granules.

Injury patterns from spray drift are generally most severe on the side of the field closest to the area from which the drift originates. The injury typically lessens as one moves across the field away from the side showing the greatest degree of injury. Each growing season, reports of soybeans showing injury symptoms from exposure to growth regulator herbicides such as 2,4-D and dicamba (Banvel/Clarity) are received. The question often asked is will this type of injury reduce soybean yield. Yield reductions are difficult to predict and may vary according to degree of exposure, growth stage of the soybean plant, and environmental conditions during the remainder of the growing season.

Injury from Direct Herbicide Application

Crop injury from direct herbicide application is probably the most common type of injury. Crop injury from direct application can range from a slight discoloration of the foliage, to shortened internode length, to complete death of the plant if an excessive amount or the wrong herbicide was applied. Herbicide residues remaining in the spray tank from previous applications can result in crop injury if the next crop sprayed is sensitive to the residues. Patterns of crop injury in the field may be distinct, such as a consistent overlap pattern, or subtle, such as injury symptoms apparent only where the application began.

Soil Applications

Corn • Injury to corn from soil-applied herbicides occurs most frequently when growing conditions are cool and wet. The chloroacetamide and thiocarbamate herbicides may cause corn injury when these growing conditions occur. Most of the injury rapidly disappears once the soil has warmed and dried. Corn has very good tolerance to soil-applied atrazine and injury is not likely. However, corn is less tolerant to cyanazine (Bladex) and injury is possible. This past season, many producers in Illinois and Iowa were expressing concern about potential corn injury from the new herbicide flumetsulam, sold as Broadstrike + Dual. Flumetsulam is an ALS (acetolactate synthase) inhibitor, which is the same mode of action as the imidazolinone and sulfonylurea herbicide families. The observed injury symptoms more closely resembled those resulting from ALS inhibitors than those resulting from chloroacetamide (metolachlor) injury.

Soybean • Soybeans generally demonstrate good tolerance to most soil-applied herbicides used for soybean production. Metribuzin (Sencor/Lexone) can produce some injury symptoms on the young leaves of the plant, but the plant usually recovers quickly. This type of injury may be more prevalent when atrazine residues from previous applications predispose the soybeans to injury from metribuzin. The dinitroaniline herbicides, such as trifluralin (Treflan) and pendimethalin (Prowl), may sometimes produce injury symptoms such as swollen hypocotyls. Surface-applied pendimenthalin may cause stem callous, which can result in a weakened stem that is more prone to lodging later in the growing season.

Foliar Applications

Corn • Injury from postemergence herbicide applications tends to be more common than injury from soil-applied herbicides. Many postemergence herbicides are applied with some type of spray additive (surfactant, oil, etc.), which can increase weed control but at the same time increase crop injury. This type of injury typically consists of chlorotic and necrotic ("burnt") foliage, from which the corn plant generally recovers within several days. Some of the growth regulator herbicides, such as 2,4-D and dicamba, can severely injure the crop if applications are made at the incorrect stage of crop growth. Some forms of corn injury may not become apparent for some time following the herbicide application. For example, broadcast applications of nicosulfuron (Accent) to corn that is over 24 inches tall or has more than 6 leaf collars can produce malformed ears that do not become evident until several weeks after application or even until harvest.

Soybean • Most postemergence soybean herbicides are applied with some type of spray additive. As with postemergence corn herbicides, this can increase the potential for crop injury. The degree of foliar burn can vary depending upon the herbicide and additive; lactofen (Cobra) may produce the greatest degree of foliar injury of all the postemergence soybean herbicides. In addition to foliar injury, several of the ALS inhibiting herbicides can shorten the length of internodes on the plant. If conditions are favorable for injury from these herbicides, the apical meristem (growing point) may be killed with a resulting branching from the axillary buds of the unifoliate leaves. This injury to the meristem often results in a Y-shaped soybean plant.

Injury Symptoms from Various Herbicide Families

Development and location of injury symptoms depend upon the mobility of the herbicide within the plant as well as the method of application. Herbicide mobility within the plant is usually characterized as contact (no mobility) or translocated (mobile). If a herbicide is mobile within the plant, it may move in the xylem (water-conducting tissue), phloem (food-conducting tissue), or both (ambimobile). Placement of the herbicide (application method) can influence the mobility of the herbicide. Atrazine is mobile within the plant (moves in the xylem) if applied to the soil, but moves little within the plant if applied postemergence. This differential mobility influences the type and location of injury symptoms from atrazine.

Herbicides That Interact with Photosynthesis

These herbicides may be foliar or soil-applied. If they are soil-applied, they are able to move in the xylem along with the transpirational stream, whereas if they are foliar-applied, they are non-mobile (contact). Pigment synthesis inhibiting herbicides, such as clomazone (Command), are often classified in this category because their mode of action ultimately destroys chlorophyll and thus affects photosynthesis.

Injury symptoms from **soil applications** appear after the food reserves in the cotyledons have been exhausted. Because these herbicides, which are listed in Table 1, interact with photosynthesis, their symptoms are not evident until the photosynthetic process is providing the plant with its food requirements. The cotyledons contain food reserves that nourish the plant until photosynthesis can satisfy the plant's food requirements. Cotyledons can perform photosynthesis to a limited extent, but their primary function is to supply the plant's energy requirements from their stored food reserves. The first true leaves on the plant (the oldest leaves) are the first leaves to actively photosynthesize and will thus be the site where injury symptoms are initially observed. Because these herbicides move in the xylem when soil-applied, injury symptoms on the leaves will be along the leaf margins because this is where the transpirational water (from the xylem) evaporates from the leaf, leaving behind the herbicide. Symptoms appear as a yellowing (chlorosis) of the leaf tissue, which may eventually become necrotic (dead) tissue. Advanced chlorosis of the leaf tissue will be interveinal (between the veins). Corn injury from soil-applied cyanazine is more likely to occur following prolonged cool, wet conditions that stress the plant. Shortly after emergence, corn injured by clomazone (Command) appears bleached or white. The likelihood of corn recovery from clomazone injury is good as long as a portion of the plant remains green.

Foliar applications of photosynthesis inhibiting herbicides can result in localized bronzing or speckling of the foliage, which may eventually progress to chlorotic and necrotic areas. Because these herbicides, which are listed in Table 2, are not mobile within the plant when applied postemergence, initial injury symptoms will be confined to the areas of the leaf in direct contact with the spray solution. Unlike injury from soil applications, the chlorosis and necrosis of the foliage following foliar applications will not be confined to interveinal leaf tissue. Spray additives usually increase the degree of injury with these herbicides.

PPO Inhibitors

The members of this herbicide family, which are listed in Table 3, are primarily foliar-applied, contact herbicides. Therefore, injury symptoms will be initially observed on plant tissue that was in direct contact with the spray solution. Spray additive selection can have a tremendous influence on crop injury with members of this herbicide family.

Injury symptoms include an initial water-soaked appearance of the plant tissue, spotting or speckling, and chlorosis that gradually proceeds to necrosis.

Table 1. Herbicides that interact with photosynthesis — primarily soil-applied

TRIAZINES	URACILS	PHENYLUREAS	UNCLASSIFIED
atrazine (AAtrex)	bromacil (Hyvar)	linuron (Lorox)	clomazone (Command)
cyanazine (Bladex)	terbacil (Sinbar)	tebuthiuron (Spike)	
metribuzin (Sencor)		diuron (Karmex)	
simazine (Princep)			
hexazinone (Velpar)			

Table 2. Herbicides that interact with photosynthesis — primarily foliar-applied

DIAZINONES	BENZONITRILES	BIPYRIDILIUMS
bentazon (Basagran)	bromoxynil (Buctril)	paraquat (Gramoxone Extra)
pyridate (Tough)		diquat (Diquat)

Table 3. PPO inhibitors

DIPHENYL ETHERS	N-PHENYLTHALIMIDES
acifluorfen (Blazer)	flumicloric (Resource)
lactofen (Cobra)	
fomesafen (Reflex)	

Herbicides Inhibiting Amino Acid Synthesis

Herbicides inhibiting amino acid synthesis can be soil or foliar-applied, with a few exceptions that are foliar-applied only. These herbicide families consist of those which inhibit the ALS enzyme, listed in Table 4, and those which inhibit the 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase enzyme, listed in Table 5.

The ALS inhibitors include the imidazolinones, sulfonylureas, and sulfonamides. These herbicides are translocated in the xylem of the plant if soil-applied or the phloem if foliar-applied. Most of the amino acid synthesis in the plant occurs in the meristematic regions; as inhibitors of amino acid synthesis, these herbicides are thus translocated to these regions of active synthesis. Above-ground corn injury symptoms from these herbicide families include overall plant stunting, chlorosis and purpling of the foliage, and improper leaf unfurling. Below-ground symptoms consist of inhibited root development, often described as having a "bottle brush" appearance. Soybean plants are often stunted following postemergence applications of ALS inhibiting herbicides. The leaf veins often appear red or purple, the margins of the leaves may appear chlorotic or necrotic, and the growing point of the plant often appears golden or bronzed. If damage is extensive enough, the meristem may be destroyed, which typically stimulates the development of lateral branches. Internode length is often shortened in both corn and soybeans.

The EPSP synthase inhibitors are glyphosate (Roundup) and sulfosate (Touchdown). Both of these herbicides are non-selective, foliar-applied herbicides and are translocated within the plant to the areas of active amino acid synthesis. Injury symptoms of EPSP synthase inhibitors are similar to those produced by the ALS inhibitors: gradual chlorosis and necrosis of plant tissue, initially evident in the meristematic areas and then followed by death of the plant.

Seedling Growth Inhibitors

These are soil-applied herbicides that belong to the dinitroaniline (DNA), chloroacetamide, and thiocarbamate families (see Table 6). These herbicides inhibit the growth and development of weed seedlings, typically before the seedlings emerge from the soil. Absorption of these herbicides into the seedling occurs in both root and shoot tissue.

Table 5. Amino acid synthesis inhibitors — EPSP

PHOSPHONOS
glyphosate (Roundup) sulfosate (Touchdown)

The DNA herbicides inhibit the formation of structures that are required for cell division. The most notable cases of crop injury with DNA herbicides involve carryover and subsequent corn injury. The symptoms of corn injury consist of stunted, chlorotic plants with proliferated, stubby (clubbed-shaped) root systems. Inhibition of root development from DNA herbicides may result in the inability of the plant to absorb essential nutrients such as phosphorus, which results in the corn having a purple appearance. Lateral roots of soybeans may be pruned by excessive rates of DNA herbicides, and hypocotyls may swell and crack. Preemergence surface application of the DNA herbicide pendimethalin can occasionally cause callous tissue to form on the stems at ground level, which may lead to lodging later in the season.

The chloroacetamide and thiocarbamate herbicides produce similar injury symptoms. Corn injury may be evident when seedlings fail to emerge from the soil and instead leaf-out underground. This problem can be accentuated by compacted soils and deep planting. Following emergence, the leaves may fail to unfurl properly and often appear crinkled. Soybean leaves may also appear crinkled or puckered and have a shortened leaf midvein, giving the leaf a heart-shaped or "draw string" appearance.

Plant Growth Regulators

This group contains some of the oldest synthetic herbicides that are still commonly used (see Table 7). However, despite the fact that these herbicides have been utilized for many years, their exact mode of action that causes plant death remains unknown. These herbicides tend to mimic the activity of endogenous plant hormones that control plant development; hence the name, plant growth regulators. Most of these herbicides are applied postemergence in cropping situations, but some also possess a great deal of soil residual activity.

Injury symptoms from this class of herbicides vary greatly depending upon the crop and environmental conditions. Some of the more common symptoms include stem and leaf twisting

Table 4. Amino acid synthesis inhibitors — ALS

IMIDAZOLINONES	SULFONYLUREAS	SULFONAMIDES
imazethapyr (Pursuit) imazaquin (Scepter) imazapyr (Contain)	chlorimuron (Classic) thifensulfuron (Pinnacle) nicosulfuron (Accent) primisulfuron (Beacon) chlorsulfuron (Telar) metsulfuron (Ally)	flumetsulam (Broadstrike)

Table 6. Seedling growth inhibitors

DINITROANILINES	CHLOROACETAMIDES	THIOCARBAMATES
trifluralin (Treflan)	metolachlor (Dual)	EPTC (Eradicane)
pendimethalin (Prowl)	alachlor (Lasso)	butylate (Sutan)
ethalfluralin (Sonalan)	dimethenamid (Frontier)	
benefin (Balan)	acetochlor (Harness/Surpass)	

Table 7. Growth regulator herbicides

PHENOXYS	BENZOIC ACIDS	PYRIDINES
2,4-D	dicamba (Banvel/Clarity)	picloram (Tordon)
MCPA		clopyralid (Stinger)
2,4-DB (Butyrac)		triclopyr (Garlon)

Table 8. Lipid synthesis inhibitors

ARYLOXYPHENOXYPROPRIONIC ACIDS	CYCLOHEXANEDIONES
fluazifop (Fusilade DX)	sethoxydim (Poast Plus)
quizalofop (Assure II)	clethodim (Select)
fenoxaprop (Option II)	

(epinasty), leaf cupping, formation of callous tissues (galls), stem splitting, parallel leaf venation in broadleaf species, and improper seed or kernel development. There are, however, other symptoms of injury that may be observed following the use of these herbicides. Because these herbicides mimic the action of plant hormones that control plant development, the variety of possible injury symptoms is extensive.

Lipid Synthesis Inhibitors

The herbicides in this class, listed in Table 8, are commonly referred to as the "post grass killers." Only rarely do they produce injury symptoms on soybean plants; however, even extremely low concentrations of these herbicides can cause extensive corn injury. These herbicides are translocated to the meristems of the grass plant where they inhibit the formation of fatty acids, the building blocks of lipids. Initial injury symptoms appear slowly in susceptible grass species. The most prominent injury symptom is disintegration of the apical meristem located at the base of the shoot apex. When the flag leaf is pulled from the plant, the base is generally brown to black in color and has an extremely soft consistency. Complete death of the plant may not be evident for up to two weeks following application, depending upon species.

Environmental Provisions of the Farm Bill

Jon Scholl

Members of the agricultural community have expressed two views in response to the debate over the conservation provisions of the 1995 Farm Bill. One is the view that the farmers will see a continuing onslaught of environmental groups seeking policies that will force farmers to do things that they may want to do, but may not have the financial ability to do. The second view is that the agricultural community working together, and including environmentalists in their discussions, will be able to craft policies that are acceptable to farmers as well as friendly to the environment.

It may come as a surprise to many of you that the second view is the one that I see dominating the debate. Farmers truly believe that they are environmentalists. Similar to environmentalists, farmers want a clean environment for their families. We also see the futility in "playing defense." The role of agriculture in this debate should be to describe the public resources that will be needed to protect the environment, rather than to continue on the course of being defensive about what others view as our environmental shortcomings.

Before I proceed, let me briefly explain how my views have been shaped by the activity of the Illinois Farm Bureau over the past year and a half. We created a task force of 42 leaders to look at the questions of (1) what are the benefits to society resulting from its investment in agriculture, and (2) what do both society and farmers need as we look to the next round of farm and food policy debate. Four points emerged from the work of this task force, but most notable to this audience was "environmental security." Farmers quite often need the public's help in making the short-term financial commitment necessary to secure the long-term benefits of conservation. We have found broad agreement on this point. The Illinois Farm Bureau firmly believes that this debate is more than a debate about "farm" policy. We believe that it has more to do with "food security," and we prefer to call the upcoming legislation a "Food Security Act," rather than a "Farm Bill."

I have taken leaders of The Farm Bureau to Washington on numerous occasions over the past year to lobby for a new environmental initiative—the Environmental Stewardship Incentive Payment Program. This is a program that says, as farmers, we are willing to do more than we have committed to do in the 1990 Food, Agriculture, Conservation and Trade Act. But we will need the public's help to do it. We have met with Congressmen; congressional staff; agricultural, environmental, and food aid groups; numerous people from USDA, OMB, CBO, and others within the Clinton Administration. We are hearing a couple of things. First, farm groups seem to be getting an earlier start than ever in crafting proposals for the food security debate. Second, there seems to be more unity in agriculture than has been seen at the beginning of any recent debate on federal farm and food policy. I would suggest that this bodes well for agriculture.

A recent edition of *National Journal's Congress Daily* opened with a headline saying "Environmentalists Push Pet Proposals in the '95 Farm Bill." The story indicated that environmental groups hope to play off the pressure for more fiscal discipline in farm commodities. They hope to leverage the political sentiment to protect the environment against farmers' needs and desires to maintain support for farm programs. I suspect that environmental groups will aggressively seek changes in food security legislation, many of which the farm community will not like. However, the environmental community met substantial difficulty in achieving success in the last session of Congress, despite their early expectations of significant victories.

The failure to achieve their expectations last year and a more conservative Congress this year will make environmental groups reassess their strategies. They may be more open to striking agreements with the agricultural groups to make the food security legislation more "green." This presents a major challenge to agriculture. We have a choice. We can either work with moderate environmental groups to secure objectives we mutually seek, or we can reject their input and run the risk of appearing as unreasonable and extreme as some environmental organizations appear.

One example of this is the Conservation Reserve Program. It is one of the "hot-button" issues of the '95 Food Security Act. Farm groups in Illinois and other states have joined in coalitions with groups such as Pheasants Forever, Ducks Unlimited, and state conservation departments, to jointly promote the extension of this successful program. We have already seen the results of this cooperation. We see strong signals that this program will, in fact, have a life beyond the 10-year contracts already in existence.

Many conservation and environmental issues will be addressed in the context of the farm and food policy debate. I have touched upon the failure of environmental initiatives in the last Congress. I have also suggested that environmental groups will seek to leverage farmers' wants and needs in the farm bill. I have mentioned the general consensus that the new Congress will be more conservative. The result of all this will be fewer opportunities for the consideration of major environmental initiatives over the next two years. Perhaps the only reasonable strategy for those who want to force change is to seek inclusion of their initiatives within another bill that has momentum, such as food security legislation. This strategy need not frighten us, but it should motivate us to take the high ground, and to put forth our proposals to address environmental problems that we know we need and want to address.

This should be an exciting year for anyone interested in farm and food policy. We can seize the opportunity and better prepare ourselves for future policy changes or we can hunker down and wait for the onslaught. We are trying to take the first path in the Farm Bureau.

Pesticides and Food Safety: The Gods' Honest Truth Is It's Not That Simple

Rick Weinzierl

Many papers and book chapters begin with quotes from famous writers or philosophers. Usually those who are quoted are known for their contributions to great literature, to government, or to a particular science. The quote that comprises the subtitle of this paper comes from a less distinguished source—the song "Fruitcakes," recorded in 1993 by Jimmy Buffet. A portion of the verse follows:

> "Religion, religion . . .
> Oh, there's a thin line between Saturday night
> and Sunday morning . . .
>
> Where's the church, who stole the steeple?
> Religion's in the hands of some [crazy] people;
> Television preachers with bad hair and dimples;
> The Gods' honest truth is it's not that simple.
>
> It's the Buddhist in you, it's the Pagan in me;
> It's the Muslim in him, she's Catholic, ain't she?
> It's the born-again look, it's the WASP and the
> Jew;
> Tell me what's goin' on, I ain't got a clue."

Yes, it's a bit irreverent, but it provides a lighthearted reminder that some of our deepest personal convictions are not shared universally. So what's the link with food safety? Although it would be inappropriate to suggest that the current debate about pesticides and food safety rivals our quest to understand humankind's origins or our spiritual roles in the universe, an individual's thoughts on food safety, like thoughts on religion, often seem to result as much from beliefs and faith as from critical evaluation of conflicting evidence. Many people who are absolutely convinced that their opinions on food safety are exclusively correct know very little about the reasons why others hold different views. Although this paper is unlikely to sway many readers' opinions on pesticides (as unlikely as an even-handed comparative summary of major religions is to sway many beliefs), perhaps it will provide an understanding of why simple answers to food safety questions seldom acknowledge all the components of the big picture.

Understanding the dilemma involving pesticides and food safety is especially difficult for individuals who base their decisions on news that is filtered and biased, intended to advocate, not educate. Newsletters to members of environmental groups seldom include stories about the reasons why many unbiased scientists (not only those who are somehow linked to the agrichemical industry) question the seriousness of the threats posed by pesticide residues at the levels now detected on or in foods. Likewise, the agricultural press seldom acknowledges that expert toxicologists (not only Meryl Streep and Willie Nelson) find compelling reasons for real concerns about pesticide residues. If food safety issues are to be addressed and resolved satisfactorily, those with opposing views must expand their understanding of the overall issue. This paper attempts to help readers take a step toward such an understanding.

Problems in Perspective

In assessing food safety problems, the United States Food and Drug Administration (FDA) considers pesticides fifth in importance after microbial contaminants, nutritional imbalances, environmental contaminants, and naturally-occurring toxins (Winter 1994). Whether this ranking is high or low is perhaps irrelevant; the FDA and the public recognize a real problem. Given the nature and importance of the food industry, concern over pesticides on foods should not be surprising. Food production and delivery in the United States is a 520 billion-dollar industry that relies on more than 15 million people (White 1994). Many pesticides that are known to be toxic to humans are used to protect crops from pests and the toxic contaminants that those pests produce. Public concerns can be real and justified even though the US food supply is considered to be the safest ever available. A general desire for even safer food (free of any harmful contaminants) should be viewed no differently from widely accepted desires for safer vehicles (even though today's cars exceed the safety standards of older models), more efficient appliances, and continuing improvements in medical treatment. In food safety, as in other aspects of modern society, prior accomplishments do not justify complacency if further progress is possible.

Public concern about pesticide residues on foods is not an isolated phenomenon. Related aspects of public opinion include worries about nontarget environmental impacts of pesticides and the health risks that pesticides pose to farm workers. Also broadly linked to this set of concerns over pesticides are anxieties about antibiotics used in livestock production and their link to outbreaks of disease caused by food-borne *Escherichia coli* and *Salmonella enteritidis*. Some consider these well-publicized problems to be the inevitable "dark side" of large-scale industrial agriculture. For agriculture's current critics to suggest that these problems in general have arisen or dramatically worsened during the last decade or two is inaccurate. "Old" pesticides, even those inorganic compounds used before DDT was discovered in 1939, poisoned workers and animals and left toxic residues on foods. Microbial contamination and the presence of microbial toxins have caused food-related illnesses and deaths during all of human existence. In fact, progress related in part to the use of pesticides has allowed the production and distribution of fresh and processed foods that are less likely to contain deadly microbial contaminants than ever before. Yet for agriculture to answer its critics by saying, "The food supply is the safest it has ever been; don't worry or complain about its minor flaws," is also wrong. In a population of nearly 250 million, even a very low frequency of pesticide-related injuries or illnesses translates into hundreds or thousands of incidents each year. Additionally, agriculture, like all businesses, relies on customers. Businesses that fail to answer their customers' demands rarely thrive. Consequently, agriculture must answer consumer concerns about pesticides. In relation to food safety, these concerns can be split into at least two categories: (1) pesticides as carcinogens; and (2) residues in relation to tolerances for health effects other than cancer.

Pesticides as Carcinogens

To understand disagreements over the roles that pesticide residues on foods may play in cancer, one must understand how cancer causation is investigated. Using 20 to 50 laboratory rats or mice per replicate per dose and a range of doses, preliminary studies determine how much pesticide can be administered daily to a standard strain of laboratory rodents without shortening their lifespans. The greatest dose that the animals tolerate—the maximum tolerated dose, or MTD—and half that dose (½ MTD) are then administered daily to additional groups of rodents. As these animals reach the end of their normal lifespans, they are sacrificed and examined for tumors. A link to cancer is presumed if tumor incidence is statistically significantly greater in either of these groups of rodents than in an untreated group of the same strain.

Both doses tested in this standard bioassay (the MTD and half that dose) are much, much greater (often hundreds or thousands of times greater) than the doses that consumers are likely to encounter as residues on foods. These doses are also administered every day. Those who argue that sporadic occurrences of trace amounts of pesticides on foods are not causing cancer contend that testing at such high daily doses is meaningless. So why are maximum tolerated doses used in tests?

Cancers are not like other diseases. The noncancerous effects of many chemicals and even some pathogens are progressive—increased doses or exposures cause increased damage or illness. In studies of cancers, however, either an animal or a human develops a tumor or does not. What changes with the dose of a carcinogen is not the severity of a response, but the probability that it will occur (Salmon 1994). Additionally, cancer is thought to develop as a result of one or more "hits" in which a chemical reacts with a cell's DNA, causing a mutation that leads to cancerous cells and tumors. High-dose tests for carcinogenicity are therefore based on an assumption that MTDs simply increase the probability that testing will produce the chance contact of a carcinogen with a susceptible site—a segment of DNA. By testing at high doses, the use of relatively small groups of laboratory animals for a short time (less than 2 years) is intended to allow the maximum sensitivity for identifying compounds that might act as carcinogens in a portion of the hundreds of millions of people who will be exposed to lower doses of those compounds over several decades. This reasoning is based on the accurate observation that detecting a rare outcome—for example, even a one-in-1,000 risk of cancer in humans from a lifetime of real-world, low-dose exposures—would require testing tens of thousands of laboratory animals at the doses that humans might encounter on food in the course of a lifetime. High-dose bioassays are therefore a legitimate if not ideal compromise to increase the sensitivity of laboratory testing.

But do the extremely high doses of pesticides administered daily in laboratory bioassays cause cancers that would not occur as a result of less frequent exposures to the much lower doses that actually occur as residues on foods? Some authorities say yes, others say no (see Marx 1990 and references therein). Bruce Ames has argued loudly and publicly that MTDs cause direct toxic effects that lead to cancers. He contends that as cells proliferate to repair tissues damaged by toxic doses of chemicals, atypical opportunities for mutations occur (Ames et al. 1987, Ames and Gold 1989). He proposes that below a threshold dose at which toxic effects begin, chemicals judged to be carcinogens at high doses would not cause cancer. His conclusion that thresholds exist for carcinogens challenges the traditional linear model of carcinogenicity that supports testing at MTDs (Marx 1990). Ames and others argue that testing at MTDs seeks to enhance the sensitivity of bioassays at the expense of specificity—they insist that such tests produce too many false positives (Charnley 1994).

The conclusions expressed by Bruce Ames regarding high-dose bioassays are not shared by all toxicologists. Bailar et al. (1988) and Hoel et al. (1988) contend that toxic effects and resulting cell proliferation do not explain all cancers observed in laboratory bioassays. Furthermore, they point out that toxicologists are simply unable to determine from laboratory data what happens when a potential carcinogen is encountered at low doses instead of the high doses now tested. In the absence of more precise testing methods, they conclude that chemicals that cause cancer in high-dose bioassays should be viewed as potential carcinogens at low doses as well, and that regulatory agencies should act to minimize public exposure to such compounds (Marx 1990).

The debate over identifying carcinogens is further complicated by the fact that many naturally-occurring compounds test positive as carcinogens in rodent bioassays. These include the psoralens in celery, parsley, and parsnips, sinigrin in cabbage and related crucifers, and *d*-limonene in citrus (Ames et al. 1987). Administered at MTDs in laboratory bioassays, these naturally-occurring compounds increase the frequency of tumors in rodents, as synthetic chemicals do. Because so many common natural compounds cause or promote cancer in rodent bioassays, Ames has concluded that such tests are grossly misleading. Others assert that these findings are perhaps irrelevant because human detoxification mechanisms have probably evolved to "handle" natural compounds but not synthetic ones (Marx 1990). Such an argument depends on at least three unproven assumptions: (1) that an ability to "handle" natural carcinogens and avoid cancer (usually a disease of the elderly and post-reproductive) has been selected during evolution; (2) that mechanisms or efficiencies for processing natural and synthetic chemicals differ; and (3) that rodents—substitutes for humans in laboratory bioassays—did not evolve necessary mechanisms for handling natural carcinogens as humans are proposed to have done.

Probability, MTDs, cell proliferation, mutations, linear models, thresholds, natural carcinogens, predictions, risk assessment . . . the terminology and concepts are complex. Probability alone appears to be baffling to most citizens, as lines to buy lottery tickets clearly indicate (see Mackay 1988). It's not surprising that people look to experts for interpretations. Unfortunately, experts often acknowledge little responsibility to deliver an unbiased summary. Controversy over Alar continues to illustrate the one-sidedness of expert testimony. Daminozide (Alar) was first registered for use as a growth regulator on apples in 1968, but it was not tested for carcinogenicity using acceptable methods until 1985. Studies conducted by Uniroyal (the manufacturer) did, in fact, indicate that a break-down product of daminozide, UDMH (unsymmetrical dimethyl hydrazine), fed to rats in standard bioassays produced elevated rates of cancer. Most public health and pediatric toxicologists felt that Alar's use should be stopped (Jackson 1994), but the United States Environmental Protection Agency (EPA) did not take immediate action, instead opting to allow public comment and further studies. Subsequent events are well-known: Press releases and conclusive pronouncements from the Natural Resources Defense Council (NRDC) led to a story on television's "60 Minutes," and apples almost immediately (but temporarily) disappeared from school lunch menus. Interestingly enough, hot dogs and potato chips, despite their known negative effects on health, remained on students' plates. The National Rifle Association must have enjoyed the dilemma that gave rise to the joke, "Guns don't kill people, apples kill people." Agriculturists cried foul, complaining that a media blitz, not science, caused EPA's eventual action against Alar. Few who supported Alar acknowledged that by existing standards, UDMH is legitimately deemed a potential human carcinogen or that it indeed occurred commonly as a residue on apples and in apple products. No one from the NRDC or related groups noted that high-dose bioassays may produce many false positives; instead they offered estimates of cancer-caused body counts that would result from children eating apples. No one on either side noted that "the Gods' honest truth is it's not that simple." In hindsight, no one earned public trust.

Residues and Tolerances

For compounds that cause greater toxic effects at greater doses ("typical" poisons), methods have been established for the determination of the lowest concentrations or doses likely to cause ill effects. Exposure to lower levels of these chemicals might be considered "safe," and therefore standards can be set to allow some, but not too much consumption of such compounds as contaminants or residues on foods. Tolerances (the maximum residues legally allowed on foods) established for individual pesticides are thought by most observers to ensure that toxic levels of pesticides and other chemicals do not contaminate the food supply. Are public expectations being met?

To identify the maximum levels of unwanted compounds (pesticides or other contaminants of natural or synthetic origin) that pose no risks in the human food supply, studies use laboratory animals, primarily mice and rats. Using groups of animals for each dose level and a range of doses, a potential or existing pesticide is fed to laboratory rodents daily over their lifespans. Growth rates, reproduction, and other measures of health are assessed over the course of each trial. As the animals reach the end of their normal lifespans, they are sacrificed and examined for any ill effects. Based on these trials, the highest dose that causes no observable adverse effects in the animals (the NOEL, or no observable effect level) is established. This NOEL is usually divided by 100 to establish an "acceptable daily intake" (adi) or "reference dose" for humans. The reference dose is defined by the EPA to be the level of daily exposure to a pesticide residue which, over a 70-year human lifespan, is thought to have no negative effect. The NOEL is divided by 100 to calculate the reference dose so that ten-fold safety factors are "built in" to account for (1) the possibility that humans are more sensitive to the chemical than rodents are, and (2) individual differences in sensitivity within human populations.

How does a reference dose correspond to tolerances for specific chemicals? Because people consume a variety of foods, only a portion of the reference dose should be allowed as a residue on any single food. Based on survey data that describe average diets (Winter 1994), information on the consumption of individual foods can be used to apportion the reference dose among different foods and establish appropriate residue tolerances on specific crops or groups of crops. Done correctly, tolerance setting should ensure that if residues do not exceed tolerances on any specific crops, consumers will not ingest more than the reference dose of any pesticide residue. Disagreements over the value of current tolerances are numerous; they include observations that:

- Not all existing tolerances are based on the process described above.
- Many consumers do not eat the average diet that provides the basis for apportioning tolerances among several crops; the peculiar diets of children are of special concern.
- Animal-based NOELs may not be accurate for assessing risks to children.

  Tolerances for related chemicals should not be set independently, because a combination of residues is likely to act in an additive manner.
- Current monitoring and enforcement programs do not provide for inspection of a significant portion of the nation's food supply, and intervention (seizing contaminated foods before they reach consumers) is seldom possible.

In answer to the first of these criticisms, it is true that many pesticide tolerances were established decades ago based on "good agricultural practices." Pesticides were used in trials at required rates and frequencies, and then samples were taken to determine the residues that remained on the crop at harvest. The resulting residue concentration (or even a slightly higher concentration) was proposed and often accepted as the tolerance (based on the results of field use, not assessments of health effects). Although such an approach is no longer accepted by the EPA, some "old" tolerances do remain in effect and provide a basis for criticism. For the debate over this issue to be fair, however, those who wish to educate (not advocate) should be as complete as possible when describing the current dilemma. Jackson (1994) and the National Research Council (1993) state simplistically that tolerances are based on agricultural practices, not health risks (implying no consideration of reference doses), but the same authors note that the EPA does not now grant tolerances that result in dietary consumption of residues in excess of the reference dose or adi. Those who contend that tolerances are set appropriately note the use of NOELs and safety factors, but do not mention older tolerances that were set under less strict standards.

In the report, *Pesticides in the Diets of Infants and Children*, the National Research Council (1993) noted that children consume much more food and water per unit of body weight than adults, and they often consume relatively large amounts of only a few foods. Consequently, established tolerances for residues on or in a specific crop, for example apples, might result in adult consumption of pesticides at levels well below the reference dose, but consumption by children might exceed the reference dose.

This potential problem is intensified because any residues that children consume represent a greater dose on a per-weight basis than they do in larger adults. In the words of the National Research Council, "children are not little adults." Regulators have responded to concerns about the diets of children by noting that although tolerances do not reflect the peculiarities of childhood eating habits, those habits are reflected in calculations of pesticide consumption based on residues in the FDA's annual total diet study (see Food and Drug Administration 1990 for an example). With consumption estimates adjusted for body size and dietary habits for specific age groups, few pesticides are consumed, *even by children*, at levels greater than 1⁄100 or 1⁄1000 of the established adi or reference dose (Food and Drug Administration 1990). These findings indicate that on average the vast majority of pesticides are not present as residues at levels that approach established tolerances on most foods. Consequently, substantial differences in the diets of children and adults do not appear to result in hazardous exposure to most pesticides. One might conclude that the tolerance setting procedure is not adequately designed to protect children, but that actual residues are nonetheless low enough on most foods that children very rarely consume pesticides at levels near the reference dose.

Whether or not reference doses based on NOELs from animal studies are accurate indicators of safety for children is another contested issue. Developing animals (and therefore presumably developing humans) are less able than adults to detoxify some compounds and better able to detoxify others. Sensitivity to specific compounds (independent of rate of detoxification) may also vary with age. The National Research Council (1993) recommended using an additional 10-fold safety factor in calculating reference doses for compounds thought to pose particular risks to children. If this recommendation is adopted, the reference dose for such chemicals would be 1⁄1000 of the NOEL in laboratory animals.

Many toxicologists argue (as does Jackson 1994) that residues of related pesticides should be regulated as a group. Related pesticides now are granted tolerances independently of one another based on reference doses derived from separate studies. As a result, if residues in a person's daily diet are present at levels near the reference dose for several chemicals (a possibility if residues are at or near tolerance levels on each of several foods), the additive effects of such residues could realistically cause mild to severe symptoms of poisoning. For example, the National Research Council (1993) used food consumption and residue data to estimate that the combined use of five organophosphates on eight foods could result in 1.3 percent of the nation's children consuming more than the average reference dose of these pesticides in combination on a given day. Based on simulations studied by these scientists, approximately 1 in 1,000 children might consume enough of the organophosphates in combination to cause some symptoms of poisoning.

Actual estimates of residue concentrations are fundamental to the debate on the risks of pesticide residues on foods. FDA's 1989 data (Food and Drug Administration 1990) from residue surveys are similar to those of prior and subsequent years. In roughly 8,000 samples of domestic foods, violative residues were detected in less than 1 percent; no residues were detected in 65 percent of the samples. From approximately 11,000 samples of imported foods, violative residues were detected in 3.5 percent; no residues were detected in 67 percent of the samples. Most residue violations involved pesticides that were not registered on the crop that was treated or contaminated; in most instances these residues did not exceed concentrations that were allowed on other crops. As noted above, FDA's market basket survey has consistently indicated that consumption of pesticides as residues (on average) falls well below estimated reference doses. Critics, however, note that only a tiny portion of the nation's food supply is tested for residues, and that violative residues are detected too late to allow seizure of contaminated lots of foods before they are sold and consumed. A valid basis for this criticism was provided during the late 1980s when more than 1,000 people in western states experienced symptoms of poisoning after ingesting illegal residues of aldicarb sulfoxide in tainted cucumbers and watermelons. Even so, unless monitoring programs indicate more frequent problems, legislatures are unlikely to appropriate the funds that would be needed for greater and more vigorous detection and enforcement efforts. Critics also note that individuals do not consume average residues, but instead the residues that remain on specific food items. The National Research Council (1993) reported that average residues of aldicarb sulfoxide (from samples taken during the time when the use of Temik/aldicarb on potatoes was legal) from a 100-pound bulk sample of potatoes were well below the established tolerance, but that one potato in the sampled lot contained 465 times the reference dose.

Safe or Unsafe?

In sum, Jimmy Buffet probably said it correctly: "The Gods' honest truth is it's not that simple." Many aspects of pesticide regulation fall well short of providing complete assurance that all the food we eat is "safe." Many questions are very difficult to answer. Although testing for carcinogens at MTDs is an imperfect process, no better process has been proposed. Peculiar diets, age-related differences in physiology, and multiple residues pose real dilemmas for those who must establish residue tolerances. There is indeed some risk that pesticide residues may occur on a given food product at toxic levels. Yet pesticides allow the production and distribution of an abundant supply of foods—including fresh fruits and vegetables—that are especially important to human health.

Answers to food safety questions may require an acknowledgment that for food to be "safe" does not mean that it must be risk-free. Meyers and Craigmill (1994) point out that what individuals (or the public in general) define as safety is "acceptable risk." To assure consumers that food is safe, or that the level of risk that it presents is acceptable, those who produce food and use pesticides must first truly understand the risks posed by pesticides and other toxins, and then honestly discuss them with consumers. In response to current concerns, some regulations will likely need to change to better protect against unacceptable risks. The extent of those changes will depend on society's judgments, because as Meyers and Craigmill (1994) point out, in a democracy it is public opinion, not expert opinion, that sets public policy. Meyers and Craigmill offer a quote from Thomas Jefferson to reinforce the validity of public opinion as a basis for policy. Jefferson wrote, "I know of no safe depository of the ultimate powers of society but the people themselves, and if we think them not enlightened to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion."

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Stewardship of Crop Protection Products: What Will EPA Require in the Future?

Doug Rushing

Acetochlor is a new herbicide that received registration in March of 1994 for use in corn. This was the first new crop protection product registered under the Clinton Administration Environmental Protection Agency's new pesticide policy. Issues such as risk reduction, pollution prevention, and pesticide use reduction will be key determining factors in future new product registrations. The unique conditions for the registrants, Monsanto Company and Zeneca Ag Products Company, reflect the new direction that the administration plans to take with new pesticide registrations, in order to address EDA's concerns about the potential excessive use of pesticides. The acetochlor registration conditions are not necessarily a template, but EPA apparently intends to implement more stringent environmental regulation and product stewardship requirements when a new product registration is granted.

The conditions of the acetochlor registration include four major areas:

- product reduction
- ground water protection
- surface water protection
- endangered species study

Product Reduction

The registrants agree to meet product reduction goals of 66 million pounds (cumulative) of competitive corn herbicide active ingredients after five use seasons. By the end of the fifth season of acetochlor use (1998), a reduction in the use of six common corn herbicides will occur in the U.S. This will result in a 33 percent reduction from 1992 levels in aggregate use of the herbicides alachlor, metolachlor, atrazine, EPTC, butylate, and 2,4-D. These reductions will be a result of forces in the corn herbicide market, and they do not imply that the current risk posed by these displaced products is unacceptable. The reductions that must be met in order to maintain acetochlor registration are shown in Table 1. All years will be adjusted to U.S. corn 1992 planted acreage base of 79.3 million acres and will be monitored by an independent research firm.

Ground Water Protection

The registrants will conduct several monitoring studies of ground water supplies in seven midwestern states for acetochlor and other commonly used corn herbicides, as well as conduct eight scientific studies designed to evaluate potential movement of acetochlor and its breakdown products. The eight sites will be located in areas that are representative of use in accordance with label directions, or in accordance with widespread and commonly recognized practices, including vulnerable and typical use situations.

A state ground water monitoring program will be conducted in seven states to analyze approximately 25 wells per state. Objectives are to detect possible patterns of movement to ground water. Acetochlor at 0.1 ppb will be considered a detection and subsequent monthly samples will be obtained to evaluate possible trend increases. Cancellation may occur if detection trends occur and increase over sampling intervals of seven months.

Table 1. **Reductions in the use of six common corn herbicides, required to maintain acetochlor registration**

	REDUCTION YEARS	REDUCTION TARGETS CUMULATIVE REDUCTION
18 months	'94, '95	4.0 M lbs
3 years	'94, '95, '96	22.6 M lbs
5 years	'94, '95, '96, '97, '98	66.3 M lbs

Surface Water Protection

The registrants will sponsor surface water monitoring programs in seven midwestern states. Suspension of the use of acetochlor in a specific water body may occur if detections exceed 2.0 ppb on an annual mean concentration in a targeted watershed. Monitoring locations and protocols will be coordinated with State Lead Pesticide Agencies.

Endangered Species Study

The registrants will sponsor endangered species surveys in the acetochlor use area and evaluate reproduction studies on aquatic and bird species. These studies will be conducted by the registrants and outside researchers.

Acetochlor Stewardship Program

The registrants will implement an environmental stewardship program in the acetochlor use area to inform applicators of the potential environmental impact of pesticides. Training will include safe chemical handling practices, ground water and surface water protection, worker protection standards training, ag-chem facility improvement programs, pesticide toxicology, and acetochlor label training.

Environmental Stewardship Programs

The registrants will continue the Well Assistance Program that Monsanto has operated for four years, which is designed to provide financial assistance to rural well owners who have Monsanto crop protection products in wells used for drinking water. The program will provide up to $5,000 to any owner of a domestic well containing acetochlor above 1 ppb, for the purpose of either digging a new well, installing a carbon filtration system, or connecting to a community water system.

End User Training

Field representatives from Monsanto and Zeneca will conduct end user training programs designed to educate applicators on proper acetochlor use in vulnerable areas. Field maps indicating ground water vulnerability, coarse textured soils, and low organic matter will be available along with SCS field maps.

The acetochlor label will contain the following statement: "Do not apply acetochlor to soils if all three conditions exist":

- sands with less than 3 percent organic matter when ground water is within 30 feet of soil surface
- loamy sand with less than 2 percent organic matter when ground water is within 30 feet of soil surface
- sandy loam with less than 1 percent organic matter when ground water is within 30 feet of soil surface

Acetochlor ***can*** be applied to ***any*** soil type ***unless*** all three restriction criteria—soil texture , organic matter level, and depth to ground water—are met .

Water Quality Update: The Results of Pesticide Monitoring in Illinois Streams and Public Water Supplies

A.G. Taylor and Steve Cook

One of the primary functions of the Illinois Environmental Protection Agency (IEPA) is monitoring the quality of Illinois water resources. This involves programs that periodically sample ambient water from lakes and streams, groundwater from community water supply wells, and finished drinking water from community water supply treatment plants and distribution systems. Testing for pesticides has become an integral component of these sampling programs because of the extensive use of agrichemicals in Illinois crop production systems. This paper summarizes the recent findings of the IEPA's pesticide monitoring programs.

Ambient Stream Monitoring

Since October 1985 the IEPA has routinely monitored 30 streams throughout Illinois for commonly used agricultural herbicides and insecticides. Twenty-six of the sampling stations are located in streams predominantly influenced by agricultural drainage. Four of the stations are less affected by agricultural activities and are located in watersheds that contain higher percentages of urban and forested land. These four stations represent control watersheds where agricultural pesticides are less likely to be detected. The four control watersheds were established for evaluation purposes.

When the monitoring program was initiated, samples were collected six times per year from each station. The test results accrued through 1989 showed that the highest pesticide concentrations occurred during the spring and summer. These results suggested that the pesticide levels in the streams were associated with field applications and subsequent precipitation/runoff events. The consistency of these results made it possible to reduce the frequency of sampling to three times per year without compromising the data. The analytical data have been compiled for all stream samples collected from October 1985 through February 1994. The herbicides detected, the percentage of stations where they have been detected, and the percentage of sample detections for the 1,278 samples collected during this period, are shown in Table 1.

The data indicate that four of the herbicides used most extensively in corn and soybean production are being detected on a regular basis. The high percentage of station detections reflects the widespread use of these chemicals within the state. Atrazine is the most frequently detected pesticide currently being monitored by the IEPA. It is the only herbicide that shows a mean concentration above 1 microgram per liter (μg/l); however, individual analyses of atrazine, cyanazine, alachlor, and metolachlor have been as high as 65 μg/l, 38 μg/l, 18 μg/l, and 17 μg/l, respectively.

The streams in the sampling network with the highest and the lowest mean concentrations of the herbicide contaminants have been identified. Those with the lowest mean concentrations are Lusk Creek in Pope County, the South Fork of the Saline River in Saline County, the Fox River in McHenry County, and the Apple River in Jo Daviess County. Three of these four streams are in the designated control watersheds. Lusk Creek and the South Fork of the

Table 1. Summary of pesticide detections at 30 stream monitoring stations in Illinois, October 1985 – February 1994.

PESTICIDE	STATION DETECTIONS	SAMPLE DETECTIONS	MEAN CONCENTRATION
	%		μg/l[1]
Atrazine	97	69.6	1.12
Metolachlor	100	50.5	0.45
Alachlor	97	47.9	0.19
Cyanazine	100	44.4	0.65
Metribuzin	100	8.1	0.06
Trifluralin	88	6.7	0.01

[1] μg/l = micrograms per liter or parts per billion.

Saline River are in heavily forested drainage basins. The Fox River is primarily affected by urban area drainage. The Apple River is not in one of the control watersheds. Its drainage basin consists of a hilly terrain where livestock and dairy production are predominant. Row crop production is less intense in this area than in other parts of the state.

The streams with the highest mean concentrations include the Little Wabash River in Clay County, Bay Creek in Pike County, Bear Creek in Adams County, and Silver Creek in St. Clair County.

The monitoring data represent ambient levels of pesticide contaminants in Illinois streams. The extensive presence of these contaminants in Illinois streams appears to be attributable to runoff of field-applied agricultural pesticides.

Community Water Supply Monitoring

All community water supplies in Illinois are required to monitor finished drinking water for pesticide contaminants in accordance with state and federal drinking water regulations. Those supplies that utilize surface water sources began compliance monitoring in July 1992. Initially this involved 135 community water supply systems. Since then, several supplies have obtained water from other sources, and there are now 124 surface supplies participating in the monitoring program. Approximately one-third of the 1,259 groundwater supplies in the state have also initiated pesticide monitoring. The remainder will be phased-in during the next two years.

Samples are collected from each supply on a quarterly basis for at least one year. If a pesticide that is regulated under the federal Safe Drinking Water Act is detected above its method detection limit, the sampling is continued until it is demonstrated that the concentration is reliably and consistently below its Maximum Contaminant Level (MCL). An MCL is the federal drinking water standard. The United States Environmental Protection Agency (USEPA) has established MCLs for a number of commonly used agricultural pesticides, including alachlor at 2 μg/l, atrazine at 3 μg/l, simazine at 4 μg/l, and 2,4-D at 70 μg/l.

Individual samples may exceed an MCL without causing a violation of the standard; however, if the average concentration of four consecutive quarterly samples exceeds an MCL, the water supply is deemed to be out of compliance. Conversely, one sample that is more than four times the MCL could cause a violation. When a pesticide that does not have an established MCL is detected, a Health Advisory (HA) is used as a guide to determine the potential danger of the chemical as a contaminant in the drinking water. Unlike an MCL, a HA is not an enforceable standard. Some examples of HAs for commonly used agricultural pesticides include cyanazine at 1 μg/l and metolachlor at 100 μg/l.

Surface Water Supplies

During the first year of compliance monitoring, July 1992 through June 1993, over 80 percent of the surface supplies reported pesticide detections. Ten of the supplies were cited for non-compliance due to values exceeding the atrazine standard.

The analytical results for the second year of monitoring (July 1993 through June 1994) indicate that atrazine was detected in 113 of the surface water supplies. Other pesticides detected in at least one-third of surface water supplies include 2,4-D, metolachlor, simazine, and cyanazine. Thirty-nine of the supplies had one or more samples with concentrations of atrazine above 3 μg/l, while the concentration of simazine exceeded 4 μg/l in three supplies, and the concentration of alachlor exceeded 2 μg/l in one supply. Twenty-four of the supplies had one or more samples containing cyanazine in concentrations above its HA of 1 μg/l. These detections and those of other pesticide compounds are summarized in Table 2.

Table 2. Detections of pesticides in Illinois community water supplies which utilize surface water as a potable source, July 1993 – June 1994[1]

PESTICIDE	NO. OF SUPPLY DETECTIONS	MAXIMUM CONCENTRATION	MCL[2]/HA[3]	SUPPLIES WITH SAMPLES > MCL/HA
		μg/l[4]		
Alachlor	25	9.00	2[2]	1
Atrazine	113	30.00	3[2]	39
Cyanazine	41	9.30	1[3]	24
Metolachlor	59	3.60	100[3]	0
Simazine	50	18.00	4[2]	3
2–4,D	74	1.40	70[2]	0
DBCP	6	0.04	0.2[2]	0
PCP	5	0.60	1[2]	0
Propachlor	1	0.54	90[3]	0
Picloram	10	0.14	500[2]	0
Dalapon	26	9.00	200[2]	0
Dinoseb	1	0.21	7[2]	0
Dicamba	6	1.10	200[3]	0

[1] Four of the water supplies with reported detections use both ground and surface water as a source.

[2] MCL = Maximum Contaminant Level – Federal Drinking Water Standard.

[3] HA = USEPA Lifetime Health Advisory.

[4] μg/l = micrograms per liter or parts per billion.

The maximum concentrations listed in Table 2 show that several of the pesticides were detected at relatively high concentrations as compared to their respective MCLs or HAs. The high levels of detection occurred primarily in the samples collected during the spring of 1994. Figure 1 illustrates this point by comparing the mean values of the detected concentrations of atrazine for each sampling period between July 1993 and June 1994. This phenomenon is attributed to the application of the pesticides coincident with intense rainfalls in many areas of the state.

Multiple pesticide detections were common among the surface water supply samples collected during the second year of monitoring. This may be a concern when two or more of the contaminants present in a sample are known to produce similar toxicological effects. Table 3 gives the number and percentage of supplies with multiple pesticide detections. Over 50 percent of the supplies tested reported samples containing detectable concentrations of three or more pesticides. Pittsfield, Carlinville, Paris, and Springfield each had one sample that contained six pesticides. Of the 404 samples that had pesticide detections, 53 percent were contaminated with two or more pesticides. Figure 2 illustrates the percentage of contaminated samples with multiple pesticide residues.

Table 3. Number and percentage of surface water supplies in Illinois with multiple pesticide detections reported as the result of testing, July 1993 – June 1994

NO. OF PESTICIDES DETECTED	NUMBER OF SUPPLIES[1]	PERCENTAGE OF SUPPLIES
6	4	3
5	20	16
4	17	14
3	25	20
2	31	25

[1] The total number of water supplies tested was 124. Those with only one or no pesticide detections are not accounted for in this table.

Groundwater Supplies

Compliance monitoring for community water supplies utilizing groundwater as a source was started during the first six months of 1993 and involved 150 supplies. Since that time, 300 additional groundwater supplies have been phased into the program.

Between July 1993 and June 1994, detectable levels of one or more pesticides were found in samples from 95 of the groundwater supplies. A summary of the pesticide detections for that period is provided in Table 4. Atrazine, which was the most frequently detected pesticide, was reported in the analyses from 54 of the supplies. Simazine and 2,4-D were the only other pesticide compounds with a significant number of detections. These two compounds were found in 28 and 27 of the supplies, respectively. Three of the groundwater supplies had samples that contained atrazine above 3 μg/l.

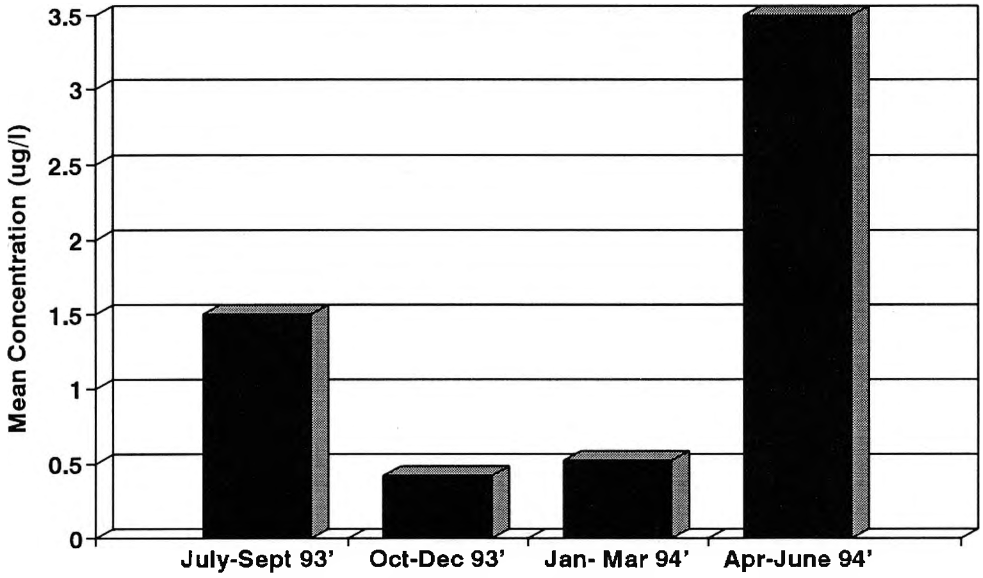

Figure 1. Quarterly mean concentrations of atrazine detections in Illinois' surface water supplies, July 1993 - June 1994

Water Supply Compliance

Since the compliance monitoring program was initiated in July 1992, a total of 16 surface water supplies have been determined to be out of compliance due to pesticide contamination. All 16 cases resulted from values exceeding the MCL for atrazine. None of the groundwater supplies involved in the monitoring program to date have exceeded a pesticide standard. The 10 surface water supplies that were out of compliance during the first year of moni-

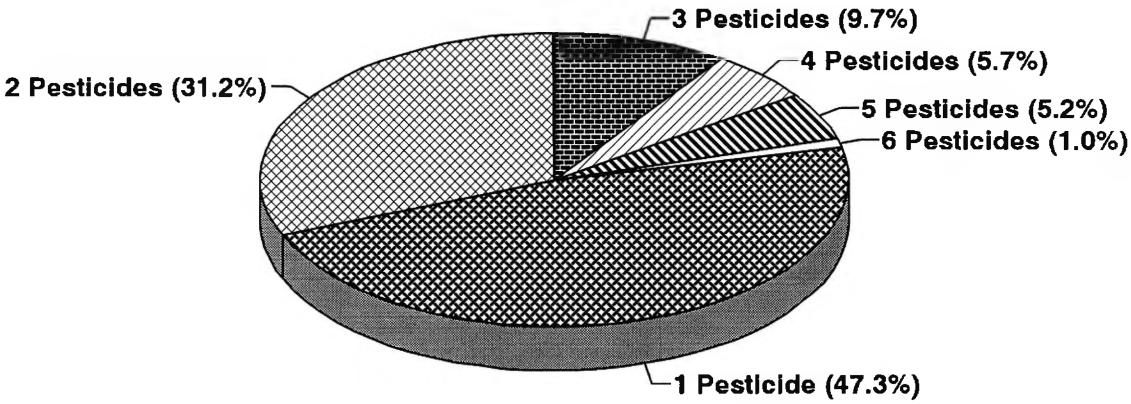

Figure 2. Percentage of pesticide contaminated samples with multiple pesticide detections collected from Illinois' surface water supplies, July 1993 - June 1994 .

toring have all returned to compliance. At the time of this writing, four of the community water supplies remain out of compliance. These supplies are Paris, Carthage, Patoka, and Hillsboro.

Table 4. Detections of pesticides in Illinois community water supplies which utilize groundwater as a potable source, July 1993 – June 1994

PESTICIDE	NO. OF SUPPLY DETECTIONS	MAXIMUM CONCENTRATION	MCL[1]/HA[2]	SUPPLIES WITH SAMPLES > MCL/HA
		µg/l[3]		
Alachlor	2	0.39	2[1]	0
Atrazine	54	6.30	3[1]	3
Cyanazine	4	2.10	1[2]	1
Metolachlor	6	1.80	100[2]	0
Simazine	28	1.90	4[1]	0
2–4,D	27	1.40	70[1]	0
DBCP	1	0.02	0.2[1]	0
PCP	3	0.23	1[1]	0
Picloram	8	0.20	500[1]	0
Dalapon	4	2.43	200[1]	0
Dicamba	2	0.29	200[2]	0

[1] MCL = Maximum Contaminant Level – Federal Drinking Water Standard.
[2] HA = USEPA Lifetime Health Advisory.
[3] µg/l = micrograms per liter or parts per billion.

Ambient Community Well Network

In July 1994, the IEPA initiated an ambient groundwater monitoring network for community water supply wells. The design of this network was developed through consultation with the United States Geological Survey, the Illinois State Geological Survey, and the Illinois State Water Survey. It is a random, stratified network of 350 wells intended to represent ambient conditions in all active community water supply wells. The well network is stratified by depth, aquifer type, and the presence of aquifer material within 50 feet of the surface. Additionally, the network is based on a probability of occurrence that will provide a 95 percent confidence level of all analytical results.

Immunoassay equipment is being used as a cost-effective screening technique to assess the 350 network wells for triazines and alachlor. The IEPA field staff have finished the initial round of sampling and the detections obtained through the immunoassay screening are being quantified with gas chromatography and mass spectrophotometry. The results of this sampling program will be available after all confirmation and quantification testing is complete.

Vegetative Filter Strip Establishment

Michael D. Plumer

The loss of pesticides, nutrients, and sediment from cropland can be a significant environmental problem. The use of vegetative filter strips has been recognized as a management practice that can have a significant impact for slowing or stopping these materials from entering surface or ground water. Vegetative filter strips are land areas that are planted to a heavy vegetation located between a field (potential pollutant-source) and an area to be protected (surface water, stream, river, sinkhole, or other sensitive land). Vegetative filter strips work by trapping sediment, organic matter, chemicals, and nutrients when the runoff from the cropland passes through the vegetation. Generally, filter strips are very effective in trapping sediment and the sediment-bound nutrients and pesticides. These include phosphorus and ammonium nutrients. Soluble nutrients and pesticides are trapped when the runoff stops within the filter strip. Therefore, heavy vegetation should slow water movement, thus allowing for better infiltration. Established vegetation also helps to change the soil properties, which provides better infiltration and enhances the biological and chemical processes that break down pesticides and utilize the nutrients, thereby trapping them in the filter strip.

Design

There are many criteria for determining the design of a vegetative filter strip:

- Field runoff potential: the rate and volume of water movement, tillage practices, slope
- Soil characteristics: the infiltration rate, organic matter, soil type
- Type of pollutants to control: sediment, nutrients, pesticides, etc.
- Use of filter strip: haying, grazing, wildlife, ARP, conservation easement, riparian area
- Contouring to create maximum flow area and efficiency

Vegetative filter strips can be quite effective. A Virginia study showed that nitrate removal ranged from 46 to 75 percent for 15- and 30-foot wide filter strips. A recent Iowa study indicated that atrazine removal ranged from 28 to 35 percent for a 15-foot wide filter strip and 51 to 60 percent for a 30-foot wide filter strip. The wider the vegetative strip, the greater the pollutant removal. To ensure that the filter strip is effective, the ratio of the field drainage area to the filter strip area should not exceed 50:1, and 10:1 would be better.

To comply with current pesticide restrictions for atrazine, pesticide setbacks must be 66 feet wide. This width helps to ensure a large enough area to properly slow the runoff, thus trapping the pesticides and nutrients and preventing movement off the field. Tile inlets and areas where runoff enters ditches also require the 66-foot pesticide setback. Using vegetative filter strips for the setback area reduces the chance that pesticides will enter surface or ground water. For maximum trapping efficiency, the runoff from a field should enter the filter strip in a shallow, slow moving, uniform flow across the whole filter strip. Contoured filter strips will work better than strips where runoff is concentrated.

Vegetation

The plants selected for a vegetative filter strip must have a dense top growth, form a uniform ground cover, have a heavy fibrous root system, and tolerate the pesticides that will be used in the field. Grasses are the best selection and sod-forming grasses are better than bunch grasses. Cool season grasses are preferred because they are actively growing with dense foliage in the spring. This increases their effectiveness because this is the time when most damaging runoff can occur.

Grasses differ in their ability to tolerate pesticides. A recent study at the Dixon Springs Agricultural Research Center showed marked differences in susceptibility of grass species to pesticides. A ranking of tolerance to some common corn and soybean herbicides suggests that orchardgrass is the most tolerant, followed by Kentucky 31 tall fescue, redtop, timothy, smooth bromegrass, and Kentucky bluegrass. Orchardgrass and tall fescue are bunch grasses, which means that they do not form a dense cover unless seeded heavily.

Smooth bromegrass forms a dense sod that is very good for erosion control. Warm season grasses can also be used if they are managed to provide maximum cover in the spring and early summer. Switchgrass is often used because it is easy to establish and tolerant to many commonly used herbicides.

Seeding and establishment should be done according to the guidelines for establishment contained in the *Agronomy Handbook*. However, seeding rates of two to three times the normal rate can provide a denser stand and quicker filter strip establishment.

Maintenance of the vegetative filter strip is important to ensure maximum operating effectiveness of the filter strip. Filter strips should be checked for damage, especially after heavy rainfall, and reseed any bare or damaged areas to minimize the development of erosion rills. The strip should be mowed to maintain a good height of not less than 6 to 10 inches. Moving should be done after mid-July to avoid destruction of wildlife nesting areas. Weeds and brush should be controlled either by timely mowing or with appropriate herbicides.

Vegetative filter strips can help greatly in maintaining or improving water quality. For greater benefit, filter strips should be used in conjunction with other good management practices to help protect our soil and water resources.

White Mold of Soybeans: Management and Control

Craig R. Grau

Whereas brown stem rot, Phytophthora root rot, sudden death syndrome, and the soybean cyst nematode generally are regarded as the most significant diseases of soybean in the North Central States, white mold, also called Sclerotinia stem rot, has been a chronic problem in Minnesota, Wisconsin, and Michigan for many years. Beginning in 1992, and again in 1994, Sclerotinia stem rot developed throughout the northern range of the North Central Region. Nationally, the disease is considered to be minor because it does not involve a high percentage of the total soybean acreage. Chamberlain (1951) was the first to make a detailed report on Sclerotinia stem rot in the Midwest after he observed localized, but severe outbreaks of the disease in Illinois in 1946. Chamberlain (1951) summarized his findings thusly: "There appears to be no ready explanation as to why Sclerotinia stem rot, certainly one of the least prevalent of soybean diseases, can cause such severe but localized damage." After almost 50 years, more is known about factors that impact on the incidence and severity of this disease, but an element of mystery still remains as to why sudden outbreaks occur.

Cultural practices associated with soybean production have changed in recent years and such changes may be associated with the increased recognition of Sclerotinia stem rot. In addition, soybean production has expanded into areas of the upper Midwest where other hosts of *S. sclerotiorum* are frequently grown in rotation with soybean. Although the interest in Sclerotinia stem rot has increased, the disease is still treated only as a curiosity by many soybean pathologists, breeders, and agronomists. However, a person needs to have only one encounter with this disease to realize its destructive potential.

The Pathogen

Sclerotinia sclerotiorum (Lib.) d By. (Grau, 1988) is the cause of Sclerotinia stem rot of soybean. This pathogen is characterized by fluffy white mycelium and black sclerotia that are formed by aggregations of mycelium. Sclerotia are usually 0.25 to 2.0 inches long, formed on and within diseased tissue, and they function as resting structures that enable this fungus to survive in soil or mixed with seed. Sclerotia germinate at or slightly below the soil surface by producing apothecia, which in turn produce ascospores, which are forcibly ejected and wind disseminated.

Symptoms

Symptoms of Sclerotinia stem rot typically appear during the early stages of pod development (growth stages R3-R4). Foliar symptoms at the canopy level indicate that the disease is present. These include chlorosis and wilt, with tissues between major leaf veins developing a gray-green cast while vein tissues remain green. In time, leaves become totally necrotic, tattered, and curled, but remain attached to the stems past maturity. Foliar symptoms of Sclerotinia stem rot can be mistaken for late season Phytophthora root rot, brown stem rot, sudden death syndrome, and stem canker, but differences in stem symptoms among these diseases can be used for diagnosis.

Initially, stem lesions develop at nodes and appear gray and water-soaked. The pathogen rapidly progresses into stem tissues above and below nodes and causes lesions that are 3 to 18 inches long and usually encompass the entire stem (Grau 1988). White fluffy mycelium covers the lesion area, especially during periods of high relative humidity. The characteristic black sclerotia of *S. sclerotiorum* are differentiated from mycelium and in time are readily observed on the lesion surface. Initially, lesions are tan and progressively become white, presenting a sharp contrast at the interface with green stem tissues. By crop maturity, stem tissues are white and tissues have a shredded appearance if disturbed; often a reddish discoloration is interspersed within these tissues and at the borders of lesions. At harvest, diseased stems are characterized by poor pod development, a white appearance, and an abundance of sclerotia inside them. Diseased pods are outwardly white in appearance, mycelium and sclerotia are readily observed inside, and infected seed appear white and moldy. Sclerotia are commonly observed with the harvested grain, and if free water is present, they can cause seed decay problems in storage.

Epidemiology

Sclerotinia stem rot, which is found in soybean with high-yield potential, is favored by moderate air temperatures and frequent rain events immediately prior to flowering and on into the pod development stage of growth. Sclerotinia stem rot is responsive to cultural practices that promote moderate air temperatures in the crop canopy and cool and moist soil conditions.

Sclerotinia sclerotiorum survives as sclerotia and produces apothecia, which in turn produce ascospores, the infectious progagule (Abawi et al. 1975, Grau 1988). Apothecia optimally form at soil temperatures of 55 to 70 degrees F and near water-holding capacity for 10 to 14 days (Abawi et al. 1975, Grau 1988). Apothecia produce ascospores that are forcibly ejected and disseminated by air currents to the host surface. Canopy temperatures less than 80 degrees F and plant surface wetness for 12 to 16 hours recurring on a daily basis, or continuous surface wetness for 42 to 72 hours, are the environmental conditions needed for disease development (Abawi et al. 1975, Grau 1988).

Blossoms are a primary site of infection by *S. sclerotiorum* (Abawi et al. 1975, Boland and Hall 1986, Sutton and Deverall 1983). Ascospores germinate and colonize blossom tissues, which in turn provide a food base needed by the pathogen to invade pod tissues, and progress into the nodal and eventually stem tissues. Infection of tissues other than nodes such as leaves, petioles, and internodes can occur when plants come in contact with diseased adjacent plants. This is more common when the crop is lodged. The pathogen causes lesions that completely encircle the stem and disrupt the transport of water, mineral nutrients, and photosynthates to developing pods. Sclerotia are formed as host tissues are depleted of nutrients needed by the pathogen. Sclerotia are returned to the soil at harvest or as contaminates associated with seed at planting. The importance of infected seed in the epidemiology of this disease has not been studied, but its effect is likely to be less than that of sclerotia mixed with seed.

Host Range

Sclerotinia sclerotiorum is reported to infect almost 400 species of plants (Grau 1988; Table 1). Although Sclerotinia stem rot develops in corn-soybean rotations, it is greatly enhanced if another host crop is rotated with soybean. Sudden outbreaks of Sclerotinia stem rot have been observed in fields monocultured to corn for 5 to 11 years prior to soybean planting (C. R. Grau, personal observations). Lambsquarter (*Chenopodium album* L.), red-rooted pigweed (*Amaranthus retroflexus* L.), velvetleaf (*Abutilon theophrasti* Medic.), and common ragweed (*Ambrosia artemisiifolia* L.) are broadleaf hosts of *S. sclerotiorum* and contribute to the maintenance of inoculum in fields during the nonhost year of a rotation. Corn, small grains, and grass weeds are not hosts of *S. sclerotiorum*.

Soybean Cultivars

Soybean cultivars differ in reaction to Sclerotinia stem rot (Boland and Hall 1986, Grau 1988, Grau and Radke 1984). Cultivars range from moderately resistant to very susceptible within maturity groups 0 through II. However, less resistance is reported within maturity group III and later (Grau 1988). Most cultivars released by commercial companies have not been evaluated extensively for resistance to Sclerotinia stem rot. However, this situation is rapidly changing as the disease becomes more important in the North Central Region. Some question still remains whether differences in cultivar

Table 1. A partial list[1] of agronomic and vegetable crops reported to be hosts of *Sclerotinia sclerotiorum*

CROP	SCIENTIFIC NAME
Table Beet	*Beta vulgaris* L.
Rapeseed (Canola)	*Brassica napus* L.
Cole crops (Cauliflower, etc.)	*Brassica oleracea* L.
Crownvetch	*Coronilla varia* L.
Soybean	*Glycine max* (L.) Merr.
Birdsfoot Trefoil	*Lotus corniculatus* L.
Alfalfa	*Medicago sativa* L.
Sweetclovers	*Melilotus* spp.
Lima Bean	*P. limensis* Macf.
Green & Dry Bean	*P. vulgaris* L.
Pea	*Pisum sativum* L.
Field Pea	*P. sativum* L. subsp. *arvense* Poir
Clovers (Red, White, etc.)	*Trifolium* spp.
Potato	*Solanum tuberosum* L.
Carrot	*Daucus carota* L. var *sativa* DC.
Sunflower	*Helianthus annuus* L.

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[1] Taken from a host range list prepared by H. F. Schwartz, Dept. of Botany & Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

reactions are due to physiological resistance to S. sclerotiorum, or to other factors such as plant architecture, maturity, and lodging characteristics. For example, early maturity cultivars are believed to escape infection because of their usual short stature and early flowering. In contrast, late maturity cultivars are believed to be more diseased because of lush vegetative growth and later flowering. I contend that highly susceptible cultivars can be found in maturity groups 0 through III. I do support the contention that cultivars that characteristically lodge tend to express greater disease, but lodging is only one of several factors that govern cultivar reactions to Sclerotinia stem rot.

Soybean cultivar performance in the presence of Sclerotinia stem rot is influenced by inoculum density, cultural practices, and climate (Grau 1988, Grau and Radke 1984). Cultivar resistance is thus difficult to standardize. Disease incidence and severity have been used to evaluate cultivar reaction to Sclerotinia stem rot (Grau 1988, Grau and Radke 1984), but disease incidence/severity values need to be used in conjunction with yield data. General field observations indicate that considerable yield reduction can occur. Seed production of infected plants can be completely inhibited, but generally some seed are set, even though they are usually reduced in size. Cultivars differ in the ability of their infected plants to set seed. Thus, two cultivars of similar yield potential and disease incidence can differ in yield. There is evidence that some cultivars may compensate for diseased plants better than others.

Because soybean cultivars differ in susceptibility to Sclerotinia stem rot, cultivar selection can greatly reduce the risks associated with specific management systems. For example, highly susceptible cultivars are at risk if planted in reduced row widths or planted immediately after another host crop in a field infested with *S. sclerotiorum*. When the potential for disease is high, narrow row culture should be discontinued and a cultivar with a low disease reaction should be selected for planting in order to achieve the lowest risk situation. In many cases cultivars with low disease reactions are not available or are undesirable because of poor agronomic traits. In this situation, the shift from narrow to wide row culture may be enough to lower the risk of yield loss due to Sclerotinia stem rot. Many growers are not aware of the potential for this disease until they change to drilled soybeans.

Row Versus Drilled Soybeans

The crop canopy can greatly affect environmental conditions needed for optimum activity by the pathogen and subsequent disease development (Grau 1988, Grau and Radke 1984). Thus, cultural practices that modify the canopy environment have a potential impact on the incidence and severity of Sclerotinia stem rot. A major change in soybean production in the upper Midwest in recent years has been a reduction of row widths from 30 inches (conventional) to 7 to 10 inches (drilled). Yields are often 20 percent greater in drilled soybean compared to yield in systems practicing conventional row widths (Costa et al. 1908). However, a 65 percent increase in incidence of Sclerotinia stem rot and a 42 percent reduction in yield has been measured for soybean cultivars grown in narrow row widths as compared to wide row widths (Grau and Radke 1984). Greater severity is observed if plant populations are increased regardless of row width. Although disease severity is greater in drilled soybeans, the yield of drilled soybeans is frequently greater than yields in row soybeans.

Tillage

The effect of tillage on Sclerotinia stem rot is not conclusive. The survival and activity of sclerotia is greatly dependent upon soil moisture, and more importantly, the range of soil moisture extremes (Yorinori and Homechin 1985; Williams and Stelfox 1980). Thus, sclerotia that are buried by tillage may survive longer because soil moisture is more constant at lower depth in the soil profile compared to the soil surface. The effect of tillage should be a high priority for research on this disease.

Fungicides

Benomyl and thiophanate (methyl) are registered as foliar fungicides for soybeans and are effective against *S. sclerotiorum* on similar crops such as snap beans. Studies conducted in Wisconsin indicate that one application of benomyl (Benlate 50W at 1 lb/acre) can reduce Sclerotinia stem rot (C.R. Grau, unpublished data). However, fungicides must be applied when soybeans are producing flowers or when pods are beginning to emerge on the lower half of the plant. Thus, timing and penetration of the fungicide through the soybean canopy are important determinants of its effective use for control of Sclerotinia stem rot. Foliar-applied fungicides are more feasible for seed production than for cash grain.

Herbicides

Soil-applied herbicides have been shown to affect mycelial growth and carpogenic germination of sclerotia of *S. sclerotiorum* (Casale and Hart 1986, Radke and Grau 1986). Herbicides commonly used for soybean production, such as trifluralin, pendimethalin, and metribuzin, stimulate carpogenic germination of this soil-borne plant pathogen (Radke and Gray 1986). However, the effect of this stimulation on carpogenic germination has not been studied in relation to its effect on disease severity. Atrazine and simazine, herbicides commonly associated with corn production, stimulate sclerotia to germinate, but apothecia develop abnormally and do not produce asci and ascospores (Casale and Hart 1986, Radke and Grau 1986). Thus, corn culture may reduce soil inoculum of *S. sclerotiorum* by several mechanisms: corn is not a host; associated herbicides provide broadleaf weed control, which reduces the population of potential hosts; and herbicides stimulate sclerotia to germinate, but abnormally so, resulting in reduced reproduction, which in turn leads to a depletion of sclerotia in the soil. The reduced use of atrazine may be contributing to the sudden occurrence of Sclerotinia stem rot in more regions of the corn belt.

Summary

Many of the factors discussed in the previous section can be modified to reduce the risk of yield loss due to Sclerotinia stem rot. The specific combination of management practices implemented depends greatly upon specific grower situations. Soybean cultivar selection is the foundation of a management system to control Sclerotinia stem rot. Cultivar performance can be supplemented by crop rotation. Production practices designed for high yield potential should not be totally abandoned because of Sclerotinia stem rot. For example, planting at reduced row widths, irrigation, and high soil fertility all are implemented because of greater yield potentials, but all can result in a dense canopy that also favors the development of Sclerotinia stem rot. Each management practice presents a potential risk, but specific modifications can usually reduce the overall risk factor.

Future Research Needs

The development of resistant cultivars within northern maturity groups is a critical need for the soybean industry. This objective is greatly curtailed by the lack of understanding of how resistance functions and is inherited. Actually, there is debate over whether physiological resistance to *S. sclerotiorum* actually exists within soybean germplasm. I believe resistance does function, but many breeders and pathologists maintain that measured differences between cultivars for disease incidence and severity result from plant architecture, flowering date, or other factors that allow the plant to escape infection. Research is needed to resolve this issue, because the factor(s) responsible for host responses influence breeding and selection techniques. Currently, techniques to evaluate soybean lines for resistance are relatively inconsistent and often time and space consuming, so refinement of these techniques would be of value.

Critical research is needed on the biology of sclerotia of *S. sclerotiorum*. Our knowledge is limited on the fate and activity of sclerotia subjected to different tillage systems. The role of contaminated seed lots and infected seed has not been studied for the introduction of the pathogen into uninfested fields and the general epidemiology of the disease. Greater knowledge in these areas is needed to supplement benefits gained from soybean cultivar selection.

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Electronics for Precise Application

Robert E. Wolf

Whether it is simply a monitor, or a spray rate controller, or a more sophisticated computer system, more and more applicators are installing electronic hardware and using specially designed software to improve their application accuracy. Whatever the application requirements, electronic systems provide the versatility and intelligence to improve the efficiency and make the application process more precise, automatically.

The basic principle of operation for electronic control systems is the use of one or more sensors to **measure or sense** a condition and a CPU (central processing unit) to **translate** the signal for display and for activating a process. Sensors are the key to electronic control systems and include speed, flow, flow rate, pressure, clogged nozzles, and boom height. Monitors simply use the variables that determine gallons per acre (GPA), which are speed, flow and/or pressure, and spray width, to calculate and display the resulting GPA. It is up to the operator to make adjustments as necessary to apply the desired GPA.

A combination of the above electronic components constitutes a rate controlling system that will adjust application rates on-the-go. Rate controllers input the desired GPA and control the flow rate (gallons per minute, GPM) by activating a servo-valve, which is a regulating valve in the system, to maintain the required GPM. As the speed sensor detects an increase or decrease in ground speed, the electronic control system calculates a new flow rate and automatically commands the servo-value to adjust the application rate back to the original desired application rate. The new variable-rate systems use computers to determine the proper rate and control the amount of chemical applied. It is important to know that the limiting factor for precise application rests with the spray nozzles rather than the rate controller. With these units, GPA is controlled by changing nozzle pressure and it is critical to maintain the pressure within the recommended pressure range (for example, 10 to 50 psi for extended range flat-fan nozzles, 20 to 40 psi for Raindrop nozzles). Remember that pressure must increase four times to double the nozzle flow rate. Therefore, even with a rate controller, ground speed must be kept within a narrow range in order to maintain a quality spray pattern.

These same electronic components provide the operator with the ability to detect any application malfunctions. Sensors located at critical points on the application system will alert the operator to any problems that may occur. The console will either provide an audible warning or display an error message. The system may also be capable of providing a percent application error by calculating the difference between the target rate and the actual application rate.

Probably one of the major advantages resulting from the development of electronic components in the application industry has been with the variable-rate application process. Variable Rate Technology (VRT), the application of variable rates of ingredients to areas based on an extensive testing and mapping program, is becoming a widely accepted practice in the application industry. Grid testing information is placed on a computer chip, inserted into an on-board computer, and then will direct a variable-rate application of ingredients onto the target area according to the test needs. For cropping systems, yield information mapping can also be used to vary the application rate by area location. The computer commands the system to control the rate applied. One such system is equipped with on-board sensing devices to measure needs and then command the applicator device to vary the rate of the ingredients as the applicator goes across the area.

Another major development in the application industry has been with the use of direct injection. Direct injection is a process that involves the injection of pesticide(s) into the carrier at some point in the spray boom. In this process the chemicals are stored in dedicated containers and are pumped to the spray carrier without applicator contact. Mixing and handling of the products is either eliminated or reduced. Sensors and computers are critical for this process to work effectively. Not only can this system be used to apply up to six different ingredients at a time, but it can also be used on previous mapping or accomplished with sensors on-the-go.

In addition to their ease of use with electronic systems, variable-rate application and direct injection provide environmental and safety benefits. These include protection of the environment through more efficient and selective use of inputs, and safety benefits to the applicator, because the products are not handled in a typical mixing scenario. Dedicated containers can be returned for refill rather than remaining behind to contaminate the environment. Because there is no mixing of carrier and pesticide in a spray tank, leftover spray mixtures are no longer a disposal problem.

A major advantage of using an electronic system with application is that it reduces the guesswork and headaches about calibrating that many applicators have experienced. The stakes are high when the ingredients are misapplied. High costs associated with the product rates per acre and costs to the environment resulting from over-application can be eliminated. Applicator confidence cannot be over emphasized.

One major disadvantage of using electronics is the added cost to the system. Basic systems will add various amounts to the application unit cost. The more advanced systems, VRT and direct injection, can add potentially much higher costs to the equipment. Some of the costs may result from the basic expense of the electronic components, whereas others may result from associated features, such as grid testing and computer mapping. The electronic components will also add a serviceability cost increase to basic application systems. The service function may need to be supplied by the manufacturer or an outside service group. With direct injection systems, many are add-ons and may require retrofitting, which can be costly. Another major problem with an electronic system is the possibility that it may become obsolete very quickly. This is hard to avoid because the technology changes so rapidly.

Although electronic devices are widely used and accepted, some applicators are hesitant to make the initial investment in learning to use this technology. They view electronics either as an expensive toy, which is complicated and too high tech, or as a magic black box that is always correct and is for people who don't know how to accurately apply chemicals. Taking the time to learn the basic principles of electronic controllers and their principle of operation will alleviate most of the fears for new users.

There are many options available to applicators. The options need to be explored and decisions made regarding which features are needed and how much money can be invested in a system. Cost must be weighed against the advantages for each individual situation.

Attractants for Adult Corn Rootworm Monitoring and Control

Lesley Deem-Dickson and Robert L. Metcalf

Introduction

For over 20 years our laboratory has investigated the association between Diabroticite beetles and the plant family Cucurbitaceae. Diabroticite beetles have co-evolved with this plant family and they are thought to have been the original pollinators of its open, bowl-shaped flowers (Avila et al. 1989). These plants produce bitter oxygenated tetracyclic triterpenoids, or cucurbitacins (cucs), which are allomones or deterrents for most insects, but are kairomones for host selection for *Diabrotica* spp. (Metcalf 1986, Metcalf and Metcalf 1992). When the *Diabrotica* adults contact these compounds, they immediately cease movement and feed compulsively. The genus *Diabrotica*, consisting of at least 338 valid species, is largely neotropical—only the *virgifera* subgroup of about 35 species are found in North America. The *virgifera* species are usually univoltine and they overwinter in the northern hemisphere as diapausing eggs. The majority of species in this subgroup feed as larvae on grasses and are polyphagous pollen feeders as adults (Krysan and Smith 1987). Two members of the *virgifera* subgroup, the northern corn rootworm (NCR), *Diabrotica barberi*, and the western corn rootworm (WCR), *Diabrotica virgifera virgifera*, are generally considered to be the most important insect pests of corn, *Zea mays*, in the major corn producing areas of North America (Levine and Oloumi-Sadeghi 1991, Metcalf and Luckman 1994). These Diabroticite beetles have evolved away from their primary association with cucurbits to graminaceous plants. The immature stages of the NCR and WCR are rootworm feeders on corn. However, this apparently does not affect their adult preference for cucurbits, because most species of the *virgifera* group have been collected from the blossoms of Cucurbitaceae (Krysan and Smith 1987, Krysan et al. 1983). The behavioral responses of the corn rootworm beetles to cucurbitacins suggested the use of these compounds for control of the adult rootworms. A dry corn cob bait containing cucurbitacins (5 percent buffalo gourd root powder from *C. foetidissima*) and 0.3 percent carbaryl has already been successfully used for the control of adult corn rootworms (Metcalf et al. 1987).

In addition to the cucs from this plant family, the blossom volatiles can also be used to manipulate the beetles' behavior, so these can also be used to monitor and control adult corn rootworms. It is assumed that volatiles arose evolutionarily for pollination. They make the blossoms of Cucurbitaceae highly attractive to the *Diabrotica* beetles. Both the northern and western corn rootworm were first collected from the blossoms of the buffalo gourd, *Cucurbita foetidissima*, in southeastern Colorado in 1824 and 1868 respectively (Smith and Lawrence 1967). Cucurbit floral volatiles are long-range Diabroticite attractants. Thirty grams of shredded blossoms of *C. maxima* in cheesecloth-covered cylindrical sticky traps caught twelve times more *D. v. virgifera* adults after one hour of field exposure than unbaited control traps (Metcalf and Lampman 1989a). Many of the volatiles in Cucurbit blossoms have been identified. GC-fractionation of blossom volatiles showed the presence of numerous constituents: 40 from *C. maxima*, 16 from *C. moschata*, and 12 from *C. pepo*. Rootworm beetle preference for *C. maxima* blossoms was correlated with high release rates of 1,2,4-trimethoxybenzene, indole, cinnamaldehyde, cinnamyl alcohol, and β-ionone (Andersen and Metcalf 1987). *D. v. virgifera* (WCR) and *D. barberi* (NCR) have specific patterns of responses when exposed to a broad spectrum of the blossom volatile attractants. Both species respond to the simplified synthetic blossom mixture of 1,2,4-trimethoxybenzene, indole, and cinnamaldehyde (TIC). *D. v. virgifera* (WCR) respond specifically to 4-methoxycinnamaldehyde and cinnamaldehyde. *D. barberi* (NCR) respond to cinnamyl alcohol, 4-methoxyphenethanol, and phenylpropanol (Anderson and

Metcalf 1986; Lampman et al. 1987; Lampman and Metcalf 1987, 1988; Metcalf and Lampman 1989a, 1989b, 1989c).

Objectives

The behavioral responses of the corn rootworm beetles to blossom volatiles from these cucurbit plants suggested the use of these volatile kairomone attractants in the cucurbit baits for the control of the adult rootworms and on various traps for monitoring the beetles. The focus of the work discussed here was to evaluate the efficiency of traps and baits with attractants as compared to traps and baits without attractants, and determine whether the chemical attractants can be used to significantly improve the performance of both traps and baits. The TIC mixture was used as the basic combination of volatile attractants and other effective attractants were evaluated in combination with the TIC as well as separately, in order to optimize the attraction of adult northern and western corn rootworms. The optimum mixture has as few individual components as possible without sacrificing a significant amount of its effectiveness as an attractant for both WCR and NCR.

Methods

Use of Attractants on Traps

Experiments comparing different volatile attractants singly and in combination were conducted during the summer field seasons of 1990 through 1993. Attractant combinations (prepared at University of Illinois) were compared in a variety of small scale field experiments to determine the most effective formulations for NCR and WCR attraction. In the experiments that will be discussed here, the volatile attractants were either applied directly to cotton dental wicks or blotter paper squares, or mixed with cucurbit bait. These were then placed on a sticky trap.

The volatiles included 1,2,4-trimethoxybenzene (T), indole (I), cinnamaldehyde (C), cinnamyl alcohol (CA), phenylpropanol (PP), 4-methoxycinnamaldehyde (MCA), and 4-methoxyphenethanol (MPE). The 4-methoxycinnamaldehyde was obtained from the Chemical Dynamics Corp. (South Plainfield, NJ) and the other six volatiles were obtained from the Aldrich Chemical Co. (Milwaukee, WI). The most complex formulation contained all seven compounds (V7).

Experiments with baited sticky traps were carried out along the edge of corn fields. Four different types of traps were compared: white 1 qt. paper ice-cream cartons, yellow 16 oz. Solo cup traps, Pherocon AM traps (yellow), and Multigard (greenish yellow) traps. Pherocon AM and Multigard traps were commercial items with the insect adhesive already applied. For the two cylindrical traps, the exterior was coated with Tangle-trap adhesive (Tangle Foot Company, Grand Rapids, MI) and the traps were inverted over wooden stakes. All four types of traps were placed on wooden stakes approximately one meter above the ground (ear height). The individual stakes were 10 m apart and each treatment was replicated 4 times. The experiments were arranged in linear randomized complete blocks.

Experiment 1. Counts of WCR (Experiment 1a) and NCR (Experiment 1b) on white sticky traps treated with 100 μl of volatile attractants on dental wicks compared the following volatiles: MPE, CI/MPE, CI, TIC, MCA/MPE, MCA, CI/MCA/MPE, V7a, CI/MCA. Counts were made after 24 hours.

Experiment 2. Counts of WCR on white sticky traps treated with 200 mg of bait without attractants were compared with counts for bait containing the following volatiles: TIC/MPE, TIC, TIC/CA, V7a, TIC/MCA/MPE, TIC/MCA/MPE/CA, TIC/MCA, V7b. Counts were made after 24 hours.

Experiments 3 and 4. Counts of NCR and WCR on three types of traps (Solo cup, Pherocon AM, and Multigard) treated with 100 mg of 4-methoxycinnamaldehyde or 4-methoxyphenethanol on 2 inch by 2 inch blotter paper were compared. Counts were made after 24 hours. The corn was silking.

Experiments 5 and 6. Counts of NCR and WCR on three types of traps (Solo cup, Pherocon AM, and Multigard) treated with 100 mg of 4-methoxycinnamaldehyde or 4-methoxyphenethanol on 2 inch by 2 inch blotter paper were compared. Counts were made after 24 hours. The corn was past silking.

Cucurbit Baits and Semiochemical Attractants

A basic formulation of 95 percent corn grits and 5 percent *Cucurbita foetidissima* root powder (for a final concentration of approximately 0.01 percent cucs) was impregnated with 0.3 percent carbaryl. Solvent (acetone) impregnation was used to incorporate a spectrum of one to seven kairomone volatiles, typically at 0.1 percent each. When volatile attractants were added, the attractants were impregnated onto the granules by mixing the semiochemicals with acetone and shaking with 100 grams of granular bait until thoroughly mixed, approximately 3 minutes. The acetone was allowed to evaporate before the baits were used in experiments.

Experiment 7. Field experiments to identify differences in attractiveness of cucurbit baits to adult WCR were conducted by placing measured quantities of bait in corn whorls (top cluster of leaves) and counting dead and moribund beetles following a specific exposure period. Adult WCR and NCR were considered moribund when irregular involuntary movements of legs and antennae or unnatural postures attributed to exposure to neurotoxins were observed.

The whorl experiments were conducted in a 60-acre field of hybrid corn with a natural infestation of 0.7 WCR per plant at South Farms, University of Illinois, Urbana, Illinois. Approximately 200 mg per plant of (a) bait without volatile attractants and (b) bait plus the seven attractants (V7a) were sprinkled into the whorls of mature corn plants immediately prior to silking. The amount placed in the whorls approximates a rate of application of 10 kg per ha (10 lb per acre) in a field of 50,000 plants per ha (25,000 plants per acre). The baits were applied to 10 plants 10 m apart in single rows with 4 replicates of each bait alternated in separate rows, 10 rows apart.

Experiment 8. The second whorl experiment was done in the same field with the same design as Experiment 1. In this experiment a third bait treated with 0.1 percent 4-methoxy cinnamaldehyde (WCR attractant) was compared to the seven volatiles. Because NCR were not present in the field at this time, NCR attractants were not tested.

Field Scale Application of "Attracticide" Bait

With the cooperation of the U. S. Department of Agriculture, Northern Grain Insects Research Laboratory, Brookings, SD, a commercially prepared granular bait ("Slam" formerly "Nemesis," Microflo Company, Lakeland, FL) was applied by air to approximately 20 ha (44 acres) of hybrid corn, detasseled for seed production, near Pesotum (Champaign County, IL) (8-9-90). An adjacent equal-sized field was left untreated as a reference. The formulated bait, applied at 10 kg per ha, consisted of dry corn cob grit bait, 0.3 percent carbaryl, 5 percent of Cucurbita foetidissima root powder (containing about 0.2 mg per g cucs), and 0.1 percent each of cinnamaldehyde, cinnamyl alcohol, indole, 1,2,4-trimethoxybenzene, 3-phenylpropanol, 4-methoxyphenethanol, and 4-methoxycinnamaldehyde. This formulation was licensed under patents of the University of Illinois.

The effectiveness of the bait application was measured by (a) counting WCR and NCR on 100 individual maize plants at each of four corners of the treatment and reference areas, (b) placing four replicates of unbaited yellow sticky plastic cup (Solo, Urbana, IL) traps (Levine and Metcalf 1988) at each of the four corners of the treated and reference areas (n=4), and (c) placing four replicates of yellow sticky Solo cup traps, each baited with 100 mg of TIC attractant (equal portions of 1,2,4-trimethoxybenzene, indole, and cinnamaldehyde), at each of the four corners of the treatment and reference areas.

Results and Discussion

Sticky Traps with Attractants

Treated sticky traps were used to evaluate the relative activity of various combinations of the seven kairomonal attractants. Different combinations of the individual components were tested in an effort to find a bait that was effective for both NCR and WCR, incorporating as few attractants as possible. White cylindrical sticky traps with treated dental wicks were used to determine whether differences could be found in the attractive capacity of up to nine attractant mixtures for both WCR and NCR. For WCR, significant differences (p=.05) were detected for the baits. In subsequent means comparisons, three distinct groups emerged. MPE and cucurbitacin bait without an added attractant had the lowest mean number of WCR captured on the sticky traps, 18±5.12 and 19±2.48 respectively. The second group contained CI/MPE (132.7±29.86), CI (159.7±35.12), TIC (211.5±15.64), MCA/MPE (231.0±43.65), and MCA (265.5±50.52). The last group contained six baits with added attractants: TIC, MCA/MPE, MCA, CI/MCA/MPE (359.5±40.43), V7a (367.3 ±31.85), and CI/MCA (408.8±11.97).

For NCR, only two groups, each containing five baits, emerged as significantly different at p = .05. MCA (3.8±0.85), CI/MCA (4.3±0.60), bait without attractant (4.8±1.60), CI (7.8±1.03), and TIC (8.0±1.29) had significantly lower means than the second group, which contained MCA/MPE (24.8±4.59), V7a (28.0±2.12), CI/MCA/MPE (31.5±5.17), MPE

Table 1. Mean WCR and NCR counts for experiments 1a and 1b using cucurbitacin bait with and without volatile attractants on white cylindrical sticky traps.

Means followed by different letters are significantly different at p<.05

	EXP. NO 1A	EXP NO. 1B
VOLATILE	WCR	NCR
None	19.0 a	4.8 a
MPE	18.0 a	42.0 b
CI/MPE	132.7 b	45.5 b
CI	159.7 b	7.8 a
TIC	211.5 bc	8.0 a
MCA/MPE	231.0 bc	24.8 b
MCA	265.5 bc	3.8 a
CI/MCA/MPE	359.5 c	31.5 b
V7a	367.3 c	28.0 b
CI/MCA	408.8 c	4.3 a

Table 2. Mean WCR counts for experiment number 2 using cucurbitacin bait with and without volatile attractants on sticky traps.

Means followed by different letters are significantly different at *p*<.05

VOLATILE	WCR
TIC/MPE	22.3 a
TIC	24.1 a
TIC/CA	25.1 a
V7a	43.4 a
V7b	78.4 b
TIC/MCA/MPE/CA	79.6 b
TIC/MCA/MPE	80.9 b
TIC/MCA	84.5 b

(42.0±10.98), and CI/MPE (45.5±7.31). All the baits that contained MPE consistently attracted significantly more NCR than controls. Mean WCR (Experiment 1a) and NCR (Experiment 1b) beetle counts are given in Table 1.

In another experiment means tests revealed two significantly different (*p*=.05) groups of four volatile combinations. The group showing lower attraction of WCR consisted of TIC/MPE (33.0±6.5), TIC (35.0±8.1), TIC/CA (37.5±9.5), and V7a (62.6±13.6). The other group showed considerably higher mean WCR captures with TIC/MCA/MPE/CA (125.1±26.6), TIC/MCA/MPE (125.1±21.0), TIC/MCA (127.6±15.4), and V7b (129.4±23.7). When these four baits were compared on September 2, 1991, no significant differences in capture of WCR were found. The best baits for WCR all contained MCA. Means for Experiment 2 are presented in Table 2.

For the next experiments, colored traps with and without attractants were compared. All three types of traps captured more beetles when attractants were included. Means for Experiments 3 and 4 are presented in Table 3. Means for Experiments 5 and 6 are presented in Table 4. As can be seen in Tables 3 and 4, there is a species specific response of NCR to MPE and WCR to MCA.

Use of Attractants in Cucurbit Bait

One-way ANOVA of dead and moribund adult western corn rootworm beetles found in corn whorls after 24 hours showed a significant difference (*p*=.05)

Table 3. Northern (NCR) and Western (WCR) corn rootworm beetle capture on sticky traps (n = 4)*.

Traps baited with 100 mg. of attractant on 2" × 2" blotter paper. 24 hour counts. (Mean ± S.E.)

A. 4-Methoxyphenethanol (July 14 1993)

TRAP		NCR	WCR
Solo	unbaited	1.5 ± 0.3	0.7 ± 0.4
	baited	57.0 ± 34.8	0.3 ± 0.5
Multiguard	unbaited	1.0 ± 0.7	4.0 ± 3.5
	baited	61.2 ± 20.8	3.7 ± 1.3
Pherocon AM	unbaited	0.7 ± 0.8	0.8 ± 0.8
	baited	45.2 ± 8.1	1.4 ± 0.8

*Plant counts WCR 0.63, NCR 0.06 per plant, corn silking.

B. 4- Methoxycinnamaldehyde (July 13,1993)

TRAP		NCR	WCR
Solo	unbaited	0	8.3 ± 1.7
	baited	0	254.0 ± 50.5
Multiguard	unbaited	0.3 ± 0.3	28.0 ± 2.5
	baited	0	297.3 ± 107.1
Pherocon AM	unbaited	0	10.5 ± 3.0
	baited	0	269.3 ± 27.0

*Plant counts WCR 0.23 per plant, corn silking.

Table 4. Northern (NCR) and Western (WCR) corn rootworm beetle capture on sticky traps (n = 4)*.

Traps baited with 100 mg. of attractant on 2" × 2" blotter paper. 24 hour counts. (Mean ± S.E.)

A. 4-Methoxyphenethanol (August 24 1993)

TRAP		NCR	WCR
Solo	unbaited	4.0 ± 1.2	4.2 ± 2.8
	baited	89.7 ± 28.6	4.0 ± 1.1
Multiguard	unbaited	2.2 ± 0.8	2.0 ± 0.7
	baited	22.0 ± 2.9	1.3 ± 0.8
Pherocon AM	unbaited	1.7 ± 1.5	3.2 ± 3.5
	baited	24.0 ± 11.0	3.2 ± 5.7

*Plant counts WCR 0.06, NCR 0.02 per plant, past silking.

B. 4- Methoxycinnamaldehyde (August 25,1993)

TRAP		NCR	WCR
Solo	unbaited	1.7 ± 0.4	2.7 ± 1.3
	baited	3.2 ± 2.2	124.7 ± 42.0
Multiguard	unbaited	0	1.7 ± 0.8
	baited	4.5 ± 0.5	70.2 ± 17.8
Pherocon AM	unbaited	0	0.5 ± 0.5
	baited	2.0 ± 1.2	42.5 ± 6.9

*Plant counts WCR 0.06, NCR 0.02 per plant, past silking.

between two cucurbitacin baits, one with seven volatile attractants and one without attractants. The number of WCR attracted to and killed when the seven attractants (V7a) were added to the cucurbitacin bait (3.1±0.20) was 2.6 times greater than for the bait alone (1.2±0.20). A similar field trial conducted with three baits, one plain cucurbitacin bait and two with volatile attractants added, showed that the baits with volatile attractants were more effective in attracting WCR to corn whorls. The mean number of dead and moribund WCR found in whorls baited with the plain cucurbitacin bait was 1.4±0.29 but increased when volatile attractants were added to the bait; 2.4 times for 0.1 percent MCA (3.3±0.29) and 3.2 times for V7a (4.5± 0.32). In addition, V7a was 1.4 times more effective than 0.1 percent MCA for attracting WCR. Mean beetle counts for the whorl experiments are given in Table 5.

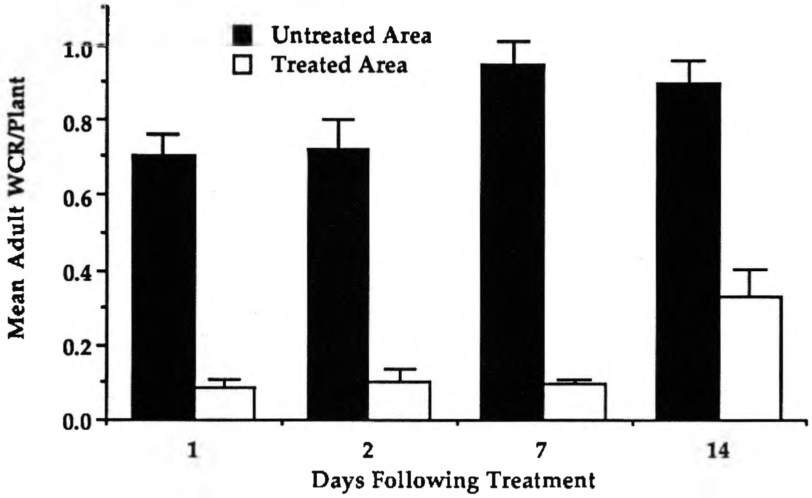

Figure 1. **Western corn rootworm plant counts following aerial treatment with cucurbitacin bait with seven attractants on 9 August 1990 at Kleiss Farm near Pesotum, Illinois.**

Large Scale Field Experiment

In August 1990, a large scale application of cucurbitacin bait containing the seven volatile attractants was tested on a seed corn field east of Pesotum, Illinois. Individual plant counts before the application showed an average adult rootworm population of 0.78 WCR and 0.28 NCR per plant (400 plants counted).

The effectiveness of the bait following application was readily apparent from both plant counts and trap counts for corn rootworm beetles in the treated and untreated areas (Figures 1 and 2). Within 15 minutes after application, large numbers of dead and moribund beetles were observed in the corn leaf whorls and on the ground. Mean plant counts and trap counts for NCR and WCR at various intervals following treatment are presented in Figures 1 and 2. Based on plant counts, the control from the bait application remained effective over a two-week period.

Similar results were found using yellow Solo cup sticky traps with and without TIC attractant. After 1 hour, the baited and unbaited trap catches fell to zero. Effectiveness of the baits after 1, 2, 7, and 14 days is depicted in Figure 2 for both NCR and WCR. Due to considerable migration of rootworm beetles into the treated area from the adjacent control area, the actual control obtained at 1 and 2 weeks was undoubtedly higher than measured.

The yellow sticky trap catches were greatly improved by the use of TIC attractants (equal portions of 1, 2, 4-trimethyoxybenzene, indole, and cinnamaldehyde) applied at 100 mg per trap on 2 cm portions of dental wick (Levine and Metcalf 1988). In a total of 16 comparisons of the mean catches of 4 traps baited and unbaited, the average 1 day catch was 19.2 times greater for WCR and 7 times greater for NCR on traps with attractant. These results clearly indicate the utility of the baited yellow Solo sticky traps for assaying adult corn rootworm populations. (The Solo cup traps are inexpensive, convenient to use because they are easily inverted over ears of corn, and are omnidirectionally attractive to beetles.)

In 22 comparisons of the WCR populations over the 14-day period before and after "attracticide" treatment, linear regression analysis showed that the correlation (R^2=.59) between the mean plant counts (n=100) and the mean TIC baited yellow trap counts (n=4) was significant at p<.001. The mean baited trap counts were approximately 1,000 fold more effective

Table 5. **Mean dead or moribund WCR 24 hour counts for whorl experiments 6 and 7 using cucurbitacin bait with and without volatile attractants added.**

Means followed by different letters are significantly different at $p < 0.05$. NA = Not applicable

EXP. NO.	SPECIES	ATTRACTANTS COMPARED		
		NONE	V7A	0.1% MCA
1	WCR	1.2 a	3.1 b	NA
2	WCR	1.4 a	4.5 b	3.3 c

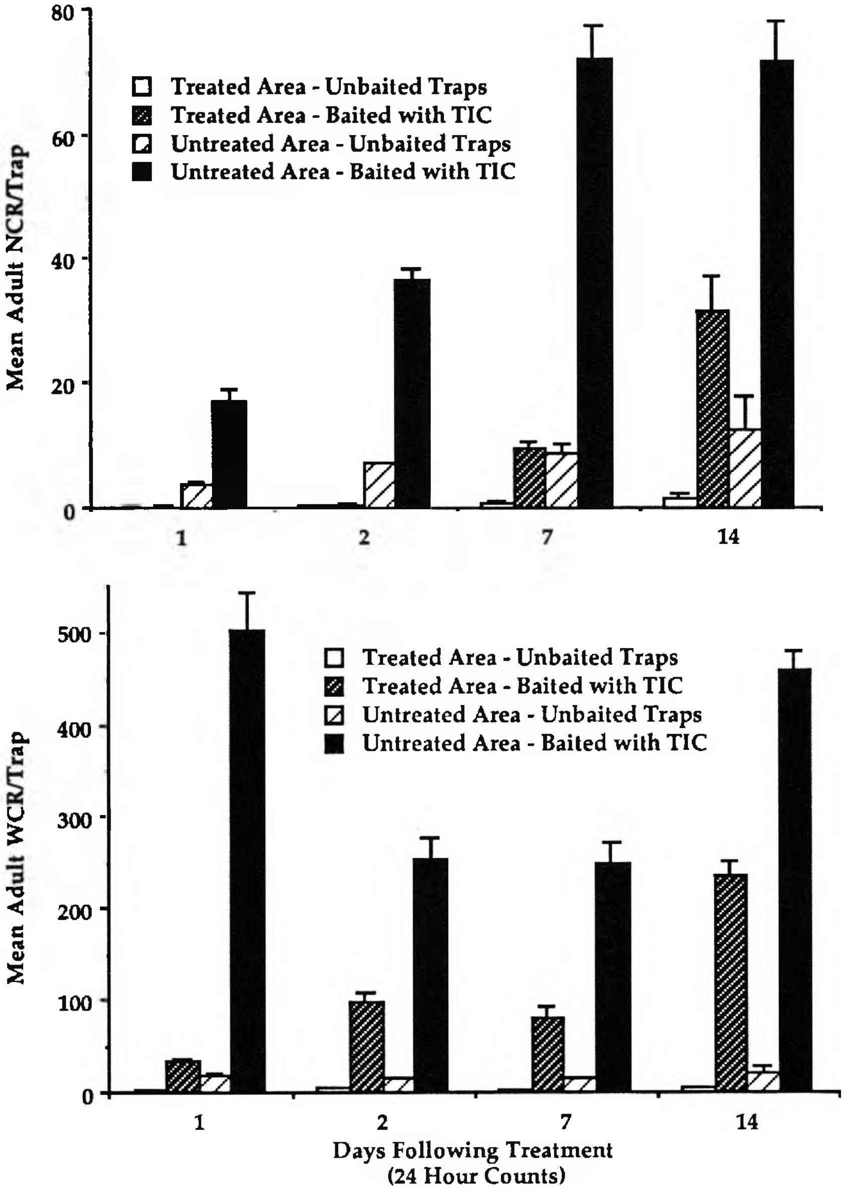

Figure 2. **Mean number of adult western corn rootworm beetles (WCR) and northern corn rootworm beetles (NCR) captured per Solo sticky traps with and without volatile attractants (TIC) in untreated and treated fields near Pesotum, Illinois. Traps were exposed for 24 hours.**

in quantifying the adult WCR population than the mean plant counts (Metcalf and Metcalf 1993).

It is evident from this study that the aerial application of toxic baits with attractants can dramatically decrease adult corn rootworm populations at the time of egg laying, with greatly reduced amounts of insecticides as compared to conventional soil or aerial applications. In addition, there was no observable evidence of detrimental effects on populations of beneficial insects.

These experiments conclusively demonstrated the marked superiority of the corn grits bait with cucurbitacins and carbaryl plus the 7 attractants (V7) over the bait without volatile attractants for both WCR and NCR beetles.

Summary

"Attracticide-baits," containing cucurbitacin arrestants and feeding stimulants, and carbamate or organophosphorous insecticides can provide very high mortalities of Diabroticite rootworm beetles when applied at 10 kg per ha. The minimum effective concentrations of cucurbitacins are about 1 g per ha and insecticide about 10 g per ha.

The addition of volatile kairomones to these cuc-baits improved the performance by several fold. These experiments showed that the most effective volatile attractant mixtures for WCR adults were those containing TIC plus 4-methoxycinnamaldehyde (MCA). The most effective single component for WCR was 4-methoxycinnamaldehyde (MCA). The most effective attractant mixtures for NCR adults were those containing TIC plus 4-methoxyphenethanol (MPE). 4-methoxyphenethanol (MPE) was the most consistent and effective individual volatile in attracting NCR. The optimum attractant mixture for both NCR and WCR adults contained the following five components: 1,2,4-trimethoxybenzene, indole, cinnamaldehyde (TIC), 4-methoxycinnamaldehyde (MCA), and 4-methoxyphenethanol (MPE). Other additives did not significantly enhance the activity of these lure-combinations for either NCR or WCR adults.

The use of such baits provides highly selective Diabroticite control with applications of insecticides of about 1 percent of those used in conventional aerial application when the bait is broadcast over an entire field, as was the case in the large scale field application. The success of the large scale field evaluation and the ability to draw corn rootworm adults from untreated areas with the volatile kairomones indicates that whole fields may not need to be treated. For example, it might be effective to use strip treatments or treat the interior of a field only, thus cutting down on the amount of bait and insecticide needed to treat a given area. Such an approach would also cut down on application expenses and provide environmental as well as economic benefits. However, not enough is known about the behavioral ecology and distribution of the adult beetles to formulate recommendations to farmers without further experimentation. The proper amount of bait and its placement in the field must be determined.

Using the cucurbitacin bait with the attractants or simply the attractants alone on a trap might be very useful for small scale applications and monitoring systems. The traps with attractants are sensitive enough to detect the early arrival or emergence of adult beetles. Home gardeners could use the trap for a control method in itself for a small area because the trap can hold several hundred beetles, or a baited trap could be used in conjunction with other control methods. For the large scale grower, if a correlation between beetle density in a field and trap catch could be worked out, the baited traps could be used for population estimation and timing determination for other control measures. For either the small scale grower or the large scale grower the attractant baited trap is an efficient detection tool, which could possibly be used for determining economic thresholds.

Effective use of the cucurbitacin bait with volatile attractants needs further development and refinement due to limitations inherent in the bait and problems associated with application methodology. Baits need to remain active in the field for longer periods of time for control of adults during critical periods (corn silking and oviposition). Although this was not a problem in the large scale field experiment of this report, all applications cannot be expected to be conducted under such ideal weather conditions (no major precipitation during experiment). The widespread use of attracticide-baits by farmers will be facilitated if the bait can be applied with currently available farm equipment or with newly developed, reasonably priced machines.

Much remains to be learned about the proper use of the "attracticide-bait" technology in general, but this alternative insect control method has considerable potential in integrated pest management, e.g., for use as "artificial trap crops" for many insect pests such as tephritid fruit flies, Japanese beetles, and tsetse flies, and for the dissemination of insect growth regulators and pathogens.

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Areawide Pest Management for Corn Rootworms: Fantasy or Realistic Expectations?

Michael Gray

Introduction and Background

The topic of areawide pest management, although not new, is currently receiving considerable attention in some segments of the crop protection community. This renewed interest is at least partially in response to the Clinton Administration's proposal (September 1993), to have 75 percent of the nation's managed acres under some form of Integrated Pest Management (IPM) by the year 2000. It is becoming clear that the USDA, EPA, and FDA all associate IPM implementation with pesticide use reduction, even though this was not the primary goal of IPM supporters twenty years ago, when other criteria were used to define success of IPM programs. In addition to the pressure from these federal agencies, environmental interest groups continue to challenge the agricultural community to reduce pesticide use, simply put, to reduce the number of "pounds in the ground" of pesticides. Hoffman (1993) elaborated at length on the need to substantially reduce pesticide and fertilizer use in the Great Lakes basin: "Agrichemical retail industry leaders are trying hard to convince dealers that developing and practicing an environmental stewardship ethic is now a requirement for business survival and growth. While the Great Lakes basin dealers we interviewed all said that their firm has a role in helping farmers become better environmental stewards, the study found that their services and farmer recommendations are not always as progressive as their ethic." In October of 1994, a pesticide use reduction bill (HR 5270) was introduced in the U.S. House of Representatives by Representative Cynthia McKinney (with 10 cosponsors), a Democrat from Georgia. This proposed legislation, entitled the "Farm Viability and Pest Management Improvement Act of 1994," is intended "to foster a substantial reduction in pesticide use, and thereby reduce the public health and environmental risks of the present level of usage, while maintaining agricultural productivity and an affordable food supply" (*Pesticide & Toxic Chemical News*, October 12, 1994). It appears that some policy makers, environmentalists, and scientists view the implementation of areawide pest management systems as one approach toward the realization of pesticide reduction goals.

In the summer of 1993, the USDA developed a briefing paper on areawide pest management systems and circulated it among interested parties. This briefing paper outlined a vision of areawide pest management as proposed by E.F. Knipling and G.G. Rohwer in September of 1992 to the North American Plant Protection Organization: (1) areawide pest management must be conducted on large geographical areas; (2) areawide pest management should be coordinated by organizations rather than individual producers; (3) areawide pest management may involve eradication, if practical and advantageous, but should focus on reducing and maintaining a pest population at an acceptably low density; and (4) areawide pest management involves a mandatory component to ensure project success within the geographic area. The briefing paper further described areawide pest management as an approach to reduce the reliance on pesticides and identified the following strategies as alternatives: (1) biological control; (2) rearing and release of sterile insects; (3) cultural practices; (4) use of host plant resistance; (5) use of pheromones; (6) timing of population suppression measures to coincide with low pest population densities and optimal conditions for natural control; and (7) an understanding and exploitation of information on the movement and dispersal of pest and beneficial species. The paper emphasized that areawide pest management would succeed only if these tactics are carefully woven together as appropriate and consideration is given to the management of multiple pests in an overall coordinated effort. Finally, in August of 1993, a list of pests that should be considered for areawide pest management was distributed for discussion. The pests on this list included: codling moth, pink bollworm, leafy spurge, Colorado potato beetle, Russian wheat aphid, European corn borer, corn rootworm, tobacco budworm, fall armyworm, and sweetpotato whitefly.

The briefing paper and the pest list served as the focal point for an areawide pest management meeting held in September of 1993 in College Park, Maryland. Representatives from the USDA, state departments of agriculture, industry, and the environmental community participated in this meeting. IPM coordinators from the north central region prepared a list of their questions and concerns for discussion during the meeting: (1) If an areawide approach is attempted, what will be the role of the Cooperative Extension Service? (2) How much lead time will be allowed for planning and preparatory efforts prior to actual implementation of an areawide pest management system? (3) Who will decide the candidate pest(s) for an areawide program? (4) Will the pest(s) rebound with vigor if areawide inputs are eventually removed? and (5) Will private interests assume the areawide pest management responsibilities once university and USDA personnel are removed? In addition, the north central region IPM coordinators indicated that as long as 1½ to 2 years would likely be required to adequately plan for the areawide management of any selected pest. Furthermore, they suggested that before any proposed project for a selected pest is begun, adequate documentation should clearly substantiate that it is likely to succeed. Following this meeting, the participants evaluated 10 areawide pest management preproposals (one for each candidate pest) that were submitted by invited experts. The two highest ranked preproposals were those for the management of corn rootworms in the Midwest and the management of the codling moth in apple production systems of the west. Presently, although the areawide management program for codling moth is progressing, the one for corn rootworms is not.

In February of 1994, representatives from the Agricultural Research Service, Cooperative Extension Service, Animal Plant Health Inspection Service, and the Cooperative State Research Service were asked to develop a plan for implementing a corn rootworm areawide management program. The representatives from each of these four organizations outlined the following goals for areawide pest management projects: (1) demonstrate effective, sustainable, and economical pest management with methods that emphasize alternative management practices; (2) emphasize food safety by reducing pesticide residues; (3) minimize the impact of pest management methods on nontarget organisms and beneficial agents; (4) increase the sustainability of pest management technologies by decreasing the rate at which management options are being lost to the evolutionary power of the pests; and (5) increase the competitiveness of American agriculture for large and small producers through cost effective areawide pest management strategies. Implementation of a plan for achieving these goals for the areawide management of corn rootworms had been projected for October of 1994; however, this has not occurred, primarily because of a shortage of financial support partially resulting from the mixed support of various agricultural sectors in the Midwest. The Agricultural Research service decided to fully support only one areawide management program, rather than to split its resources between two large projects. The selection of the codling moth program instead of the corn rootworm program was seemingly based upon the ability of the organizers of the moth program to garner more coordinated support from many sectors, including growers, researchers, extension personnel, and other federal and state agencies. This type of overall support has not been forthcoming from researchers and extension specialists across the Midwest, whose opinions are mixed regarding the worthiness and feasibility of areawide management for corn rootworms. Informal discussions among many of these scientists as of the fall of 1994 seem to indicate increasing support for at least pilot studies in several states. In January of 1995, a technical research committee (NCR-46) on corn rootworms will convene and discuss, among other topics, how best to proceed with the concept of areawide management. If support for areawide pilot studies emerges from this session, perhaps lost momentum can be regained.

Have There Been Previous Successful Areawide Management Examples?

Screwworms

The most famous example of successful areawide management involved the screwworm, *Cochliomyia hominivorax*, a potentially devastating insect pest of livestock. Left untreated, screwworms may kill livestock and significantly damage the quality of cowhide. Metcalf and Metcalf (1994) reported that annual damage has been estimated at 20 million dollars in the southeastern United States and 50 to 100 million dollars in the southwestern states. Knipling (1955) proposed that by sterilizing male screwworm pupae with gamma radiation and subsequently releasing the adult sterile male flies into the wild, screwworm populations could be eradicated. The assumption underlying this strategy was that sterile male flies could compete successfully with wild nonsterile males for females across large geographical expanses. Also important to this approach was the knowledge that female screwworm flies mate only once during their lives. Dramatic successes were achieved with this areawide approach in the 1950s on the island of Curacao (40 miles off the coast of Venezuela) and in Florida. The efforts in Florida are estimated to have cost 10 million dollars and in return have saved livestock producers 140 million dollars since 1958 (Baumhover 1966). After very encouraging initial results with the sterile male release technique in the southwestern United States, populations of screwworms started to rebound. Because of the very large and unisolated target area in the southwest, constant reinfestations from Central and South America have prevented total eradication of the screwworm.

Boll Weevils

In 1978, the USDA Animal Plant Health Inspection Service, along with growers, state departments of agriculture, and land grant universities, initiated a boll weevil eradication program on 15,000 acres of cotton in North Carolina and Virginia (Bacheler 1990). Plans to eliminate the boll weevil included (Frisbie et al. 1994): (1) "enforced uniform planting and harvest dates; (2) deployment of pheromone traps across every acre of cotton in the program; (3) areawide applications of insecticide in the fall to reduce boll weevils entering diapause and going into overwintering quarters; (4) spring applications of insecticides based on trap catches to prevent feeding and reproduction; (5) in-season application of insecticides based on field inspection and trap catches, and (6) then a repeat of these tactics for another two years." By 1980, only two years after program initiation, the boll weevil had been eradicated from targeted areas in North Carolina and Virginia. Three years later, the boll weevil had been eradicated in the remaining 300,000 acres in North Carolina and all of South Carolina. In 1987, eradication programs were implemented in Florida, southern Alabama, and southern Georgia, and currently this insect has been nearly eradicated from these states (Frisbie et al. 1994). Similar successes have been reported in Arizona and California regarding boll weevil eradication programs. Almost 2 million acres of cotton have now been declared "weevil-free" and insecticide use has been reduced by 60 to 75 percent in these areas while at the same time an expansion of 1.25 million acres of cotton has occurred in these states.

Corn Rootworms?

In the late 1960s, researchers in Nebraska (Pruess et al. 1974) embarked upon a program to suppress adult corn rootworm densities across a large area. They applied ULV malathion (9.7 oz. AI/acre) by air to 16 square miles in August of 1968, 1969, and 1970. Adult densities were reduced by 39, 54, and 72 percent respectively for the three seasons. They concluded: "The program was successful to the extent that no economic infestations occurred in the treated area during any year following adult control while use of soil insecticides was virtually abandoned in that area." However, the researchers pointed out that the total use of insecticide was **greater** under this program compared to more conventional approaches in the area. They also concluded that the advantages of an areawide adult suppression program centered around the use of an insecticide based upon scouting input and thresholds rather than prophylactic insecticide treatments each spring. Finally, and most importantly, corn rootworm densities across a large area could be reduced more effectively by using adult control techniques rather than soil insecticides. In a sense, continued use of soil insecticides by producers perpetuated a continued need for their use.

It should be pointed out that the suppression program of Pruess et al. (1974) centered around the exclusive use of an insecticide applied by air. It was not the more integrative areawide approach being discussed currently by entomologists.

In 1991, 16 square miles near Brookings, South Dakota, were used to more closely examine the feasibility of corn rootworm suppression (Sutter and Hesler 1993). This approach differed from that of Pruess et al. (1974) primarily on the basis of the type of adulticide used. In the South Dakota study, a semiochemical-based bait (COMPEL, Scentry, Inc., Billings, Montana) was aerially applied to fields. The formulation consisted of biotac (45.5 percent, nontoxic adhesive), dried and ground roots of buffalo gourd (50 percent), and carbaryl (4.5 percent). The treatment was applied at a rate of 0.89 pound per acre to those fields that exceeded an economic threshold of 1 beetle per plant. The amount of active ingredient applied was only 10 grams per acre, 98 percent less than typically applied with most of the soil insecticides (Force being an exception). Sutter and Hessler (1993) concluded: "This study suggests that semiochemical-based baits can successfully suppress corn rootworm populations and prevent significant levels of oviposition but require careful monitoring to predict when pests emerge and their densities per field." Although beetle densities were suppressed, data regarding egg densities or root injury the following season were not provided. Thus, some critics of the areawide management approach remain skeptical.

Why Consider Corn Rootworms for Areawide Management?

If we accept the premise that pesticide reduction, specifically fewer "pounds in the ground," is at least one reason to examine areawide management more closely, then corn rootworms are an attractive candidates for this type of program. In the North Central United States 60 million acres of corn are produced and where corn is grown continuously (not rotated), a high percentage of these acres is treated prophylactically (no scouting input) with a soil insecticide each spring at planting. For instance, in Illinois alone, 3.3 million acres of continuous corn were grown in 1990 and 88 percent of these acres were treated with a soil insecticide. Not surprisingly, the total amount of soil insecticide delivered each spring by producers across the Corn Belt captures the attention of many agricultural and environmental policy makers. Some proponents of an areawide management program for the corn rootworm complex undoubtedly see the potential for tremendous reductions in insecticide load across the Corn Belt if rootworm populations could be more effectively managed by integrating several tactics and not continually focusing on soil insecticides as the primary tool.

Additional support for an areawide management program comes partially from critics of soil insecticides who cite studies that show that these products do not always lower the overall population density of corn rootworms across a widespread area (Pruess et al. 1974, Sutter et al. 1991, Gray et al. 1992). In essence, often the number of rootworm beetles emerging from insecticide treated areas within a field is equal to or greater than the number emerging from untreated portions of the same field. Supporters of the use of soil insecticides argue that these products were not necessarily designed to suppress populations of rootworms, but instead are sold to producers as root protection tools. Acceptance of the latter argument will perpetuate the use of soil insecticides and maintain the overall long-term population level of rootworms in a given geographical area. And even as a root protection strategy, they are used on more continuous corn acres than necessary and thus represent a financial loss to some growers. Gray et al. (1993) indicated that only 26 of 58 on-farm trials in 1990 and 1991 had root injury above "economic" levels (root rating of 3.0 or greater; Hills and Peters 1971) in untreated portions of producers' fields. An economic analysis of these Illinois experiments revealed that many growers often lost money or gained marginal profits by using soil insecticides. Not surprisingly, financial gain from soil insecticide use was greatest when a product was targeted against a high density of corn rootworm larvae. However, Gray et al. (1993) concluded that "the likelihood of sustaining economic damage has been overestimated." If a root rating of 4.0 is used as an economic injury level (Sutter et al. 1990), then only 7 of 58 trials (12 percent) in Illinois had root injury of this magnitude.

It is evident that producers in Illinois and other parts of the Midwest have become over-reliant on soil insecticides for corn rootworm management. However, many farmers readily admit that they look upon the use of soil insecticides in continuous corn as but one part of their standard production practices. If we take seriously the goal of pesticide reduction, is this approach likely to lead to success? With the current rootworm management model in place on so many farms in the Midwest, proponents of areawide management programs are looking at rootworms with some interest.

What Areawide Pest Management Tactics Could be Utilized Against Corn Rootworms?

Several management tactics could be interwoven to achieve population suppression across an area. The most obvious one, in view of the biology of corn rootworms, is crop rotation, which effectively interrupts the normal life cycle of corn rootworms. Approximately 67 percent (7.1 million acres) of the corn produced in Illinois is rotated with soybeans (Pike et al. 1991). However, many producers in other parts of the Corn Belt, particularly western states, do not practice corn rotation for economic, agronomic, or sociological reasons. Increasing the adoption rate of crop rotation by farmers would undoubtedly lead to a reduction of soil insecticide use; however, major policy shifts in USDA commodity and subsidy programs would be required in order to make growing corn less attractive (or growing other crops more so). If pilot areawide management studies are initiated for corn rootworms, crop rotation should be a first consideration.

Adjusting planting dates is another tactic that should be considered. Recent trends in planting patterns indicate the shift toward earlier and earlier planting dates. This practice favors corn rootworm survival in areas of continuous corn. Producers unwilling to rotate corn in areawide pilot studies may be required to delay planting efforts until late May in order to starve a higher percentage of rootworm larvae. In these situations, the use of insecticides could be limited to rescue cultivation treatments based upon scouting efforts and larval thresholds. It seems certain that growers will need to be reminded of the program objective, that is, to reduce rootworm densities, not to maximize corn yields.

Finally, the use of adult control tactics should be the focus of areawide suppression programs for corn rootworms. The key difference between more contemporary adult management efforts and those of Pruess et al. (1974) involves the use of semiochemicals (Metcalf et al. 1987; Lance and Sutter 1990, 1991, 1992). Although Atochem has been very successful in marketing Penncap-M as an adulticide for corn rootworms, particularly in western states such as Nebraska, products such as SLAM, which contains the active ingredient carbaryl (13 percent) and root powder of *Cucurbita foetidissima*, are likely to be of interest as potential tools. BASF has signed an agreement with MicroFlo Company of Lakeland, Florida, to market and develop SLAM. A product such as SLAM has some advantages over more conventional products, most notably safety to workers and nontarget organisms; however, extension entomologists at the University of Illinois have not seen convincing evidence to date that suggests that SLAM results in effective root protection the following season. In an areawide pilot program, SLAM and other semiochemical products should be examined more critically.

In summary, in order to generate support across many sectors, an areawide program for corn rootworms would likely involve multiple strategies, including crop rotation, adjusting planting dates, use of cultivation rescue treatments based upon the level of root injury and larval densities, scouting for beetles and use of adult thresholds, and finally, reliance on products with semiochemical(s) that contain low concentrations of an insecticide. In addition, some proponents of areawide management insist that other insects such as the European corn borer be considered in the overall equation. If this occurs, a management scheme becomes even more complex as we attempt to suppress the densities of two key corn insect pests.

Concluding Comments

A shift in favor of areawide suppression for corn rootworms versus a primary reliance on prophylactic treatments of soil insecticides would represent a very significant change in the philosophical direction of corn rootworm management. First of all, it is important to emphasize that this paper has dealt with the concept of population **suppression, not eradication**. To date, I have not been involved in any discussions with other entomologists in the Midwest that have led me to conclude that eradication of corn rootworms is possible or should even be attempted. There are obvious and overwhelming obstacles suggesting that corn rootworms are not suitable candidates for an eradication program. Because corn rootworms occupy such an enormous geographical range in the US (60 million acres of corn in the Corn Belt alone), extending from states such as Colorado to the east coast, an eradication effort would be futile. Previous eradication efforts for other insect pests have been most successful when the target insect was confined and isolated geographically. In addition, although corn rootworms prefer corn as a primary host, both western and northern corn rootworms would likely survive (although at lower densities) on alternate grass hosts. Therefore, although areawide suppression of corn rootworms is worthy of further scrutiny and debate, and perhaps a closer examination in pilot studies, these efforts should not be confused as eradication attempts. Finally, successful implementation of pilot studies will require the close cooperation of researchers and extension specialists within Land Grant institutions, researchers within several USDA agencies, and most importantly, farmers and key individuals within the agricultural support industry. Areawide suppression of corn rootworm populations is not a fantasy and could become a reality if this cooperation is achieved.

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Effect of Rainfall on Soil-Applied Herbicide Performance

Bill Simmons, Loyd Wax, Gregory Steckel, and Steven Hart

The efficacy of soil-applied herbicides is dependent upon soil-water relations as they affect weed seed germination, herbicide concentrations in the soil solution, and absorption of the herbicide by weed seedlings. After a soil-applied herbicide is sprayed onto a surface consisting of soil and crop residues, it is subjected to dissipation processes. The ability of a herbicide to remain as the parent molecule under photolytic and volatilization loss mechanisms is a function of the herbicide chemistry.

Producers who are interested in controlling weeds are interested in several general properties of a herbicide. They want to know how well a herbicide works under dry soil and climatic conditions, and how much rainfall is required to "activate" or increase efficacy to an acceptable level. Furthermore, they are interested in how long a herbicide can remain on the soil surface without rainfall and still be effective once it is "watered in" by rainfall. The general research questions fall into two areas: (1) How much rainfall is needed to provide efficacy to soil-applied herbicides shortly after they are applied, and (2) What are the interactive consequences of delayed rainfall periods and amounts. Little is known about the behavior of common acetanilide herbicides and related compounds when there is limited moisture. Rainfall and soil moisture are critical for performance of surface-applied (PRE) herbicides, but less so for incorporated (PPI) applications.

We are reporting on general trends observed in two first-year studies. The database is currently too limited to conclusively differentiate for various herbicides, but some interesting trends are evident.

Materials and Methods

Rain Exclusion Shelter (RES)

Soil. The soil at the research site is Drummer silty clay loam (Fine-silty, mixed, mesic Typic Haplaquoll). The Drummer contains approximately 5-6 percent organic matter and is typical of the poorly drained loess-derived soils that make up a significant portion of the grain producing areas of the upper Midwest.

Experimental Design. The research site has 120 usable experimental units (4 by 4 feet), with rainfall controllable over 4 adjacent units. A factorial experiment, including acetochlor, metolachlor, dimethanamid, a check plot, and five water amounts (0.0, 0.1, 0.25, 0.50, and 1.0 inch), was used with three replications. The experiment was performed in two parts. One set of herbicide treatments was applied within 24 hours with irrigation (0 days after treatment) and the other was left for 10 days before the rainfall was imposed (10 DAT). Foxtail plants were counted and percent control was calculated using appropriate check plots.

Soil-water content at the soil surface was measured gravimetrically. We initiated this experiment on soil that had dried from field capacity condition and had approached the water content slightly drier than when field operations would normally begin.

Prior to herbicide application, weed seed was drilled in a strip across the plots to supplement the natural weed seed distribution and aid in rating efficacy of the herbicides. The herbicides were premeasured into individual containers and evenly sprayed on the 4 by 4 foot squares. The herbicide rates used in the experiment were Surpass EC 1.8 lb ai/acre, Dual II 2.2 lb ai/acre, and Frontier 1.29 lb ai/acre.

All plots were rated and weeds were counted two to three times after application. Drilled weed seed species did not germinate or emerge as well as expected, so we counted grass weeds, which included primarily foxtail species.

Effect of Rainfall Amounts on Herbicide Efficacy (Field)

Soil. Two sites were used for this experiment: Drummer silty clay loam (Fine-silty, mixed, mesic

Typic Haplaquoll) on the Agronomy South Farm at Urbana and near Dekalb, IL. The Drummer at both locations contains approximately 5-6 percent organic matter.

Experimental design. The field experiments were designed using plots 7.5 by 7.5 feet that were subjected to natural rainfall. A factorial experiment with three replications was used which included acetochlor (1.8 lb ai/acre), metolachlor (2.2 lb ai/acre), dimethanamid (1.29 lb ai/acre), alachlor (2.75 lb ai/acre), a non-treated check, and five water amounts (0, 0.10, 0.25, 0.50, and 1.0 inch) applied immediately after herbicide application. Two weed rating periods were used for analysis.

Results

Rain Exclusion Shelter Experiment

Herbicide performance was linearly related to applied rainfall where rainfall was applied shortly after herbicide treatment (0 DAT, Figure 1). It should be emphasized that the initial soil water condition was drier than one might encounter in the field because the shelter precluded natural rainfall for several months prior to our experiment.

Where water was not applied until 10 days after application of herbicides, the overall grass control was greatly reduced at all simulated rainfall levels (Figure 1). The data indicate that after the herbicide had remained on the surface for 10 days, simulated rainfall did not have as much effect on efficacy differences or where plots were watered earlier. Presumably, some of the herbicide was rendered unavailable through sorption, volatilization, or some other dissipation pathway.

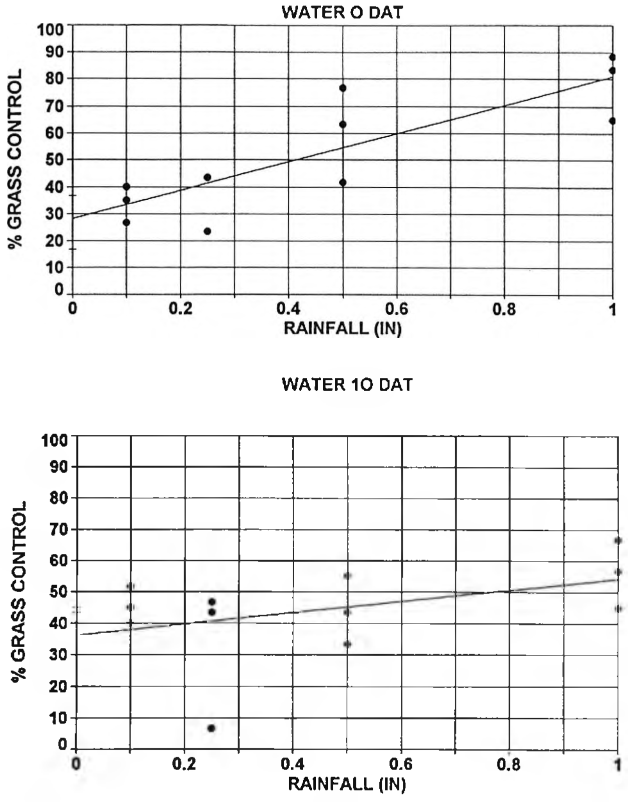

Figure 1. **Acetamide activation—sheltered study**

Table 1. **Rainfall following experiment initiation at the 2 sites**

		RAINFALL IN DAYS AFTER HERBICIDE APPLICATION		
Location		**0-3**	**3-7**	**7-14**
Dekalb 1	May 26	0.0	0.0	0.31
Dekalb 2	June 9	0.44	1.13	0.61
Dekalb 3	June 29	0.0	0.26	0.37
Urbana 1	May 11	0.35	0.14	0.0
Urbana 2	June 20	0.28	1.06	0.22

Field Experiments

Five field tests were put out and subsequently received differing amounts of natural rainfall following our imposed irrigation treatments. Each experiment had five irrigation amounts (0, 0.1, 0.25, 0.5, and 1.0 inch) and five herbicide treatments (Check, Dual, Frontier, Lasso MT, and Surpass) replicated three times, for a total of 120 experimental units. Natural rainfall amounts after the experiments were established appear in Table 1.

Foxtail control data for all the locations was pooled and a regression analysis was conducted for the total amount of "rainfall" (irrigation plus rain) occurring within 3 days of herbicide application (Figure 2). A variety of rainfall amounts was obtained because the imposed rainfall was sometimes supplemented with natural rainfall. The relationships

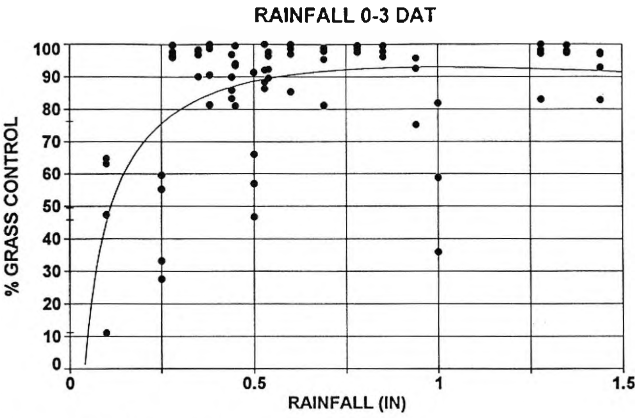

Figure 2. **Acetamide activation**

are considered significant even if the correlation coefficients are not always high. An additional year of data will improve our ability to predict the relationship of rainfall to efficacy for individual herbicides.

All the data were fit to the following function:

$$\text{Weed Control} = a + b(\ln(\text{rainfall}))^2.$$

In conclusion, insufficient rainfall after surface application of herbicides can lead to grass control failures. The rainfall occurring within 3 to 5 days of application appears to be the most critical. For most acetamide herbicides, a range of 0.35-0.70 inch of rainfall may be needed to obtain commercially acceptable weed control.

Identification and Distribution of Pigweed Species

Loyd M. Wax

A wide variety of pigweed species can be found in Illinois, and most can be very troublesome, reducing yields by competition and creating harvesting problems. Pigweeds were in most fields as problem weeds prior to the widespread use of herbicides. Later, as the use of single and combination treatments of soil-applied herbicides became very popular, the presence and importance of pigweeds in production fields declined greatly, to the extent that few questions were received by our extension staff regarding identification and control of these weeds. Currently, however, many questions are received regarding identification and control of pigweeds.

Pigweeds are now evident in an increasing number of fields. In a survey that we conducted two years ago, respondents indicated that pigweeds were among the top four most important weeds in the central corn belt. We are not certain why we are having a resurgence of pigweeds in general, but we suspect that some combination of the following practices may be contributing to the problem: (1) reduction in rates and in use of soil-applied herbicides that are very effective, (2) increased use of postemergence herbicides (especially total postemergence), (3) increase in no-till acres, and (4) reduction in cultivation on conventionally tilled acres.

Because of the increasing questions and concern about pigweeds, it is important to convey information about identification, distribution, and control of these weeds to all those involved in controlling weeds or providing advice on their control. The pigweed species found in Illinois vary considerably in appearance, distribution, growth habits, competitiveness, and response to various herbicides. Some of them are also very difficult to distinguish from each other, especially in the vegetative stages; however, herbicide labels indicate a wide range of control that may be expected with different pigweeds. The difficulty in identification may create a significant problem for producers, applicators, and educators (both public and private).

Distribution

There are a number of pigweed species in Illinois, but this discussion will be limited to the ones that are most commonly found in cropping situations. Some pigweed species do not present a significant weed problem. Our most common weedy pigweeds can be separated into three distinct groups, based on taxonomic characteristics and general growth habits. The first group includes some of the most common pigweed species in Illinois: redroot pigweed (*Amaranthus retroflexus*), smooth pigweed (*Amaranthus hybridus*), and Powell amaranth (*Amaranthus powellii*).

Redroot pigweed occurs throughout Illinois, but usually is not the main pigweed found in fields. Smooth pigweed is also found throughout the state and is the dominant pigweed in much of the state, especially in the northern two-thirds. Powell amaranth has been encroaching from the north for many years and is most often found in the northern part of the state, although not usually in large populations. These three pigweed species have similar upright growth habits, are rather competitive with crops, and have flowers that contain both male and female parts.

The second group includes common waterhemp (*Amaranthus rudis*), tall waterhemp (*Amaranthus tuberculatus*), and Palmer amaranth (*Amaranthus palmeri*). These pigwood species have separate male and female plants, have an upright growth habit, and are very competitive, but they differ widely in color and branching within individual species. Common and tall waterhemp can be found in isolated, usually wet or poorly drained areas throughout the state. They are the dominant pigweed species found in cultivated fields on the claypan soils of southern Illinois. These species are very similar and difficult to distinguish from each other. Based on samples collected from fields and identified over the past several years, it would appear that a large majority of the waterhemp in cultivated fields in Illinois is common waterhemp, with tall waterhemp found only occasionally. Palmer amaranth is a rapidly emerging species with a vigorous growth habit. It has long been the dominant pigweed in southwestern states such as Texas and Oklahoma, and is now well-established in Kansas, in the Mississippi Delta region, and in the Southeast. Occasional plants can be found in the southern one-third of Illinois.

The third group includes spiny amaranth (*Amaranthus spinosus*), tumble pigweed (*Amaranthus albus*), and prostrate pigweed (*Amaranthus blitoides*). These pigweeds are similar with either prostrate or fairly short height, much branching, and they usually do not provide much competition to either corn or soybeans. They can be troublesome in shorter, less competitive crops. Spiny amaranth advanced into Illinois many years ago from the southeastern U.S., where it can be a major problem. Although this species can be found in most of Illinois, it is most prevalent in the southern part of the state. It is most commonly found in pastures, presumably left because livestock avoid its spiny nature. Tumble and prostrate pigweed are distributed throughout the state, but seldom gain a foothold in corn and soybean fields except in skips and along edges in late season. However, all of these pigweeds can cause problems from time to time in some areas.

Identification

Because of the similarities among species, and variation within species, identification of pigweeds can be very difficult, especially when the plants are in early stages of growth. An additional complicating factor is that some of the species may on occasion cross-pollinate other species. This usually results in sterile hybrids, but sometimes in hybrids that produce seed, and essentially always in plants that do not seem to fit anyone's pictorial guide or taxonomic key.

A complete identification guide is beyond this discussion. However, I am joint author for a new publication that will provide pictures, descriptions, distribution maps, and taxonomic keys for all of the species mentioned in this article. It includes photographs of the seeds and plants in various stages. The publication is "Pigweed Identification: A Pictorial Guide to the Common Pigweeds of the Great Plains." It will be available in the near future from Kansas State University. Please contact me in this regard, because I will have a number of copies available and will be able to tell you where to get more copies.

Identification of the pigweed species in this article will be discussed in the same order as above regarding distribution and importance. As mentioned earlier, all pigweeds in the first group have flowering structures that contain both male and female parts in the same flower. Redroot pigweed as a very young plant has many small hairs throughout, rough leaf and stem surfaces, and rounded leaves. It is very similar to smooth pigweed and Powell amaranth, and is especially difficult to distinguish from smooth pigweed. Sometimes there is a difference in coloration on the petioles of early leaves, but this is not found consistently and is not easily identified. At maturity, redroot pigweed has fine hairs throughout the plant and a much branched flowering structure. One of the most important points is that the branches of the flowering structure are compact, less than 2 inches long, and wider than a common pencil. The mature flowering structure, when grasped in the hand, often feels somewhat rough and prickly due to the medium length bracts that subtend the sepals in each flower. The seed, when very gently threshed from the plant, will have the sepals attached. These sepals are about twice the length of the seed, have rounded tips, and are curved outward slightly. These sepal characteristics alone clearly separate redroot from smooth pigweed and Powell amaranth.

Smooth pigweed in its early stages is very similar to redroot pigweed and possesses essentially the same characteristics as does redroot, having very fine hairs throughout, rounded leaves, and rough leaf and stem surfaces. As mentioned above, early minor coloration differences sometimes are apparent, but are not consistent. As smooth pigweed approaches maturity, it continues to have fine hairs throughout and has a highly branched flowering structure, with compact branches that are usually more than 1½ inches long and thinner than a common pencil. The flowering structure, even at maturity, has a smooth feel when grasped in the hand, because of the lack of medium or long bracts. In the early stages of maturity, the smooth pigweed flowering structure resembles the general shape and form of a spruce tree. The seed of smooth pigweed, when very gently threshed from the plant, will have the sepals attached. These sepals are about the same length as the seed, have rounded tips, and are clearly different from the sepals of redroot pigweed. One last bit of information concerning smooth pigweed: this species occurs commonly either as a green plant with some minor reddish markings on the veins and petioles or as a totally dark red to purple plant that has all the same characteristics as the green plant except for the color difference. They are both smooth pigweed.

Powell amaranth, in its early growth stages, is very similar to redroot and smooth pigweed, with small fine hairs throughout the plant and rough stem and leaf surfaces. Unlike smooth pigweed and redroot, however, Powell amaranth has more tapered first true leaves that are slightly pinched toward the end. At maturity, Powell amaranth has small hairs throughout and a branched flowering structure (but less branched than redroot and much less branched than smooth pigweed). An obvious difference is that the branches are wider than a common pencil and are 4 to 8 inches long. When grasped in the hand, the mature flowering structure feels rough and prickly because of the long, sharp bracts. The seed of Powell amaranth, when very gently threshed from the plant, will have the sepals attached. These sepals are straight, slightly longer than the seed, and pointed. Typically, one sepal is longer than the others.

The second group of pigweeds, as mentioned previously, has separate male and female plants, and thus is dependent on cross-pollination from plant to plant for seed production. Sometimes crosses occur with species outside of this group, usually resulting in sterile hybrids. More often, crosses occur among species of this group, often resulting in fertile hybrids that look fairly normal, except that they have taxonomic characteristics of both species, so it is very difficult to attach a specific name to them.

Palmer amaranth, as a young plant, has no hairs, smooth stem and leaf surfaces, very long petioles, sometimes a v-shaped marking on the leaves, and a symmetrical leaf arrangement that is somewhat poinsettia-like. At maturity, the plant has no hairs and the stem and leaf surfaces remain smooth with very long petioles. The flowering structure is striking in that it is mostly non-branched, rather wide, and usually one to two feet long, often curving down at the end. Each plant will be either a male plant or a female plant. The male plant flowering structure sheds pollen and, when grasped in the hand, feels soft. The female plant flowering structure contains the seed, has very long, sharp bracts, and as a result is very prickly to the touch. With this species, grasp the flowering structure of mature female plant very cautiously!

Common and tall waterhemp are so similar in most ways that they will be considered together regarding identification, because they are clearly distinguishable only when female flowers or seed are available. Young waterhemp plants tend to be more variable within the species than several other species, but several good generalizations can be made that usually hold true. The cotyledons are usually more egg-shaped than on other species, and the leaves tend to be long, narrow, and waxy in appearance, although this can vary considerably. It is important to note that the plants have no hairs and the stems and leaves are smooth. At maturity, the plants will likely range in color from red to green to yellow to almost white. The leaves, although variable, usually remain long and narrow compared with most other pigweed species. Each plant will have either all male flowers shedding pollen or all female flowers producing seed. The flowering structures are rather open and near the top of the plant or tips of branches, but this is also variable. The flowering structures of both the male and female plants are soft to the touch, with no discernible prickly bracts.

Now we come to the difference between tall and common waterhemp (there may actually be a difference in height, but this is not a consistent indicator of the species). When the seeds are very gently threshed out of the flowering structure, at least two things should become apparent. One is that no sepals remain attached. Another characteristic that needs to be noted is that the seeds tend to remain in a paper-like capsule (called a utricle) covering the seed. Gentle pressure can be applied to break the capsule, and if the capsule breaks into two cup-like sections, then it is common waterhemp. If the capsule shatters in all directions, the species is tall waterhemp. Before breaking the capsule, one can usually see the fracture line around the middle of the capsule on common waterhemp. There are other characteristics that may be used to separate these two species, but this last one is the easiest one to observe in the field. Usually, what is found on a plant is that most or all of the capsules fit one category or the other and the identification is clear. However, in the populations of tall and common waterhemp in the corn belt, there are numerous instances of plants that have textbook characteristics of both species on the same plant. The general belief is that considerable crossing has occurred between these two species over many years. Noted amaranth taxonomists expressed this opinion over 30 years ago. Although pure populations of common and tall waterhemp do exist in large areas, there also are hybrids of these two in fairly large numbers. Some crossing occurs with other species as well, most probably Palmer amaranth. The last group is considerably different in shape and growth habit from any of the pigweed species in the first two groups. Spiny amaranth, as a young plant, has smooth stems and leaves with no hairs. The leaves quite often have a v-shaped variegation. Spines begin to form fairly early in the leaf axils and flowering clusters. As the plant matures, the stems and leaves retain the smooth and variegated characteristics and have no hairs. Spines in the leaf and flower axils grow longer, harder, and sharper. Forget the grasping procedure! Female flowers are found on the lower half of the plant, subtended by the sharp spines, whereas the male flowers are found on the top of the plant and at the tips of the branches. The above items are the essential ones in identifying this species, because characteristics of sepals and seeds are not especially helpful in identifying this species.

Tumble pigweed, as a young plant, has leaves that are somewhat egg-shaped and the whole plant tends to be an olive green color. As the plants mature, the leaves remain egg-shaped and in addition acquire wavy edges. The plants usually reach a height of 2 to 3 feet and are often spherical in shape. Flowering occurs throughout the plant on its many branches at the point of leaf attachment. At maturity, the plants often break off at ground level and roll away in high winds. Tumble pigweed seeds are among the smallest of the various pigweed species discussed.

Prostrate pigweed, as a young plant, has long cotyledons, a spatulate leaf shape, and a fairly dark green color. As the plant matures, it has a low profile and spreading type of growth, with leaves becoming waxy, spatulate, and narrow toward the base. Flowers are located at various places throughout the plant, usually at the point of leaf attachment to the stem. Seeds are important indicators of species in this instance because they are the largest seeds of the pigweed species mentioned.

Summary

Many different kinds of pigweeds infest production fields in Illinois and they can cause substantial losses in crop quantity and quality if they are left uncontrolled. These different species vary considerably in response to various herbicides, so proper herbicide selection is very important. To do that, correct identification of species is essential, but difficult. Mapping of fields for future years is equally important once the primary pigweed species present are known. Help is available for identification by calling us to get a copy of the new publication mentioned, and by writing or calling us with your questions, and bringing or sending samples to us. Whenever time and schedules permit, we will attempt to visit the fields in question and identify the species.

Agrichemical Facility Containment Program Update

G.C. Kirbach

A summary of the Agrichemical Facility Containment program, or 8 Illinois Administrative Code 255, was presented by Warren Goetsch to this conference in January 1991. The present paper will provide an update on the program, including summarized results of the technical review process, enforcement, and the influence of this containment program in relation to other mandated programs.

January 1, 1995, represents the end of the final phase of the containment program for most retail facilities. By this date, all permit applications are required to have been submitted and approved, including those fertilizer storage tanks with a capacity exceeding 100,000 gallons. The scope of this program, by definition, has included all facilities that are involved in the repackaging of agrichemicals, ranging from the small single proprietorship with one bulk storage tank to a facility that distributes 6 million gallons of formulated pesticides annually. The Illinois Department of Agriculture has issued permits to facilities ranging from one whose largest tank capacity is 750 gallons to one with a single tank capacity of 9 million gallons.

Results of the Technical Review Process

Table 1 shows the results of the permit application review process as of November 7, 1994. The Department has received a total of 3,209 permit applications through this date. All applications were checked to ensure that all sections and supporting documents were included with the application. All incomplete applications (378) were returned with a checklist indicating missing items.

The Department has issued a total of 876 permits and 433 permit modifications. Of the 1,451 facilities originally registered with the Department, 196 have closed during the five years of the program. Thus there are 1,257 active facilities operating in the state at this time. This indicates that 381 facilities have not received a permit, and will be operating in violation of the rules. Those facilities will be subject to enforcement by the Department.

Table 1. Results of permit application review through November 7, 1994

CATEGORY	TOTAL REGISTERED	TOTAL PERMITTED
Total Facilities	1451*	876
Total Facilities Closed	195	N/A
Operational	943	843
Secondary Liquid Pesticide	709	609
Secondary Liquid Fertilizer	807	624
Bulk Dry Fertilizer	889	442

* This number includes facilities that have been officially closed.(1256 facilities are currently registered as active.) All other numbers are the net active facilities currently registered with the Department.

Enforcement Activities

The Department pursues compliance with 8 Illinois Administrative Code 255 by first evaluating the nature of all deficiencies that are noted by the inspector during his annual on-site inspection. For deficiencies involving major deviations, the Department pursues compliance with the facility and schedules an administrative hearing only as a last resort, if compliance is not achieved. Most violations are the result of three activities.

The largest number of enforcement cases pursued by the Department involve facilities operating without an approved permit. The inspection deviations are first compared to the established compliance schedule. If a facility has failed to meet the permit issuance date and the *first* containment structure construction date, the Department schedules an administrative hearing.

The second type of violation occurs when a containment structure changes its capacity without an approved permit modification. A modification is defined as a change of capacity or efficiency in section 255.10 of the rules. To date, the Department has pursued enforcement only in those instances where there has been a change in capacity requirements. For example, if a tank replacement involves redefining the capacity of the largest tank, then an enforcement action is initiated. However, if the largest tank remains constant, an inspector is sent to verify capacity adequacy and the issue is handled as an alteration.

The final violation involves the construction of containment without an approved permit or permit modification. Some facilities have initiated construction prior to the receipt of a permit in violation of section 255.50. Enforcement has been pursued only for those facilities involved in construction. Historically, this has excluded preliminary excavation and/or basic form work.

The second enforcement procedure, for those deficiencies that have been noted during an inspection, is the issuance of a deficiency letter. This letter is mailed to the facility citing the deficiencies noted and providing approximately 30 days to respond by taking corrective action. When the Department confirms that the corrective action has been taken, the file is closed and the deficiencies are considered resolved.

If the facility fails to respond within 30 days, an inspector may be sent to follow up on the correction of the deficiencies. If a facility fails to correct the deficiencies after the second inspection, an enforcement may be pursued. To date, the Department has not pursued an enforcement action for failure to implement corrective action.

Finally, the Department has issued four **"Stop Use/Stop Sale"** orders during the past year, to facilities that have been cited in an enforcement action and have subsequently failed to achieve compliance. A stop use/stop sale order prohibits the sale and/or use of bulk pesticides until the facility achieves compliance with the containment rules. To date, all but one of these four facilities have achieved compliance, or are in the process of doing so.

Enforcement Results

The Department has recorded a total of **772** violations over the last four years. Deficiency letters have been sent in **453** of those cases. In **103** cases, the Department has pursued enforcement through an administrative hearing and received a monetary penalty. The remainder of the cases are currently scheduled for a hearing, or were recorded prior to the detailed tracking method currently in place. Finally, the Department has issued **4** stop sale/stop use orders. The field staff performed a total of **735** inspections in the last year and a half, in addition to providing technical assistance on-site.

The most common deficiencies observed by the field staff during site inspections have been: 1) Failure to provide proper backflow protection for the potable and non-potable water supplies; all fill lines must have a fixed proper air gap of six inches or twice the diameter of the supply line, whichever is greater; 2) failure to properly record, file, and maintain weekly inspection and maintenance reports of the containment structures; 3) failure to properly record, file, and maintain monthly inventory reports, including the ***physical measurement*** of each non-mobile agrichemical storage tank; 4) failure to properly secure, in the closed position, all valves, including sight gauges, that come directly off the bulk agrichemical storage tanks; and 5) failure to properly anchor bulk storage tanks to prevent floatation.

Influence of the Agrichemical Containment Program

The implementation and success of the Illinois containment program has had an impact throughout the United States. The review staff attended a national symposium a year ago and participated in a forum for the exchange of information. In addition, the proposed federal rule was discussed in detail with representatives from USEPA. The impact of the Illinois program was evident in the proposed federal rules. The major difference between the proposed federal rule and the current state program concerns the hydraulic conductivity requirements and the required containment capacity.

The state program requires a hydraulic conductivity of 1×10^{-6} cm/second, whereas the federal rule would require a hydraulic conductivity rating of 1×10^{-7}. Secondly, the federal rule would require containment volume of 120 percent of the largest tank, whereas the state program requires containment volume of the largest tank, displacement of additional tanks, and the volume of a six-inch precipitation event if exposed to rainfall. Most states believed that the proposed hydraulic conductivity rating was excessive and the capacity requirements had a wide variance. At least nine other states have contacted the Department regarding the containment program, especially on issues concerning large storage tanks.

Last year also saw the revision of the Illinois Lawncare Products Application and Notice Act. This revision addressed the permitting of wash water containment structures for all facilities involved in lawn care. The revision incorporates requirements similar to those that were developed in the agrichemical containment program. Issues that have been addressed in the revision include water protection, well setback issues, and the inclusion of an "Operations and Management Practices Plan."

In summary, the Illinois Agrichemical Facility Containment Program is considered an aggressive regulatory effort that has been successful by most forms of measurement. Its success can be attributed to the cooperative effort expended by industry in a "pro-active" framework. I have been amazed at the capital spent, the construction, and the response in addressing such a comprehensive program. The feedback from industry has commonly been along the lines that there was frustration with the permit and compliance, but most of those involved now believe that the effort was worthwhile. They have indicated that their facilities are more modern, as well as safer and more efficient. Comments such as "I am glad that I went forward with the program" are common. From my personal perspective, I can add only that I share that pride and feel fortunate to have been a part of this program. I commend you for your efforts and wish you continued success in the future.

How We Reduce Pesticide Drift and Its Impacts

Dick Stiltz

Sensors For Variable Rate Application of Agricultural Chemicals

J. W. Hummel

Sensing of crop growth and yield, soil properties, and weed infestation level is a current discussion topic for researchers, crop consultants, chemical applicators, and farmers. Electromechanical controllers are commonplace on agricultural chemical application rigs.

Recently introduced grain flow rate sensors and global positioning systems on combines allow farmers to map yield levels in their fields. As they use this information to identify low and high producing areas within each field, they will want rapid, low cost sensors to help measure soil and plant properties that contributed to the variation in productivity.

Onboard computers are being interfaced with controllers to regulate the amount of various chemicals applied. The development and use of control systems that vary application rates according to field speed has set the stage for control according to other variables. Input application may be based on a single factor or combination of factors affecting crop growth and yield, such as nutrient status, weed pressure, soil moisture, landscape position, soil organic matter content, soil acidity, or depth to a restrictive layer. Today, sensors are being developed and made commercially available to interface with low cost but powerful computers, real time controllers, and accurate navigational systems. Developments in electronic sensors have combined to provide the technology necessary to make site-specific crop management a reality (Auernhammer and Muhr 1991).

Soil Organic Matter Sensors

Research has shown that the amount of a soil-applied herbicide needed to obtain a particular level of weed control is affected by the soil organic matter (SOM) content. Manufacturer's label recommendations for soil-applied herbicides are often based on SOM and soil texture. Soil texture classes are generally "course," "medium," and "fine," and percent SOM may be split into two to five ranges.

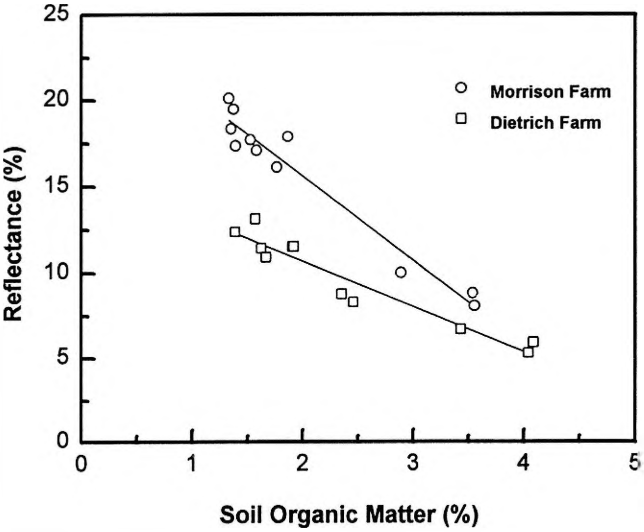

Figure 1. Calibrations for the landscape-dependent sensor for fine and medium textured soils from two representative Indiana fields (from Shonk et al. 1991)

The observation that soils with high organic matter contents appear darker led to the suggestion that electro-optical sensing of SOM might be feasible (Alexander 1969). Researchers have investigated a number of approaches to sensor development with varying degrees of success. Progress in this research has been delayed because soil color and reflectance are affected by properties such as moisture, texture, mineralogy, and parent material, as well as SOM.

The sensors used in early SOM sensor research, which generally used only one or a few pieces of spectral information (in terms of color coordinates or reflectance values), did not achieve the goal of providing optical estimation of SOM over a wide (entire state or larger) geographic range. Armed with this knowledge, researchers sought to improve their results by either using a single-wavelength sensor requiring recalibration for each field in which the sensor operated, or by developing instruments that were capable of providing additional spectral information from many narrow wavelength bands.

Researchers at Purdue University pursued the single-wavelength sensor concept, and developed an SOM sensor that uses six or eight light-emitting diodes (LEDs) arranged in an array around a photodiode to focus an intense beam of light on the soil surface directly below the photodiode. The position of the LEDs assured equal illumination of the surface sensed by the photodiode, minimizing specular reflectance. In laboratory tests, a linear relationship was found between light reflectance and SOM for fields having fine and medium textured soils (Figure 1). In field tests, there was a curvilinear relationship between sensor output and SOM, and new calibrations were developed for changes in travel speed or sensing depth (Shonk et al. 1991).

The sensor developed at Purdue University was licensed to Tyler Limited Partnership[1] in Benson, MN, for commercial development, and has been used to control the rate of granular herbicide formulation applied by a pneumatic metering system (McGrath et al. 1990). The SOM sensing probe is mounted to the front of a custom applicator truck and operated at a depth of 4 inches and speeds of up to 12 mph. Soil samples, manually collected from each field just prior to the custom application, are used to develop a specific sensor calibration curve. McGrath et al. (1990) noted that moisture and surface preparation significantly affected sensor output. In a number of field tests, the variable rate application system satisfactorily applied herbicides and weed control was reported as excellent in all cases.

A cooperative USDA-ARS/University of Illinois research project in optical sensing of soil properties has focused on developing an instrument designed to acquire near-infrared (NIR) soil reflectance data at a number of narrow-band wavelengths. An instrument of this type is more complex, more expensive, and less rugged than a single-band sensor, but the additional reflectance information allows the generation of a single, accurate calibration, which is applicable to soils obtained from fields across a broad geographic area (Sudduth and Hummel 1993a, 1993b). The sensor was developed to provide SOM data for control of a map-based herbicide application rate control system, which allowed fields to be mapped with equipment shared among a number of producers or applicators. The SOM information could be used alone or combined with other data layers in a geographic information system to generate herbicide application rate maps. The SOM information could also be used as a productivity indicator in the development of variable rate nitrogen application strategies.

A rugged, portable NIR spectrophotometer was developed to implement this prediction method, and laboratory and field tests have been completed (Sudduth and Hummel 1993a, 1993b). The sensor used a circular variable filter spinning at 5 Hz to sequentially provide monochromatic, chopped light from a broadband quartz-halogen source. A fiber optic bundle transmitted the monochromatic light to the soil surface, allowing remote mounting of the major portion of the sensor. A lead sulfide photodetector captured the energy diffusely reflected from the soil surface. The portable spectrophotometer SOM prediction accuracy was satisfactory in the laboratory (Figure 2), across a range of soil types and moisture contents (Tables 1 and 2). Prediction accuracy deteriorated when the sensor was operated in the field, due at least in part to errors introduced by the movement of soil past the sensor during the scanning process (Sudduth and Hummel 1993b).

Additional laboratory tests of the NIR sensor with soils obtained from across the continental United States (Sudduth et al. 1990) showed that it could predict soil organic matter for soils from the

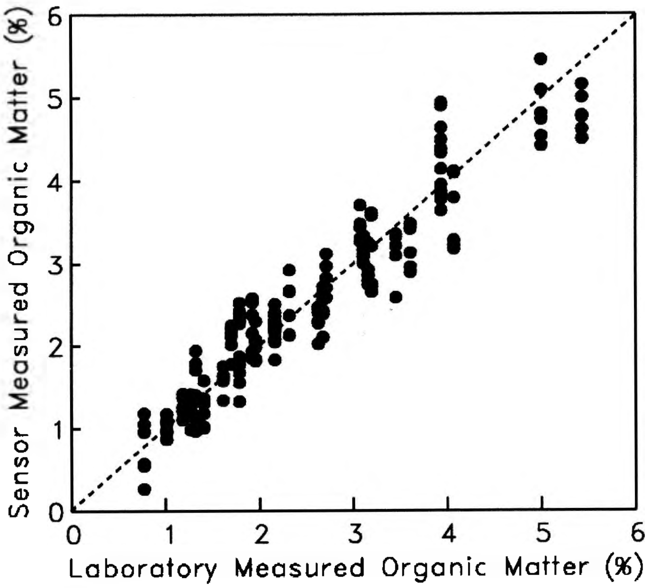

Figure 2. **Sensor versus laboratory measured soil organic matter of 30 Illinois soils at 0.033 MPa and 1.5 MPa moisture tension levels**

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[1] Trade names are used solely for the purpose of providing specific information. Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply the approval of the named product to the exclusion of other products that may be suitable.

Table 1. Laboratory performance of recent electro-optical soil organic matter sensors

	Calibration					Measures of fit		
	Wavelengths				Moisture			
Investigator/Sensor	Range, nm	No.	Method[a]	Soils	levels[b]	r^2	SE[c]	RPD[d]
Gunsaulis et al. (1991)								
--diffuse/specular sensor	660	1	LR	20 AR	AD	0.61	0.32c	1.6c
-- diffuse sensor	660	1	LR	20 AR	AD	0.48	0.37c	1.4c
-- both sensors	660	1	MLR	20 AR	AD	0.73	0.27c	1.9c
Shonk et al. (1991)	660	1	LR	11-12 IN[e]	AD	0.80-0.91[f]	--[g]	--
	660	1	LR	11-12 IN[e]	FC	0.87-0.95[f]	--	--
	660	1	ILR	12 IN[e]	AD	0.98	--	--
	660	1	ILR	12 IN[e]	FC	0.98	--	--
Smith (1991)	543-835	4	SMLR	30 IL	FC & WP	0.61	0.79p	1.2p
	531-1004	24	PLSR	30 IL	FC & WP	0.71	0.64p	1.8p
Sudduth & Hummel (1993b)	1640-2640	26	PLSR	30 IL	FC & WP	0.89	0.40p	2.9p
Sudduth et al. (1990)	1640-2640	26	PLSR	34 CB[h]	FC & WP	0.86	0.48p	2.5p
	1640-2640	26	PLSR	63 US	FC & WP	0.67	0.69p	1.7p
Sudduth & Hummel (1993c)	1890-2450	6	SMLR	30 IL	FC & WP	0.77	0.46p	2.2p

[a] Calibration data analysis methods: LR = linear regression, MLR = multiple linear regression, ILR = inverse linear regression, SMLR = stepwise multiple linear regression, PLSR = partial least squares regression.

[b] Soil moisture levels: AD = air-dry, FC = field capacity (0.033 MPa moisture tension), WP = wilting point (1.5 MPa moisture tension).

[c] SE is the standard error of the estimate, in percent organic matter. Data suffixed by a "c" is a standard error of calibration (SEC), the SE in the calibration dataset. A "p" indicates standard error of prediction (SEP), the SE in a validation dataset.

[d] RPD is the ratio of standard deviation of SE; a larger RPD indicates a more accurate prediction.

[e] Soil samples collected from within a single landscape.

[f] Range of fit obtained from three individual soil landscapes.

[g] Dashes indicate unavailable data.

[h] Includes soils from the U.S. Corn Belt states of Illinois, Missouri, Indiana, and Ohio.

lower U.S. Corn Belt—Illinois, Missouri, Indiana, and Ohio—and that this capability could be maintained with a single calibration equation. Calibrations obtained for wider geographic areas showed significantly less accuracy (Table 1).

The prototype NIR sensor has been redesigned for improved accuracy, faster data collection, and improved portability (Sudduth and Hummel 1993c). Electronic modifications were made to reduce the complexity and amount of off-line computation required to process the reflectance signal to usable form. Bandwidth of the revised instrument is 45 nm, wavelength instability is essentially eliminated, and reflectance data can be obtained on-line from the dedicated microprocessor within 10 s.

Soil Moisture Sensors

Optical sensing of soil moisture using NIR reflectance takes advantage of the several water absorption bands in the NIR spectrum. Initial research using data obtained at two or three wavelengths usually showed good correlations ($r^2 > .9$) between soil moisture and reflectance. In recently reported research at Purdue University (Price and Gaultney 1993), a real-time sensor was developed to measure soil moisture beneath the soil surface to aid in the placement of seeds at a depth where soil moisture was adequate for germination. The sensor was based on measuring the relative reflection of light from the soil surface illuminated by three sequentially pulsed laser diodes. In field tests, at speeds of 1.25-2 mph, the sensor correctly classified 82 percent of the soil samples. This sensor could estimate soil moisture with sufficient accuracy for planting depth control as long as the soil types in a field did not vary greatly.

The portable NIR spectrophotometer (Sudduth and Hummel 1993a) was also evaluated for estimating soil moisture. The spectral reflectance data obtained in the laboratory (Sudduth and Hummel 1993b) were correlated with laboratory determined gravimetric moisture for 30 representative Illinois agricultural soils. Moisture content was predicted with a standard error of prediction (SEP) of 1.88 percent ($r^2 = .94$) for soils with moisture contents ranging from air-dry to field capacity (Figure 3). The reflectance data were also correlated with cation exchange capacity (CEC), and the best CEC prediction yielded a SEP of 3.59 mEq/100g. In terms of the coefficient of variation, the prediction of soil moisture and CEC was more accurate than the prediction of SOM.

The portable NIR spectrophotometer has been patented and licensed to AgMed, Inc., in Springfield, IL, for commercial development. The instrument may be configured for SOM estimation in a laboratory, or as a portable unit for use in real or near-real time mapping of SOM, soil moisture, and CEC.

Table 2. Organic matter, textural properties, and moisture content of 30 Illinois surface mineral soils

Soil Name and Textural Class[1]	ID	Organic Matter (%)	Textural Properties			Mean Moisture (%)	
			Sand (%)	Silt (%)	Clay (%)	1.5 MPa	0.033 MPa
Loamy Sand							
Ade	1	0.77	86.5	7.3	6.2	1.52	4.08
Plainfield	2	1.02	83.7	12.7	3.6	0.97	6.04
Sparta	3	1.18	85.4	10.4	4.2	1.29	5.83
Maumee	4	1.79	84.1	7.6	8.3	1.99	5.73
Sandy Loam							
Carmi	5	1.96	67.2	21.7	11.1	3.71	8.98
Loam							
Ambraw	6	2.18	48.0	29.2	22.0	8.16	14.63
Tice	11	1.71	25.8	50.0	24.2	8.61	18.09
Clay							
Jacob	7	3.47	3.8	33.6	62.6	22.59	34.63
Clay Loam							
Proctor	8	1.41	25.6	47.1	27.3	7.25	17.98
Darwin	9	2.32	34.5	33.9	31.6	10.28	19.78
Silt Loam							
Wynoose	10	1.62	6.3	79.0	14.7	5.01	20.91
Birkbeck	12	1.79	5.4	77.5	17.1	4.29	21.19
Shoals	13	1.27	27.8	59.6	12.6	3.94	18.58
Cisne	14	2.17	11.7	68.0	20.3	8.30	20.42
Bluford	15	1.32	20.3	66.9	12.8	3.66	19.40
Saybrook	16	2.18	12.7	62.8	24.5	7.92	20.78
Catlin	17	3.21	5.2	70.6	24.2	7.31	24.16
Saybrook	18	2.72	4.8	72.3	26.9	10.00	24.04
Cisne	19	2.68	11.5	66.3	22.2	9.66	21.47
Piopolis	22	2.65	4.1	68.8	27.1	7.23	25.31
Silty Clay Loam							
Flanagan	20	3.62	5.9	57.2	36.9	15.95	28.02
Jacob	21	1.93	9.4	65.8	24.8	9.42	25.91
Flanagan	23	3.17	6.3	67.1	26.6	8.64	22.59
Drummer	24	3.09	9.0	63.4	27.6	10.99	22.43
Flanagan	25	3.95	9.2	60.0	30.8	10.96	20.22
Drummer	26	5.01	8.7	61.0	30.3	12.52	22.58
Proctor	27	3.94	6.7	64.2	29.4	10.20	23.83
Flanagan	28	3.27	6.2	66.4	27.4	8.95	21.06
Drummer	29	3.85	12.6	55.9	31.5	12.44	25.13
Plano	30	3.13	7.9	65.6	26.5	8.76	19.85

[1] Textural classification and properties from Worner, 1989.

Weed Sensors

Strategies for site-specific foliar applications of herbicides will depend on the spatial distribution of weeds and the cropping and tillage practices in use. Optical sensors have been developed to distinguish plants from soil so that foliar herbicides can be spot-sprayed in fallow fields. Concord, Inc., in Fargo, ND, is marketing an Australian-developed reflectance-based system that automatically controls the nozzles on a spray boom to apply pesticide only to green vegetation. The sensor, located in front of each nozzle, measures the reflectance in selected narrow wavelength bands to locate areas of green vegetation.

Development of sensors that distinguish weeds from a crop could greatly extend the usefulness of site-specific sprayers for postemergence herbicide application. Research at the University of Nebraska and in Canada has shown that weeds grow in patches (Brown et al. 1990, Mortensen et al. 1993). Site-specific application of foliar herbicides in response to weed density may become an attractive alternative to soil-applied herbicides, if low-cost, accurate sensors can be developed for differentiating weeds from growing crops. Herbicide use could be reduced either by applying label rates only to the weedy patches, or less than label rates could be applied to the whole field and the label rate applied to the weedy patches.

Researchers have attempted to use machine vision to detect geometric differences among plant species, such as leaf shape or plant structure. U.S.

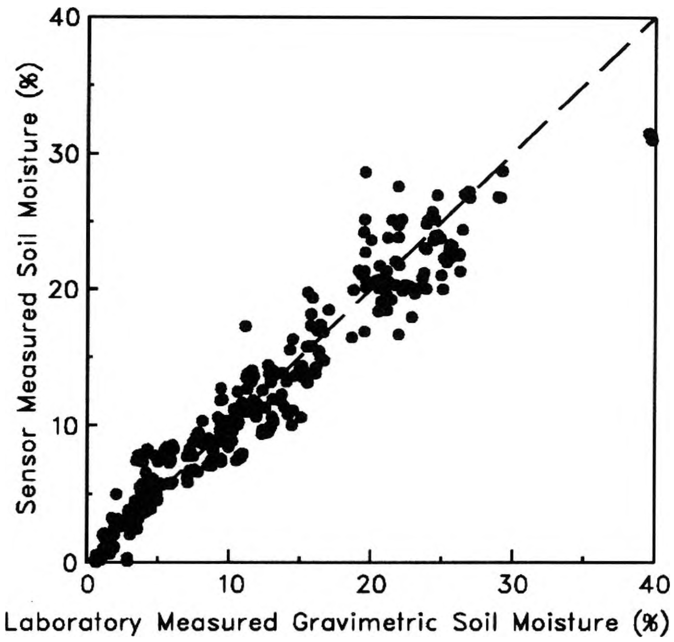

Figure 3. **Sensor versus laboratory measured moisture content of 30 Illinois soils. (Sample moisture contents ranged from air-dry to field capacity.)**

(Guyer et al. 1986) and German (Petry and Kuhlback 1989) scientists, in similar studies of leaf geometry, could not reduce errors below 10 to 20 percent even though the studies were done under controlled conditions in which the plants were carefully located in the image. Studies using machine vision methods (Franz et al. 1991, Woebbecke et al. 1993) have worked well only when a high percentage of the leaf was not obscured by other leaves or plant parts. Field conditions, with overlapping leaves of both crop and weeds, significantly reduce the reliability of the measurements. Presently, there are no commercially available systems that use machine vision. Although research is continuing, disappointing results have led some scientists to conclude that applicator-mounted sensors and real-time weed detection and sprayer control are not currently possible (Thompson et al. 1991). They suggest that field maps of weed infestations, based on image analysis, soil seed banks, aerial photography, and manual observation are more immediately possible.

Soil Nitrate Sensors

Several studies have shown that ion selective electrodes can be used to measure soil nitrates. A hand-held nitrate meter is commercially available from Spectrum Technologies, Inc., in Plainfield, IL, which provides a reading in a matter of minutes. Adsett and Zoerb (1991) reported on research on near real-time nitrate sensing using ion selective electrodes. An automated field monitoring system consisting of a soil sampler, nitrate extraction unit, flow cell, and controller were laboratory and field tested. The nitrate extraction time and methodology were limiting factors of the system, and additional research is planned to improve the mixing and extraction phases.

Ion Selective Field Effect Transistors (ISFETs) have several advantages over ion selective electrodes, such as small dimensions, low output impedance, high signal-to-noise ratio, fast response, and the ability to integrate several sensors on a single chip. However, ISFETs have the disadvantage of greater long-term drift and hysteresis than ion selective electrodes. Although these are potential problems in static measurements, the use of a dynamic measurement system such as flow injection analysis minimizes the effects of drift and hysteresis, and utilizes the specific properties of ISFETs. The ability to use small sample volumes and sense multiple species simultaneously makes the ISFET an attractive sensor for the development of a real-time soil nutrient sensing system.

A cooperative USDA-ARS/University of Illinois project (Birrell and Hummel 1993) is investigating the use of ISFETs to measure soil nitrate levels. An ISFET with four integrated sensors was tested in a flow injection system using four different flow rates, five sample injection times, and three washout times. The baseline solution was pumped through the flow cell, and the test solution was injected into the flow stream. When standard nitrate solutions were injected, correlations of the signal peak height to the nitrate concentration were quite satisfactory ($r^2 = .89 - .99$). Typical ISFET responses (Figure 4) illustrate the effect of the ratio of injection time to washout time, and the rapid response of the ISFET to a change in input. A cycle period of 1.5 s (0.5 s injection, 1.0 s washout time) seemed possible. The major problem encountered was inconsistent opening and closing of the injection valve, and an improvement in valve operation should increase the precision of the system.

Summary

Site-specific crop management requires the collection, coordination, and analysis of massive quantities of data. A large portion of the data will be collected by electronic instrumentation operating within each field. Information on soil property variations, often obtained today by laboratory analysis of manually collected soil samples, will be streamlined by the use of sensing technologies currently under development. Considerable progress has been made in the development of sensors for use

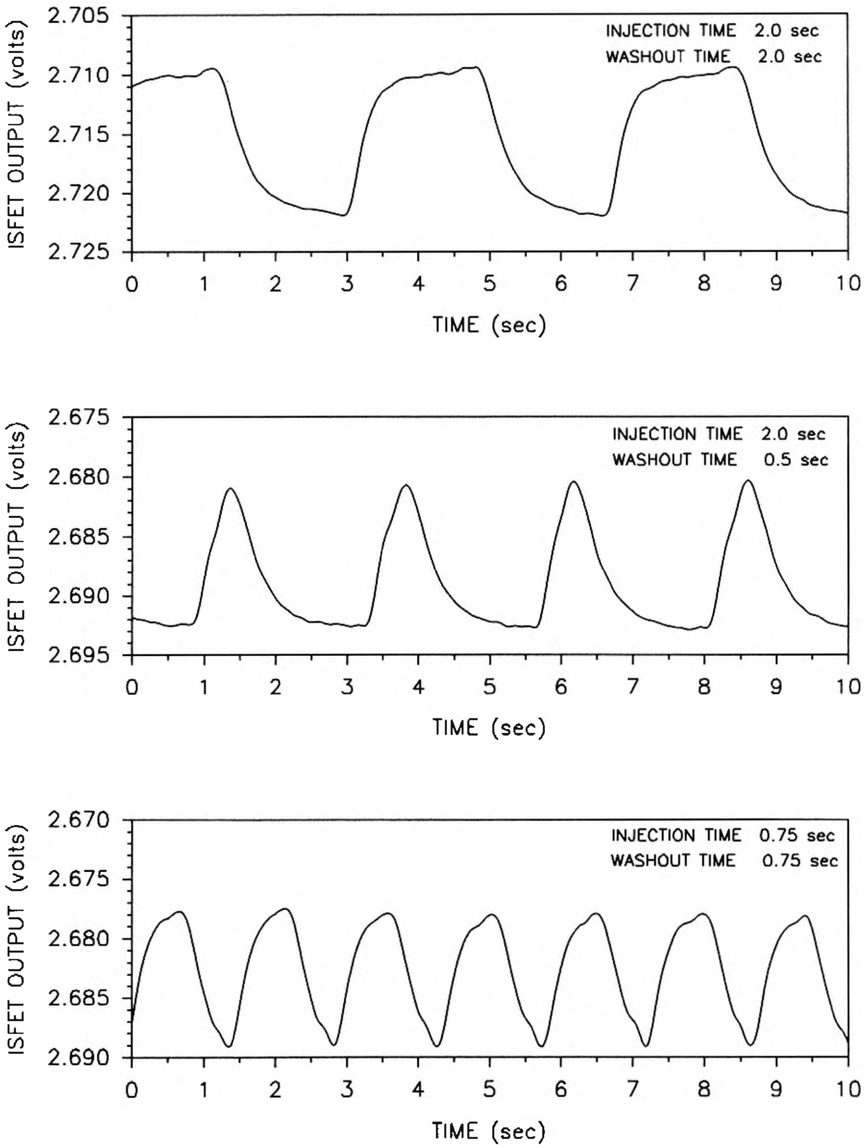

Figure 4. Effect of sample injection and washout times. (Flowrate = 0.09 ml/s; sample concentration = $2(10^{-4})$ M $NaNO_3$).

in field production systems. Two soil organic matter sensors have been developed and licensed for commercial development. Sensors for other soil parameters are being sought, and progress has been reported on weed and nutrient sensing.

Concerns of consumers about the impact of agricultural inputs on the environment accelerate the demand for sensors and sensing systems, and research and development in both the public and private sectors should expand. Future research and development efforts will undoubtedly improve the technology to provide more precise control of agricultural inputs and reduced environmental impact.

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Remote Sensing Project

Dennis Bowman

For many years researchers, consultants, and producers have been experimenting with the use of infrared aerial photography to monitor crop conditions. Satellite and space shuttle images of earth are becoming commonplace. Large corporations and the news media are frequent purchasers of commercial satellite photography. The satellites currently available for this activity do not gather data suitable for timely agricultural decision making.

Last winter a new commercial group, which has since taken the name **RESOURCE 21**, held an informational meeting for agribusinesses and farmers. Their goal was to bring together business sponsors and interested farmers to participate in a pilot project using their aerial near-infrared imaging system. This system creates digital field aerial images that can be calibrated and enhanced. Presently, the images are taken from an airplane, at approximately 6,000 feet. The group's long-term goal is to launch a string of satellites in early 1998 to do the imaging. In 1991 the group started a project in the potato growing region of central Wisconsin. It was co-sponsored by NASA's Space Remote Sensing Center and a large agricultural retailer.

Pilot programs are also underway in California and Washington state. The Illinois project is their first entry into corn and soybean country and relatively low value crops. The participation fee was $7.00 per acre. Agribusiness co-sponsors split the fee with producers and most farmers paid less than $3.50 per acre to participate. For this fee they were to receive a bare soil photo before planting plus a series of photos throughout the growing season.

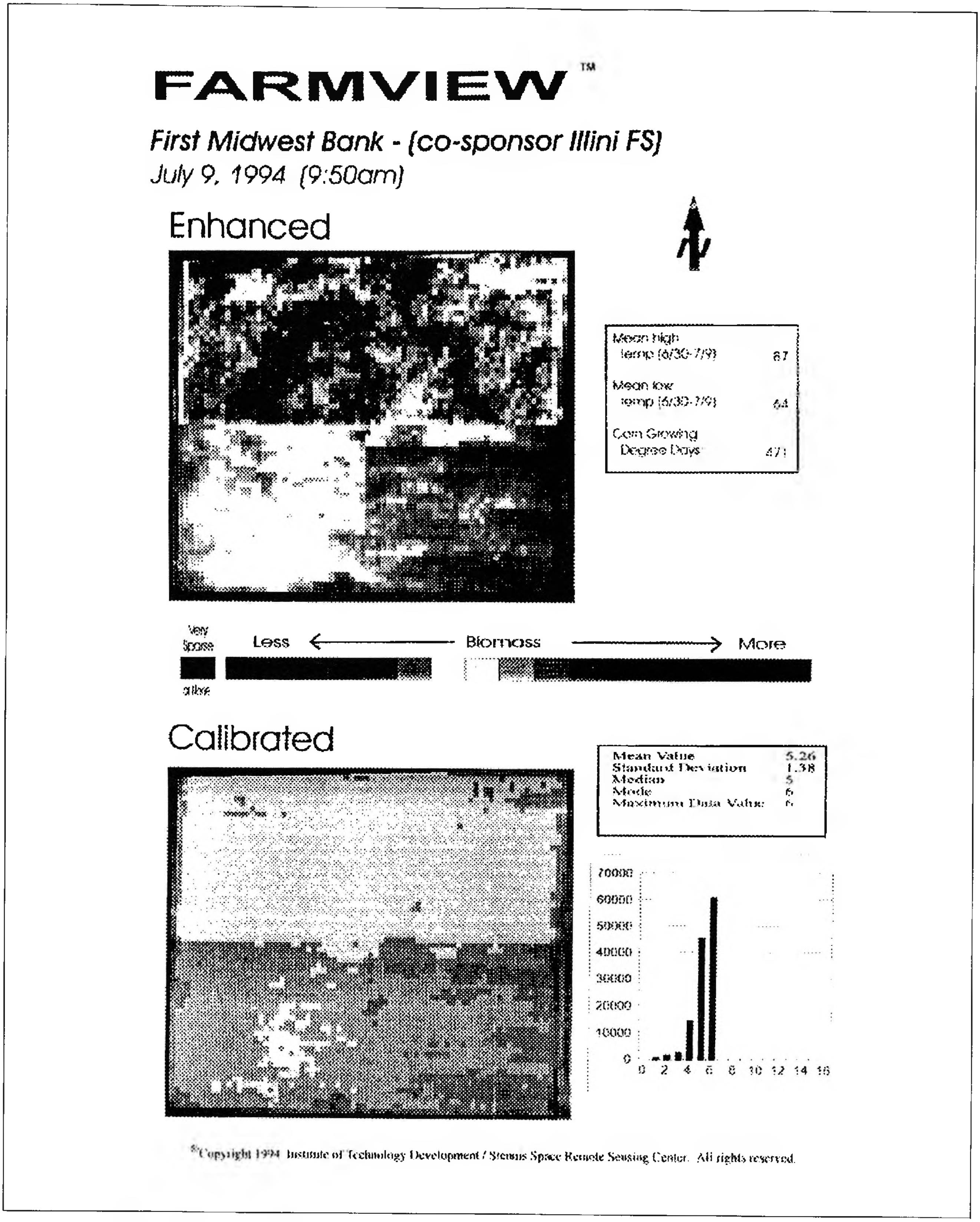
The soil map shows characteristics such as soil moisture, soil organic matter, and soil texture differences. Soil moisture variations display field drainage characteristics and may help pinpoint the location of existing drainage tile lines or indicate where additional tile is needed. One feature that showed up prominently on our test field was the "drifts" of corn stalks left by heavy rains and water ponding in the field.

One field enrolled in the program was the Little Vermilion Water Quality Project Fertility Management Demonstration Field. Ted Vinson, Extension Agriculturalist in the Vermilion Unit office, was the coordinator of the site. Illini FS and the First Midwest Bank of Danville were the field sponsors in the remote sensing project. Illini FS also provided Variable Rate Technology (VRT) for fertilizer applications on part of the field.

To evaluate the remote sensing data, extension personnel would scout the field after each new map was received. This ground truthing would attempt to identify the differences visible on the map.

A black and white version of a typical map is included in Figure 1. The map contains two color images of the field and a color bar showing the color range with dark red as the least biomass and dark green as the most biomass. A histogram that shows the amount of area in the calibrated image occupied by each of the 16 colors, and temperature data for the period preceding the flight, are also shown on the map. The bottom image is the calibrated image created from raw data and standardized so that different fields and different flights can be compared. This image generally does not use all 16 color ranges. The upper image is the enhanced image; it takes the data ranges shown in the calibrated image and breaks them up to use all 16 colors. This "enhances" any differences present in the calibrated map. When looking at a series of maps to view crop changes over a length of time, one should look only at the calibrated images. To locate trouble spots, look at the enhanced map for color differences and patterns.

The first crop image was taken on June 25 (Figure 2). Although black and white does not carry the impact of a 16-color image, most of the major points are still visible. The first thing noticed was that the 160-acre field was being farmed as two 80-acre fields, the north 80 in corn and the south 80 in



FARMVIEW™

First Midwest Bank - (co-sponsor Illini FS)

July 9, 1994 (9:50am)

Enhanced

Mean high temp (6/30-7/9)	87
Mean low temp (6/30-7/9)	64
Corn Growing Degree Days	471

Calibrated

Mean Value	5.26
Standard Deviation	1.38
Median	5
Mode	6
Maximum Data Value	6

Figure 1. Sample data from Resource 21 remote sensing evaluation project.

Figure 2. Enhanced image June 25 flight.

soybeans. Mottling or bands of color going across the field reflect the topography of the field. Low ponded areas and the higher areas of thin soil were growing more slowly than the sloping or flat better-drained areas. Color differences related to cultural practices were also obvious but required knowledge of field history information for interpretation. The dark band across the top of the corn field was planted a couple weeks earlier than the rest of the field. The bright band across the middle of the field was the ground that was set aside the previous year and was now in soybeans. There also appeared to be a difference in the west and east halves of the soybean field. Although the farmer did not think that the sides had been treated differently, the farm manager found old soil test data for the farm suggesting that a change in field orientation had occurred many years ago. A very narrow dark band along the right edge of the field is a row of evergreens and a fence row. This area was masked out of later flight data.

Later flights showed crop development progress, crop stress due to soil moisture shortages, herbicide drift from a neighboring corn field, mechanical damage, and possible nitrogen deficiencies in the corn. The maps showed where differences in the field were occurring, but field scouting was required to determine the cause of the variation. The digitized aerial maps are a great tool to maximize one's efficiency during crop scouting time. Given that not many people enjoy walking long distances through corn fields at pollination time, these maps will be useful in indicating whether such a trip is necessary and locating those areas needing special attention.

How Worker Protection Standards Will Affect Commercial Applicators in 1995

T. A. Walker

The purpose of the Worker Protection Standards Rule is to reduce handlers' and workers' exposure to pesticides on farms and in forests, nurseries, and greenhouses. This rule is expected to cover 3.9 million workers and handlers. The Worker Protection Rule was published in the *Federal Register* on August 21, 1992. In early 1994, the United States Congress passed legislation that delayed some provisions of the Worker Protection Standards until January 1, 1995. Everyone, including commercial applicators, must be in compliance with the Worker Protection Standards on January 1, 1995.

Commercial pesticide handlers and their employees are included under the Worker Protection Standards even if the pesticide handling task (mixing, loading, disposal, etc.) takes place somewhere other than the farm, forest, nursery, or greenhouse—at the commercial handling establishment or an airport hangar, for example.

All product labels must carry a statement prohibiting application of the product in a way that will contact workers or other persons directly or through drift. If a product is highly toxic (Toxicity Category I) for dermal toxicity or skin irritation potential, the label must have a requirement for "double warnings." Users will be required to notify workers of an application **both** by warning them orally and by posting warning signs at entrances to the treated areas. If a product is a fumigant with a label that allows use in a greenhouse, the rule also requires users to provide both oral warnings and posted signs for workers when the product is used in a greenhouse. The commercial applicator's responsibility is to communicate to the grower what product was applied, the restricted-entry interval, and the time the application was completed.

A new term with which pesticide handlers will need to become familiar is **restricted-entry interval** (REI). Restricted-entry intervals range from 12 to 72 hours and are based on the acute toxicity of the **active ingredient** through two routes of exposure, dermal and ocular. A restricted-entry interval of 48 hours applies to active ingredients in Toxicity Category I. A restricted-entry interval of 24 hours applies to active ingredients in Toxicity Category II. A restricted-entry interval of 12 hours applies to all other active ingredients, those in Toxicity Categories III and IV. Labels that currently have a longer reentry interval will be retained. In addition to REIs, all labels must carry personal protective equipment requirements expressed in standardized terms. The definition of personal protective equipment (PPE) is "devices and apparel that are worn to protect the body from contact with pesticides or pesticide residues." Pants, shirts, socks, and shoes are not considered personal protective equipment, but pesticide labeling may require their use in some circumstances.

After April 24, 1994, all products covered by the rule must bear the Worker Protection Statement on their labels when they are distributed or sold by the registrant. After October 23, 1995, all products covered by the rule must bear the Worker Protection Standard labeling statements when they are distributed or sold by anyone.

Exemptions from the Worker Protection Standards are: public mosquito control ; golf courses; structural pest control ; uses in rights-of-ways, pasture, and rangeland ; and commercial seed treatment. Please note that this is only a partial listing of the known exemptions.

Employers are required to provide employees:

- Information about exposure to pesticides
- Protection against exposure to pesticides
- Ways to mitigate exposures to pesticides

The Worker Protection Standard specifically defines handlers and workers and the mandatory requirements of the education program. The protective clothing requirements are also defined in the Standard. We do know that if a worker or handler is certified and licensed by the Illinois Department of Agriculture (IDOA) as a pesticide applicator or operator, the employer will not be required to train that person further under the Worker Protection Standard.

This article is intended to give you a brief description of some of the aspects of the Worker Protection Standard rule. A more in-depth description of the Worker Protection Standard is available in the "How to Comply Manual" and the Handler and Worker Manuals. These free publications are available from the Illinois Department of Agriculture. There are still some unanswered questions that await interpretation by the United States Environmental Protection Agency. If you have any additional questions, please contact the Illinois Department of Agriculture, Bureau of Environmental Programs, P.O. Box 19281, Springfield, Illinois 62794-9281, or telephone 217-785-2427, TDD 217-524-6858.

The Advantages of Becoming a Certified Crops Adviser

Harold F. Reetz, Jr.

Over the past few years, the American Society of Agronomy (ASA) has sponsored the development of the **Certified Crop Adviser** (CCA) program under **ARCPACS**, which is a federation of certifying boards in agriculture, biology, and earth and environmental sciences. The CCA program is designed to demonstrate that individuals who make recommendations to farmers on pest and nutrient management are qualified to do so. Minimum standards of education and experience have been established, and certification requires passing a written examination and signing a **Code of Ethics**. To date nearly 8,000 individuals have participated in the program, 2,500 of whom have been certified.

In 1990, a group of about 30 leaders of USDA and agribusinesses involved in making recommendations to farmers on nutrient and pest management began meeting to develop a certification program. Pressure was mounting for USDA to provide evidence that recommendations were being made by people with adequate training, experience, and awareness of health and environmental risks associated with the products being used. USDA was reluctant to impose a certification program and asked the industry to develop and implement an acceptable program over the following two-year period.

Under the auspices of ASA and ARCPACS, the CCA program began by considering the model provided by the existing ARCPACS professional certification program. Professional certification by ARCPACS requires a BS degree in the individual's area of specialization. Given that many of the people currently involved in making recommendations do not have a BS degree, but have substantial "hands-on" experience, an examination requirement was chosen instead. The exam is designed to demonstrate a working knowledge of appropriate technology that would be equivalent to the knowledge level of a BS graduate in the respective field. In addition, minimum field experience requirements were established.

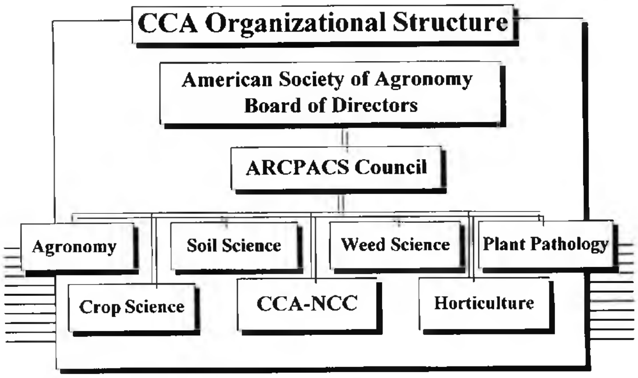


Figure 1. Certified Crop Adviser (CCA) program; organizational structure

The CCA National Coordinating Council Policy Committee serves as the CCA Board, which is one of the seven Certification Boards of the ARCPACS Council (see Figure 1), and provides direct linkage and coordination of the CCA program as a part of the ARCPACS professional certification program.

To give the program acceptable credibility, the American Society of Agronomy contracted with the Educational Testing Service (ETS) to provide consultation and support services for the exam process. ETS helped organize and evaluate a Professional Activity Requirement Study. Questionnaires were sent to several hundred individuals working as field agronomists, crop and pest management consultants, and others who make recommendations to farmers. About 200 competency areas and activities were rated for their relative importance to a person working in the field. From this survey, a set of National Performance Objectives was developed. The national CCA Exam tests the individual's knowledge of these Performance Objectives.

The core of the CCA program is the individual state CCA Board. To date 32 state or regional boards have been appointed and organized. These boards are responsible for administration of the program, with national coordination support from ASA headquarters staff. State boards develop state Performance Objectives, develop and administer state exams, establish certification requirements, review credentials, grant certification, and administer continuing education programs. Each state's CCA Board is composed of field agronomists, consultants, university staff, representatives of government agencies, farmers, and representatives from other interested groups appropriate to the individual state. Each state CCA Board has one representative on the National Coordinating Council. The NCC Chair in turn serves on the ARCPACS Council, which coordinates the overall ARCPACS certification program. Individuals wishing to obtain additional certification in a particular area of specialization may also apply for certification as a certified professional *agronomist, soil scientist/specialist, soil classifier, crop scientist/specialist, horticulturist, weed scientist, or plant pathologist*.

The Illinois Certified Crop Adviser Board was the first state board to be organized, and it provided substantial guidance to other states as they began to develop their programs. There has been excellent cooperation among the industry representatives, dealers, consultants, farm managers, extension services, state universities, Soil Conservation Service, Illinois Department of Agriculture, Illinois Environmental Protection Agency, and other interested groups. As a result, there have been more individuals tested (963) and certified (462) in Illinois than in any other state. Nationally, 8,819 exams have been given and 2,570 CCA Certificates have been issued. There are 5,089 individuals in the process of becoming certified. (Figures are as of October 1, 1994.)

The four main competency areas established for the CCA program are based upon the Professional Activity Requirement Study discussed earlier:

- Nutrient Management
- Cropping System Management
- Integrated Pest Management (Weeds, Insects, Diseases)
- Land/Water/Air Resource Management

The exam questions are divided among these areas, and scores are reported in each area to each participant, to facilitate preparation for retaking the test if the first attempt is unsuccessful. Federal, state, and local regulations are also included as appropriate in each of the competency areas. Continuing education requirements are also based upon these competency areas.

Who should be certified? The CCA program is *voluntary* in Illinois, so no one is required to participate. However, anyone who is involved in making recommendations to farmers, or in developing management plans for nutrient and pest management, is encouraged to participate so that the program can remain voluntary. Some states have made certification mandatory, and there is a possibility that some kind of certification may be required under the Clean Water Act, the 1995 Farm Bill, and/or other federal legislation. High voluntary participation in the CCA program will help it to meet such possible future requirements.

What are the benefits of CCA Certification? The early acceptance of the CCA program in Illinois is an indication that our dealers and consultants see the value of documenting their knowledge and experience. Although the driving force has been partly the threat of regulation, many of the individuals have participated because they want to demonstrate to their customers (and perhaps to themselves) that they meet the accepted standards to make recommendations to farmers. Some see it as supporting their ability to market their services and differentiate their business from their competition. Some companies use it to document abilities of their staff for promotion purposes, providing added incentive for participation. A Wisconsin dealer said that the CCA program has made his employees feel more confident in their own recommendations to farmers, and has helped persuade them that he is giving them the proper training opportunities to keep up with current technology and information.

The CCA program helps raise the level of professionalism within the agricultural industry, and provides a statement of professionalism and competency to the general public. The public, and especially our critics, can be shown that those making recommendations do possess the necessary knowledge and experience to ensure that proper products, rates, and timing are used to minimize risk of health and environmental hazards from agricultural activities. State and federal government agencies are recognizing the value of the CCA program, and environmental organizations see it as positive evidence that we are trying to be responsible partners in environmental and resource protection. This recognition will be important to agriculture as new legislation and regulations are enacted.

Perhaps the greatest benefit to individuals from the CCA program will come as a result of the continuing education requirement, which will assist in forming a framework on which to develop and administer an organized training program to keep our field workers (1) up to date on new technology and (2) reviewing basic concepts on a regular basis. The CCA program will help individuals know what they need and will help guide university, agency, and industry training programs to meet those needs in a structured, organized manner. Also, the opportunity exists to utilize video and computer technologies to provide specific training tailored to each individual's needs. One Illinois dealer commented recently that the real value of the CCA program was that it had greatly increased the agronomic knowledge acquired by the people in the field.

The CCA exam is difficult and other requirements of certification are rigorous as well. Approximately 30 percent fail the exam the first time. However, this contributes to the program's credibility and gives the certification more meaning to those who do meet the requirements. It is likely that standards will become more difficult as the CCA program develops, with the requirement of a BS degree (or at least an Associate Degree) likely to be added in the near future. This is further incentive for individuals to try to become certified as soon as possible.

The CCA program has had some detractors, has endured some "growing pains" during implementation, and has had some frustrations, but overall it has been a very positive effort. The joint efforts of industry, university, and government agencies, with substantial input from farmers, dealers, and other interested people have made this a unique cooperative venture. In the long run, it will be a positive force in keeping crop, soil, and pest management agronomically sound, economically efficient, and environmentally responsible, all of which should help make agricultural activities more socially acceptable and lead to a more truly sustainable agriculture.

For further information on the Illinois CCA program, contact the Illinois Fertilizer & Chemical Association office, P.O. Box 186, St. Anne, Illinois 60964 (Phone: 815-427-6644).

Rootworm Problems in First-Year Corn: An Increasing Problem?

Eli Levine

Introduction

In June 1987, severe corn rootworm larval injury, to corn grown for seed production in six fields that had been planted to soybeans grown for seed production the previous year, was reported within a one-square mile area near Piper City (Ford County), Illinois. All fields were free of volunteer corn or heavy weed infestations in 1986. Since that time, my laboratory has been trying to find the cause for this damage. The severe corn rootworm problem reoccurred in the same area in 1988, and again in 1992, on seed corn following seed soybeans.

We quickly determined that the damage was caused by the western corn rootworm, Diabrotica virgifera virgifera, and not the northern corn rootworm, Diabrotica barberi. This was unexpected because prolonged diapause is well known in the northern corn rootworm (Levine et al. 1992b), but it has been reported only recently in the western corn rootworm, and at very low levels (about 0.1 percent and 0.2 percent in egg populations observed in Illinois and Ontario, Canada, respectively [Levine et al. 1992a]). The prolonged diapause trait allows corn rootworm eggs to pass through two or more winters without hatching, rather than hatching after a single winter as usual. Larvae from such eggs could potentially cause damage to corn after a one-year rotation with another crop if resulting larval populations are sufficiently high enough. Eggs-hatch studies with eggs from the Piper City population of western corn rootworms, however, did not show *any* evidence of prolonged diapause.

Although we determined that significant egg-laying by Piper City western corn rootworms was indeed taking place in soybean fields, a large field study with staggered plantings (giving different plant maturities) of soybeans in Urbana, less than 60 miles away, confirmed earlier published studies (Shaw et al. 1978) that neither western nor northern corn rootworms lay enough eggs in clean (generally weed-free) soybean fields to cause economic damage to a subsequent crop of corn. Because western corn rootworm adults are quite mobile and considerable genetic mixing is thought to occur, we expected that Urbana and Piper City populations would show similar ovipositional behavior.

We also investigated the possibility that western corn rootworms may have laid eggs in the Piper City soybean fields, because pyrethroid insecticides used on neighboring seed corn may have repelled rootworm females into the nearby soybean fields. Pyrethroid insecticides are routinely used for corn earworm control in seed corn and are typically applied during the period of initial corn rootworm oviposition, that is, during the first two weeks of August. These insecticides have been reported to have anti-feedant and repellency properties with other beetles (Dobrin and Hammond 1985, Hall 1979, Moore 1980) and many other insects. It is possible that these chemicals may have driven western corn rootworm beetles from cornfields to neighboring soybean fields where they laid their eggs. In several laboratory bioassays, we demonstrated that pyrethroids could in fact repel western corn rootworms from treated corn to lay eggs in untreated soybeans, and we concluded that the situation at Piper City could very well have been caused by pyrethroid insecticide use.

In the Proceedings of the 1993 Illinois Agricultural Pesticides Conference (Levine 1993), I stated that the situation at Piper City was an isolated one and that no reports of similar damage had been reported in other parts of the state. I also noted that commercial corn would probably be less vulnerable to this problem because hybrids produce a more vigorous root system than the inbreds used at Piper City.

New Problems: 1993

During the summer of 1993, we received a few reports of rootworm larval injury to first-year seed or commercial corn following soybeans outside the Piper City area (but still in east central Illinois). One of the fields was a seed cornfield in Flatville where pyrethroid insecticides were routinely used for corn earworm control. The remaining fields were in the Homer area and involved commercial corn with no history of pyrethroid use in the immediate area. Corn rootworm larval injury was severe in the Flatville field and moderate in the Homer fields. The western corn rootworm was overwhelmingly the predominant species in both areas. We obtained western corn rootworm eggs from females collected in the Homer area and subjected them to natural overwintering conditions in the laboratory. Eighty-three percent of the eggs hatched and 11 percent appeared to be in good condition but remained unhatched by the end of June 1994. These eggs are being subjected to another over wintering cycle. If they hatch in June 1995, we will know that they have the prolonged diapause trait. As mentioned earlier, the percentage of western corn rootworm eggs found with the trait has been less than 0.2 percent. If a large portion of the Homer eggs hatch in 1995, this would certainly be cause for concern.

Purdue University entomologists in Indiana also received some reports of western corn rootworm larval injury to first-year corn after soybeans, and they suggested that perhaps female beetles found the soybean canopy a more favorable environment than cornfields during drought conditions. The floods of 1993 essentially laid this hypothesis to rest because claims of rootworm larval injury in 1994 continued to persist.

New Problems: 1994

During the summer of 1994, we received a number of new reports of rootworm larval injury to first-year commercial corn following soybeans, again all in east central Illinois. One field near Dewey, several fields near Crescent City, and a couple of fields near Sibley sustained severe rootworm injury. The overwhelmingly predominant species was the western corn rootworm in the fields near Dewey and Crescent City. The fields near Sibley also contained sizable populations of northern corn rootworm adults, so we cannot rule out the role that prolonged diapause in the northern corn rootworm might have played. Pyrethroid use in the vicinity of all these fields was minimal. We obtained eggs from western corn rootworm females collected at Dewey, Crescent City, and Sibley, and eggs from northern corn rootworm females collected at Sibley, to check for the prolonged diapause trait. Preliminary results will not be available until June 1995, and a final determination will have to wait until June 1996.

Rootworm Beetles in Soybean Fields

Rootworm beetles are found very frequently in soybean and alfalfa crops during the growing season. However, that does not necessarily mean that they are depositing their eggs in these locations. For example, historical data from Urbana show that between the years 1979 and 1982, western corn rootworm beetle counts in soybeans in mid-August ranged from 5.8 per 100 sweeps (with a sweep net) in 1980 to 15.8 per 100 sweeps in 1979 (corn-soybean rotation; Helm, unpublished data). Although we did not find significant western corn rootworm oviposition in our earlier soybean planting time study at Urbana, we decided nonetheless to examine western corn rootworm beetle populations in soybean fields adjacent to problem cornfields. For comparison, soybean fields in the Champaign-Urbana area, where no reports of problems have been received, were also sampled. The results are presented in Table 1. Western corn rootworm beetle counts never exceeded 16 beetles per 100 sweeps in Champaign-Urbana soybean fields in mid-August, the peak period for rootworm oviposition. These figures are in line with results from the 1979-1982 studies in Urbana. In contrast, beetle counts in soybean fields near problem cornfields ranged between 23 and 100

Table 1. Number of western corn rootworm beetles per 100 sweeps with a sweep net in soybean fields, 1994

	SAMPLING DATE[1]			
LOCATION	7/18-19	8/4-5	8/18-19	9/1-2
Champaign[2]	11	8	3	5
Urbana #1[2]	18	19	13	4
Urbana #2[2]	ns	ns	1	4
Urbana #3[2]	ns	ns	16	1
Urbana #4[2]	ns	ns	9	4
Crescent City[2]	116	161	100	98
Dewey[2]	28	51	23	10
Flatville[3]	ns	71	45	10
Piper City[3]	ns	71	45	10
Sibley[2,4]	ns	76	87	23

[1] ns = not sampled on these dates.

[2] Nearby fields devoted to commercial corn production with no pyrethroid use in 1993.

[3] Nearby fields devoted to seed corn production with pyrethroid use in 1993.

[4] Large populations of northern corn rootworm beetles also present.

western corn rootworm beetles per 100 sweeps. Although this does not prove that the greater abundance of rootworm adults in soybean fields near problem cornfields leads to greater oviposition in these soybean fields, the results are intriguing nonetheless. Our assumption had been that because of genetic mixing, ovipositional behavior of western corn rootworms at Urbana should be the same as that of beetles 60 miles away. That may have been an incorrect assumption.

Concluding Remarks

Although the problems with western corn rootworms at Piper City can be explained by pyrethroid use, some other problem fields in east central Illinois do not fit that pattern. Although it is too early to push the panic button that we may have selected for a insect that lays eggs in soybeans (in east central Illinois, what better place to find corn roots the next year!), we are continuing to examine that prospect. Whether pyrethroid use played a role in this process is open to question.

Acknowledgment

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