10th Year

THE 2007 UNIVERSITY OF ILLINOIS

Corn & Soybean Classic

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The 2007 University of Illinois

Corn & Soybean Classic

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College of Agricultural, Consumer and Environmental Sciences
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CROP SCIENCES
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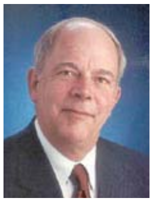
Commemorating the 10th Annual Corn & Soybean Classics

R.G. Hoeft, K.L. Steffey, M.E. Gray, E.D. Nafziger, D.L. Good, and T.E. Gleason



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The seed of the idea that grew into the Corn & Soybean Classics was planted by Department of Crop Sciences extension specialists in hallway conversations. Upon germination, the idea took firm root in an August 1997 meeting of those same specialists. The plan emerged and took shape following a September 1997 meeting during which representatives of the Illinois Corn Growers Association and the Illinois Soybean Association provided stimulation (incentive) for this program to go forward.

At the outset of planning, the goal was to develop a format that was conducive to transferring information from the University to producers and their advisers, as well as to provide a welcoming environment for the audience to share problems they had experienced and opportunities they had observed. Meeting locations were selected based upon accessibility, amount of space for large groups, and ability to provide lunch and other refreshments. To enable us to hold the meetings at nice facilities, with lunch included, and to publish a professional proceedings to support the presentations, we created a registration fee structure. Although some people believed that charging a registration fee for an Extension program would meet with great resistance, we found the reverse to be true. Over all of the years of the Classics, many attendees have told us that the registration fee is too low with regard to the quality of the program we deliver.

The educational program was designed for presentations that address the most critical and timely issues in crop management, "get to the point," and invite frequent interaction among presenters and the audience. Speakers have been limited to 25- to 35-minute presentations, with emphasis on current issues and research. All presenters have agreed to tell the audience what they (the audience) need to know, not everything the presenters know. To keep speakers on time and to keep the audience engaged, we included a program moderator who introduces all presentations and regularly solicits questions and comments from the audience, and keeps the audience engaged throughout the meeting. With this format, the audience has an opportunity to listen to at least eight or nine specialists of different disciplines in one meeting and to visit with their peers and the specialists during the meeting.

In the first year, 1998, Classics were presented at five locations—Bloomington, Rochelle, Galesburg, Litchfield, and Mt. Vernon. Not knowing what to expect, we were pleasantly surprised (actually shocked) to find 350 in attendance at the first meeting in Bloomington and another 250 at each of the next two Classics. Not being prepared for so many people to attend the first meeting, the registration process was a little slower than we would have liked, and we had to delay the beginning of the program. Fortunately, we were able to adjust, and by the next day the registration procedure had been smoothed out. We learned many valuable lessons about size and quality of venues, as well as about preparations for refreshments and about lunch offerings. Suffice it to say that we adjusted for more professionally staged meetings for future versions of the Classics.

Over the years, we have presented the Classics at several different locations in several different cities around the state, but we eventually settled on presenting the Classics at six sites—Bloomington, Malta, Moline, Springfield, Collinsville, and Mt. Vernon. Geographically, these sites are well positioned, and the facilities meet our criteria for delivering a professional meeting.

The success of these meetings for 10 years must be attributed to several individuals and groups. Were it not for the promotional mailings by several major companies and associations, the publicity provided by farm media—both written and electronic—and promotions by local Extension offices, many people would not have known about the Classics. Local and regional Extension office personnel have volunteered annually to help with the registration process and answer questions about logistics. Our own staff—Sharon Conatser, Kris Ritter, and Sandy Osterbur—have made all the local arrangements, processed pre-registration submissions, and made certain that the proceedings was completed on time and that equipment and supplies were ready to load into the vans at the time of departure The success of the Classics has been a clear result of a concerted team effort.

In the first 9 years, more than 10,000 people participated in the program (Figure 1). Fluctuation in attendance can be accounted for, in part, by development of new problems (e.g., soybean aphid in 2000, soybean rust in 2005), low grain prices (some would say continuous, but 1998 and 1999 prices were near-record lows), and big increases in input costs (e.g., N in 2000 and again in 2005 and 2006, along with increases in all energy-related prices). On average, attendees at the Classics have traveled 45 miles to each meeting, with some traveling from as far away as 280 miles. Approximately 60% of the Classics audiences have been producers, with more than half of them farming 1,000 acres or more (Table 1). The proportion of producers farming more than 1,000 acres has been slightly higher at the southern Illinois Classics (Mt. Vernon and Collinsville) than at the other Classics. Slightly more than 40% of the audience have identified themselves as non-farm participants, e.g.. dealers, consultants, farm managers, government agency personnel. Recognizing that many of the non-farming members of the audience likely influence decisions made on tens of thousands of acres, it is reasonable to assume that crop management strategies and tactics for a significant portion of the crop land in Illinois have been influenced positively by these meetings.

Results from the questionnaires that have been completed over the

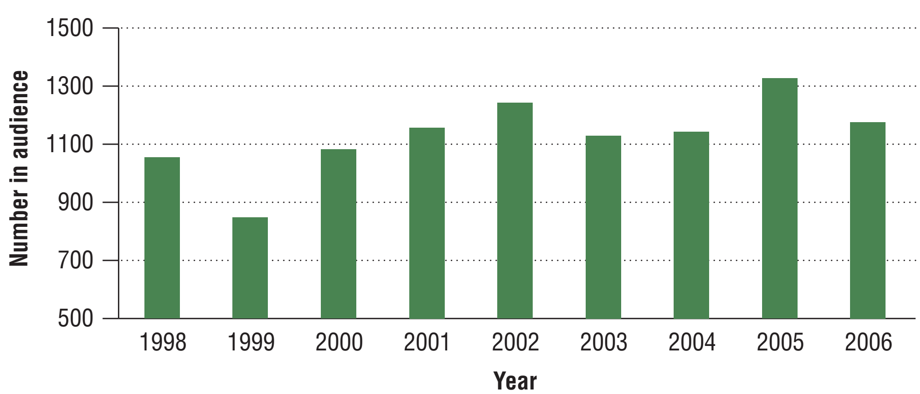

Figure 1 ■ Attendance at University of Illinois Corn & Soybean Classics, 1998–2006.

Table 1 ■ Size of farm operation for audience members, University of Illinois Corn & Soybean Classics.

Number of acres	Location						
	Bloomington	Rochelle	Moline	Springfield	Mt. Vernon	Collinsville	Avg.
				% of total audience			
0	41	50	45	45	40	31	42
<500	12	11	14	8	6	16	11
501-1000	14	14	19	14	18	16	16
1001-2000	20	14	15	20	20	22	18
>2000	12	11	7	12	16	15	12

last several years have provided useful feedback. The results have shown that a large percentage (>90%) of the people in attendance will change one or more practices in their farming operations based on information received at the Corn & Soybean Classic meetings. Participants have responded clearly about the subjects that influenced their decision making. Respondents have indicated that they like the ability to listen to and visit with eight or nine specialists at one meeting. They have requested that they wanted us to resume placing the presentations on the Web, with audio synchronized with the slides, and that they wanted more time for questions and answers. Producers in southern Illinois have asked us not to use northern Illinois data in southern Illinois, and vice versa. Responses to open-ended questions have provided suggestions for everything ranging from room temperature to ability to see the slides and presenters clearly. And with every one of these responses, we have tried to comply with the wishes of the attendees. Our overall goal has been to present a program in a professional setting, with focus on addressing the concerns and issues of those present.

We are very proud to have been able to develop and present the University of Illinois Corn & Soybean Classics to you over the past 10 years. With constant attention to your educational needs and to the most current issues and research regarding crop management, we intend to continue these Classics, in some form or other, and maybe in different locations occasionally, for years to come. Most of all, thanks to all of you for attending one or more of the Classics over time. Your continued support of our efforts has been the key to the success of these Classics.

Changing Crop Demand: Implications for Prices, Production, and Policy

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Background

Since 1996, U.S. corn and soybean market conditions can be summarized as:

1. Remarkably stable corn and soybean yields around trend value.
2. Rapidly expanding world production and consumption of soybeans.
3. Generally ample supplies and a tendency towards low prices.

The continuation of some current demand trends, along with the emergence of new demand factors, may have significant implications for corn and soybean prices, production decisions, and U.S. agricultural policy over the next several years.

One of the most significant developments for soybeans has been the rapid growth in soybean consumption and imports by China. China imported 83 million bushels of soybeans, from all sources, in the 1996–1997 marketing year. Imports grew to 1.036 billion in 2005–2006 and are projected at 1.176 billion for the current marketing year (Table 1). The 10-year increase in Chinese imports is equivalent to one-third of current U.S. production. In 2005–2006, China accounted for nearly 44 percent of world soybean imports. Initially, China imported mostly U.S. soybeans, but currently imports the majority from South America. Even so, China now accounts for nearly 40 percent of all U.S. soybean exports, up from 7 percent in 1996. Barring an economic downturn in China, consumption and imports of soybeans are expected to continue to expand.

Table 1 ■ Chinese soybean imports

Marketing year	From all sources	From U.S.	Percentage from U.S.	Percentage of world total	Percentage of U.S. exports
	Million Bushels		%		
1996	83	58	69.9	6.2	6.6
1997	108	70	64.8	7.5	8.0
1998	141	79	56.0	9.5	9.8
1999	371	191	51.5	21.2	19.7
2000	487	210	43.1	23.7	21.1
2001	382	168	44.0	19.2	15.8
2002	787	282	35.8	34.2	27.0
2003	622	302	48.6	31.2	34.0
2004	948	435	45.9	40.6	39.7
2005	1,036	357	34.5	43.9	37.7
2006*	1,176	NA	NA	45.9	NA

* Projected by USDA, November 9, 2006

Table 2 ■ Once-refined soybean oil consumed in methyl esters

Month	2006	Percentage of total oil use
	Million lbs.	*%*
January	87.9	5.9
February	77.8	5.5
March	104.4	7.4
April	106.6	6.9
May	146.0	9.2
June	169.0	10.7
July	121.2	7.8
August	165.1	9.7
September	157.2	9.1
October	142.6	7.7
November		
December		

A more recent development relative to soybean demand is the expansion of biodiesel production. The Census Bureau reports that 87.9 million pounds of once-refined soybean oil were consumed in methyl esters (biodiesel) in January 2006 (Table 2). Consumption grew to 176.2 million pounds in September 2006, accounting for 10 percent of the total consumption (domestic and exports) of U.S. soybean oil. The National Biodiesel Board reported that 85 biodiesel plants were in operation in September 2006, including one in Illinois. Most of those plants were using soybean oil as the feedstock. The Board also reported 65 plants under construction and 13 plants expanding capacity. The Board estimated biodiesel production in 2005 at 75 million gallons, with production capacity currently at 580 million gallons and projected at 1.98 billion gallons when current construction/expansion efforts are completed. That capacity is equal to about 15 billion pounds of vegetable oil, about 45 percent of the oil content of the current U.S. soybean crop.

For U.S. corn, consumption has increased in each category of use over the past 10 years. Feed and residual use has grown steadily, whereas the growth in exports has been more recent. The most dramatic increase has been in the use of corn for ethanol production. Use of corn for ethanol production was at 429 million bushels in 1996–1997, at 1.6 billion in 2005–2006, and is projected at 2.15 billion in 2006–2007 (Table 3). At the end of October 2006, the Renewable Fuels Association reported 106 ethanol producing plants in operation, including six in Illinois, and 48 plants under construction, including two in Illinois. Existing production capacity was estimated at nearly 5.1 billion gallons, and capacity after current construction and expansion efforts are completed was projected at 8.7 billion gallons (equivalent to about 3.2 billion bushels of corn). The Renewable Fuels Standard requires the use of 4.7 billion gallons of renewable fuels in 2007, increasing to 7.5 billion in 2012. It is estimated that 6.0 billion gallons of ethanol would completely replace the use of MTBE as a fuel oxygenate.

In addition to strong demand for ethanol production, export demand for U.S. corn may soon be supported by reduced corn exports from China. China currently exports about 150 million bushels of corn annually. Growing

Table 3 ■ Consumption of U.S. corn by category, 1996–2006

Marketing year	Ethanol	Exports	Feed and residual	Other[1]	Total
			Million bushels		
1996	429	1,797	5,277	1,286	8,789
1997	481	1,504	5,482	1,324	8,791
1998	526	1,981	5,472	1,319	9,298
1999	566	1,937	5,664	1,348	9,515
2000	628	1,941	5,842	1,329	9,740
2001	714	1,905	5,864	1,332	9,815
2002	953	1,588	5,563	1,387	9,491
2003	1,168	1,900	5,795	1,369	10,232
2004	1,323	1,818	6,158	1,363	10,662
2005	1,603	2,147	6,136	1,378	11,264
2006[2]	2,150	2,200	6,050	1,390	11,790

[1] Seed, food, and industrial.
[2] USDA Forecast November 9, 2006

domestic demand, along with a production plateau, may result in China becoming an importer of corn in the near future.

Implications

The potential growth in domestic and world consumption of corn and soybeans has some important implications for prices, production decisions, and policy direction. The implications extend beyond the U.S. to other major producing areas.

Marketing year average corn and soybean prices received by U.S. producers have been generally low since 1996–1997. The annual average corn price ranged from a low of $1.82 (1999–2000) to a high of $2.71 (1996–1997) and averaged $2.15 for the 10 years ending with 2005–2006. The annual average soybean price ranged from a low of $4.38 (2001–2002) to a high of $7.35 (1996–1997) and averaged $5.66 for the 10 years ending with 2005–2006. Low prices reflected an unusually long period of U.S. average yields at or above trend-value, resulting in ample supplies. The exceptions to high yields were in 2002 for corn and 2003 for soybeans. No widespread drought like the droughts in 1980, 1983, and 1988 was experienced during this past 10-year period.

Beginning in the late summer of 2006, prices began to move higher in anticipation of a change from relative abundance to shortage of corn and the likelihood for declining soybean acreage in the U.S. in 2007. On November 9, 2006, the USDA projected the 2006–2007 marketing year average farm price of corn in a range of $2.80 to $3.20 and the average farm price of soybeans in a range of $5.40 to $6.40. The futures market on November 10, 2006 projected average farm prices as follows:

Year	Corn	Soybeans
2006–2007	$3.25	$6.25
2007–2008	$3.35	$6.85
2008–2009	$3.15	$6.75

Corn and soybean prices will have to be high enough and in the right relationship over the next several years to accomplish the following:

1. Encourage planting of all available cropland area in the U.S.
2. Bring some land currently in the Conservation Reserve Program (CRP) back into crop production as contracts expire.
3. Direct a higher percentage of U.S. crop land into corn production, implying the continued shift away from small grains.
4. Encourage expansion of soybean area in Brazil and corn area in Argentina.
5. Limit the expansion of non-fuel consumption of corn.
6. Encourage consumption of protein feeds if biodiesel production expands rapidly.
7. Motivate the use of alternative livestock feeds, including distiller's grain and corn gluten meal.

For the 2007–2008 marketing year, an increase in U.S. corn acreage of about 8 million acres is probably needed to accommodate increased ethanol production and to keep corn prices at a "reasonable" level for other users. The increase in corn acreage will come primarily at the expense of soybean acreage,

Table 4 ■ Corn and soybean acreage, U.S. and Illinois, 1996–2006

Year	Corn U.S.	Corn Illinois	Soybeans U.S.	Soybeans Illinois	Total U.S.	Total Illinois
	Million acres					
1996	79.2	11.0	64.2	9.9	143.4	20.9
1997	79.5	11.2	70.0	10.0	149.5	21.2
1998	80.2	10.6	72.0	10.6	152.2	21.2
1999	77.4	10.8	73.7	10.6	151.1	21.4
2000	79.6	11.2	74.3	10.5	153.9	21.7
2001	75.7	11.0	74.1	10.7	149.8	21.7
2002	78.9	11.1	74.0	10.6	152.9	21.7
2003	78.6	11.2	73.4	10.3	152.0	21.5
2004	80.9	11.75	75.2	9.95	156.1	21.7
2005	81.8	12.1	72.1	9.5	153.9	21.6
2006	78.6	11.3	75.6	10.1	154.1	21.4

with some decline in acreage of other oilseeds, sorghum, spring wheat, cotton, small grains, hay, and pasture. In Illinois, the acreage of corn and soybeans has been relatively constant since 1996 (Table 4). Beginning in 2007, a larger percentage of acreage in Illinois likely will be in corn production, particularly in the northern two-thirds of the state. The same switch is expected in other highly productive areas of the Corn Belt. The current surplus of soybeans means that a decline of 6 to 7 million acres in 2007 can be tolerated with some loss of export sales likely, but the market may have to encourage Brazil to expand soybean acreage for harvest in 2008 to supply a larger share of world imports. Based on the peak of 97.2 million acres of soybeans in 2004, South America can easily expand by 2.5 million acres (Table 5). With futures prices above $7.00, a large expansion in soybean acreage in 2007–2008 and beyond would be likely. Likewise, continued expansion of U.S. corn-based ethanol production beyond 2008 may require Argentina to expand corn production to provide a higher percentage of the export market.

There are at least two other production implications of expanding consumption of U.S. corn and oilseeds for fuel. First, it will be important that average yields continue to trend higher and perhaps at a higher rate than in recent history. Second, with increased demand for vegetable oils for production of biodiesel and increased production of feed by-products from ethanol production, there may be some motivation to increase production of crops that are higher in oil content and lower in protein content than soybeans.

Although typically stated in terms of energy policy, current ethanol and biodiesel regulations are, in effect, producer subsidies. With the realization that current policies could result in massive structural shifts in U.S. and world crop production and consumption patterns and that there will be both winners and losers in that adjustment process, some policy issues likely will emerge fairly soon, including:

1. Income support programs may be scaled back if there are prospects of higher crop prices for an extended period.
2. The Conservation Reserve Program could be altered to selectively allow acreage to come back into crop production without penalty before contracts expire.

3. The current sugar program may come under additional pressure to accommodate the use of sugar in domestic ethanol production.
4. The import duty on ethanol might be reduced or eliminated if domestic crop prices become punitive for livestock producers.
5. Additional soil and water conservation measures may have to be considered if there is a substantial increase in corn acreage. High corn prices may also trigger increased interest in irrigation, intensifying concerns about water supply.
6. Current and proposed policies encouraging, mandating, and subsidizing biofuels production may have to be reconsidered if higher food prices become an issue or if the contribution to the energy supply proves disappointing.

Table 5 ■ South American soybean acreage and production[1]

Marketing year	Acres	Production
	Million	*Million bushels*
1996	47.6	1,517
1997	52.3	2,021
1998	55.0	1,997
1999	57.6	2,143
2000	63.5	2,583
2001	72.2	2,830
2002	80.6	3,380
2003	92.1	3,230
2004	97.2	3,529
2005	96.9	3,656
2006[2]	94.9	3,749

[1] Includes Brazil, Argentina, and Paraguay
[2] USDA Forecast, November 9, 2006

The Truth About Continuous Corn

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While there has been substantial acreage of corn following corn for decades in Illinois, it has been far more common in recent years for corn to follow soybean. Corn also can follow a forage or small grain, but that type of sequence is relatively rare. Continuous corn is expected to become more common in Illinois as the price of corn rises due to increasing demand for corn. Illinois has a substantial comparative advantage over most areas of the world corn production, primarily because of our soils, weather, hybrids, and management skills directed toward production of this crop.

When we refer to "continuous corn" here, we mean corn that follows corn, no matter how many years in a row that corn has been grown in a particular field. While it's common to distinguish "second-year" corn from "continuous" corn (which presumably is corn grown after a decision has been made to grow corn every year in a field), we have found little reason to conclude that the number of years that corn has been grown continuously affects how corn responds to management. We'll discuss some of this evidence below.

While this is not intended to be the "last word" in management of continuous corn, we have conducted a number of research trials in recent years that address both the response of corn to being grown continuously, and also provide some hints to how we can manage continuous corn for higher, more stable yields. Major points, and some evidence to support them, follow:

- *When compared directly, it is still common—and should be expected—that continuous corn yields less than corn following soybean.*

We have directly compared yields in corn following soybean (SC) to those of corn following corn (CC) in a series of 54 trials over the past 8 years in seven fields around Illinois, ranging from DeKalb (North) to Dixon Springs (South) and from Perry (West) to Urbana (East). In these trials, corn follows corn in the same set of plots every year, while corn following soybean alternates between two sets of plots next to the CC plots. All have N rates as well, but here we are using yields close to the maximum for each rotation in each trial. Averaged over all of these trials, corn following soybean yielded 163 bu/acre, and ranged from 71 to 226. Corn following corn averaged 13 bu, or about 8 percent less than SC (Fig. 1). The difference ranged from 22 bu higher for CC to 91 bu higher for SC. In 12 of the 54 trials, CC yielded more than SC.

In another set of studies, we compared CC, SC, and yields of both 1st-year and 2nd-year corn in a CCS rotation. In the four locations in the northern half of Illinois, SC and 1st-year corn (following soybean) in CCS yielded about the same (Table 1). At the two higher-yielding locations—DeKalb and Perry—CC yielded at least 10% less than SC, but the yield penalty for 2nd-year corn was only about half that for CC. At Monmouth and Urbana, CC and 2nd-year corn yielded about the same, and about 12-14% less than SC at Monmouth, but only 3% less at Urbana. In Southern Illinois locations, there was a lot of variability and yields were lower in general, while the yield penalty for CC and 2nd-year corn tended to be less than in Northern Illinois. We can't easily explain these differences among locations, but overall, corn following corn, either after 3, 4, or 5 years (CC) or after only one year, yielded 6 to 9% less than SC in these trials.

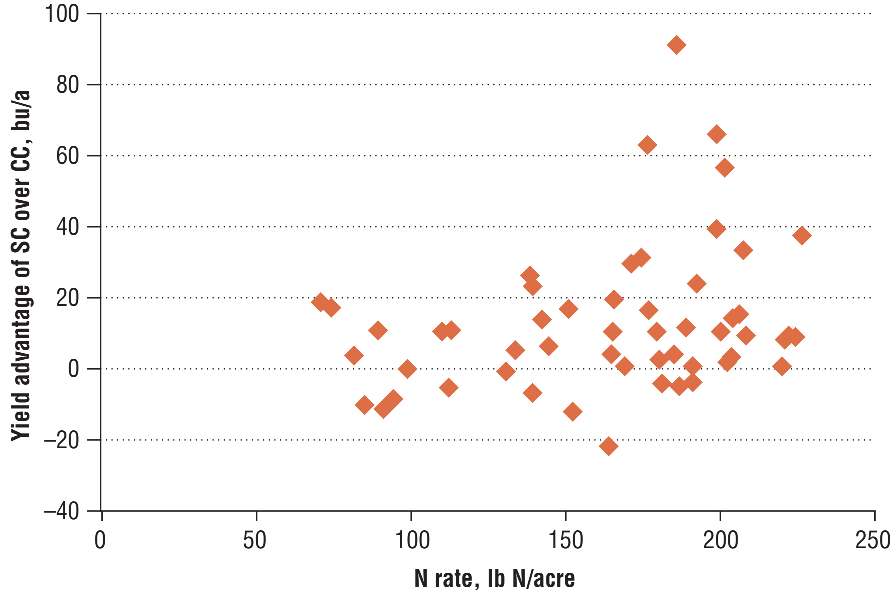

Figure 1 ■ Yield difference between corn following soybean (SC) and corn following corn (CC) over 54 Illinois site-years, plotted against site productivity as measured by the yield of corn following soybean.

While these yield results are consistent with those reported years ago, and in more recent studies in other states, it is common for producers to report that their CC yielded as much as, or more than, their SC. This is especially true in areas like East Central Illinois, where the Western corn rootworm attacks both SC and CC. It is possible that Bt RW hybrids, genetically modified to kill many rootworm larvae, might do relatively better than hybrids grown using only soil-applied insecticide. Whatever the reason, many producers have confidence, based on experience, that they can produce corn following corn with little fear that it will yield much, if any, less than corn following soybean. While our data do not give us confidence that we can do this routinely, it is possible that newer hybrids might do better following corn, whether due to better insect tolerance, general stress tolerance, or a combination of these factors.

Table 1 ■ Corn yields in a corn-soybean rotation, in the first and second corn crop in a corn-corn-soybean rotation, and in continuous corn at six Illinois sites. Data are averages over three years, 2004-2006.

Rotation	DeKalb	Monmouth	Urbana	Perry	Browns-town	Dixon Springs
			bushels per acre			
Soy-Corn	207	196	178	237	138	157
1st-yr Corn in CCS	207	195	174	241	131	162
2nd-yr Corn in CCS	191	172	170	227	131	152
Continuous Corn	174	169	170	215	123	158

- *Corn following corn needs more nitrogen than corn following soybean.*

The trials comparing SC and CC described above also allowed us to see what N rates were needed to optimize yield for corn in both sequences. On average, it took 33 lb more N for CC compared to SC, but this varied widely, from 95 lb less N to 144 lb more N for CC (Fig. 2). CC needed less N that SC about the same number of times—13 of 54—that CC yielded more than SC, but higher yields and less need for N by CC did not usually take place in the same trials. Neither was there a strong tendency for CC to need more or less N depending on site yields. Still, the correlation between yield and optimum N rate was stronger for CC than for SC, leading us to conclude that yield predicts N need better in CC, probably due to greater N immobilization by residue when yields are high.

These data indicate that the average "soybean N credit" is 33 lb of N, less than the 40 lb considered historically as the decreased N rate needed when corn follows soybean. In reality, this "credit" is more accurately thought of as a "penalty," or extra amount of N needed when corn follows corn, which we think is due mostly to the fact that corn residue ties up N, such that CC needs more fertilizer N applied. In our more recent approach to N rate guidelines, we have abandoned yield goal as a basis for N recommendations, because the correlation between N rate and yield is weak, especially when corn follows soybean. So N rate recommendations no longer include a "soybean N credit," and separate recommendations are made for CC and SC.

For reasons that are not altogether clear, using all of the N response data that we have has shown that the difference between N rates needed for CC compared to SC differs some by region of the state. This difference is about 60 lb (more for CC) in Northern Illinois, only about 5 lb in Central Illinois, and about 15 lb in Southern Illinois. We think that this might be partly explained by the fact that some of the data comes from trials with CC and SC in separate fields, not from direct comparisons in the same field like we described above. Because CC tends to be grown in more-productive fields, the crop might get more N from higher organic matter in such fields, hence need less fertilizer N. We will continue to add more data to these databases used for these recommendations, and it is possible that the differences will become more consistent over time.

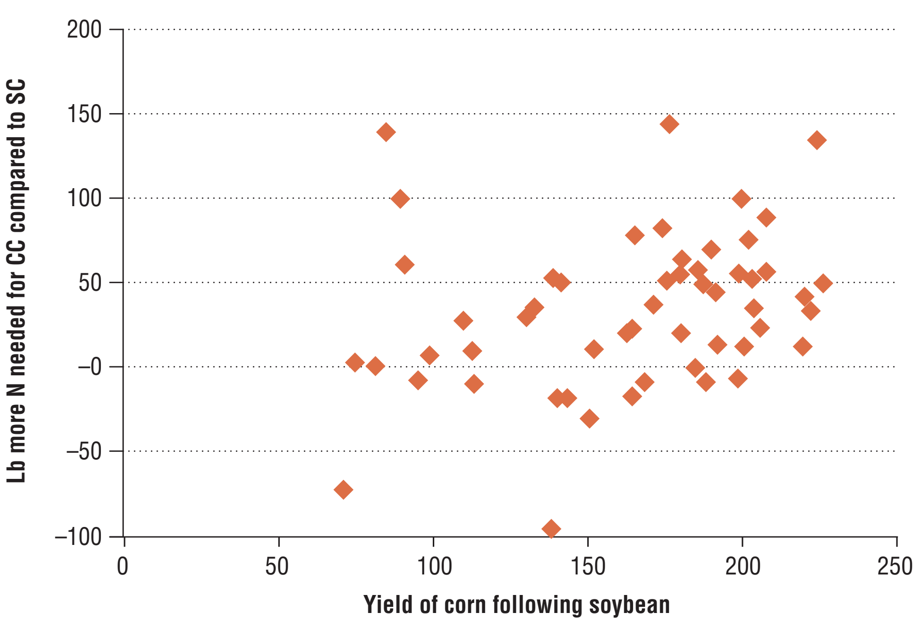

Figure 2 ■ Difference in optimum N rate for corn following corn compared to corn following soybean over 54 Illinois trials, related to site productivity as measured by yield of corn following soybean.

- *Previous corn crop residue is an issue in continuous corn*

Most producers who grow CC tend to do more tillage than they do for SC. This is done in part

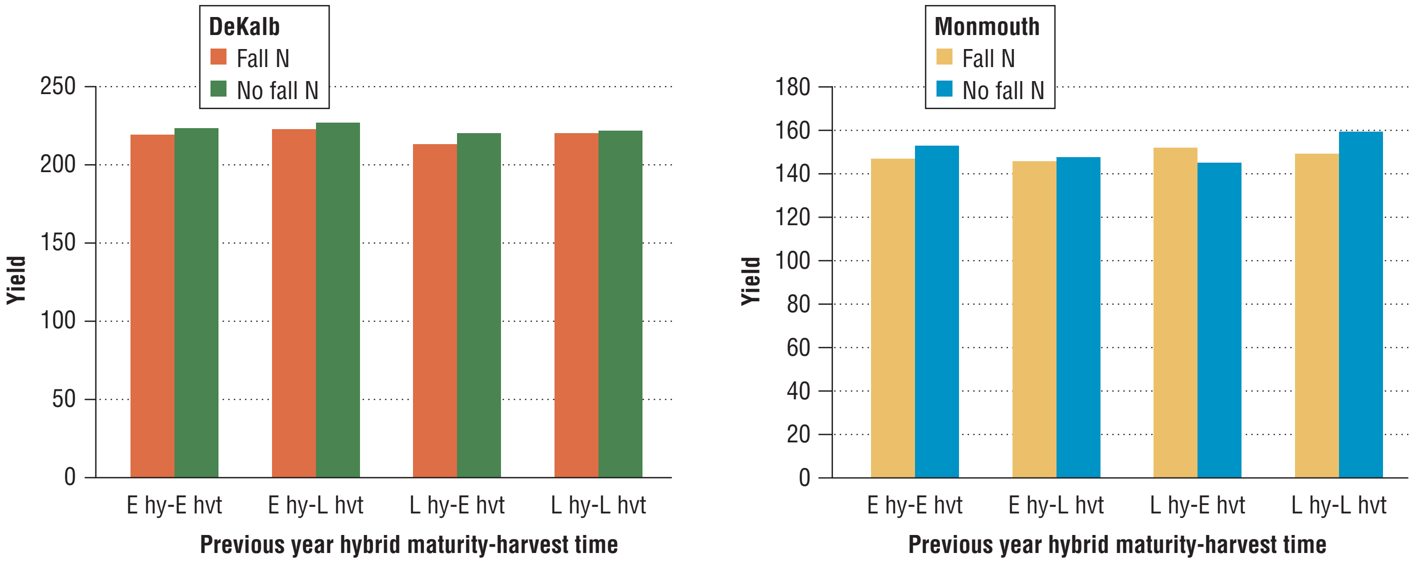

Figure 3 ■ Effect of corn maturity and harvest (and fall tillage) time the previous year, and of N applied to stalks before tillage, on corn yield, at DeKalb (a.) and at Monmouth (b.). Data are averages over three years, 2004-2006.

to reduce residue's interfering with next year's planting operations, and to lessen the amount of residue so soils will warm more quickly the next spring. Soils following corn harvest also tend to seem more compacted, perhaps due to heavier machinery used, wetter soils at planting and harvest, and other reasons, and it is not uncommon for producers to use more tillage to alleviate compaction in such fields. But trying to hasten residue breakdown is often the major reason producers give for the tillage they do following fall corn harvest.

One possible way to stimulate residue breakdown is to harvest corn as early as possible, then to till immediately, while soils are still warm enough to support microbial growth. Some also feel that adding some N to low-N corn residue might speed breakdown. In a study we recently completed at DeKalb and Monmouth, we used one early and one late hybrid, and harvested each early or late, with or without 50 lb N as UAN applied to the stalks before tillage. If N was applied in the fall, then we reduced the amount of spring-applied N so that all plots received the same N rate. We did not find that harvest/tillage timing or N applied to stalks in the fall affected corn yield the next year (Fig. 3).

One emerging issue that might affect yield of CC is the removal of corn residue to serve as a feedstock for ethanol production or as an energy supply for cattle if starch is removed from corn grain for ethanol production. We do not yet have much data on this, but results from a study in which all, half, or no residue was removed following corn harvest, half of the plots were tilled and half planted no-till, with N rates applied the following spring, are shown in Fig. 4. In this case, tillage effects were much larger than were those from changing residue amounts. We think that residue removal might reduce the immobilization of N and may even increase yield and reduce N requirement, but we need more data before we can reach solid conclusions. We also need to see how residue removal affects the soil.

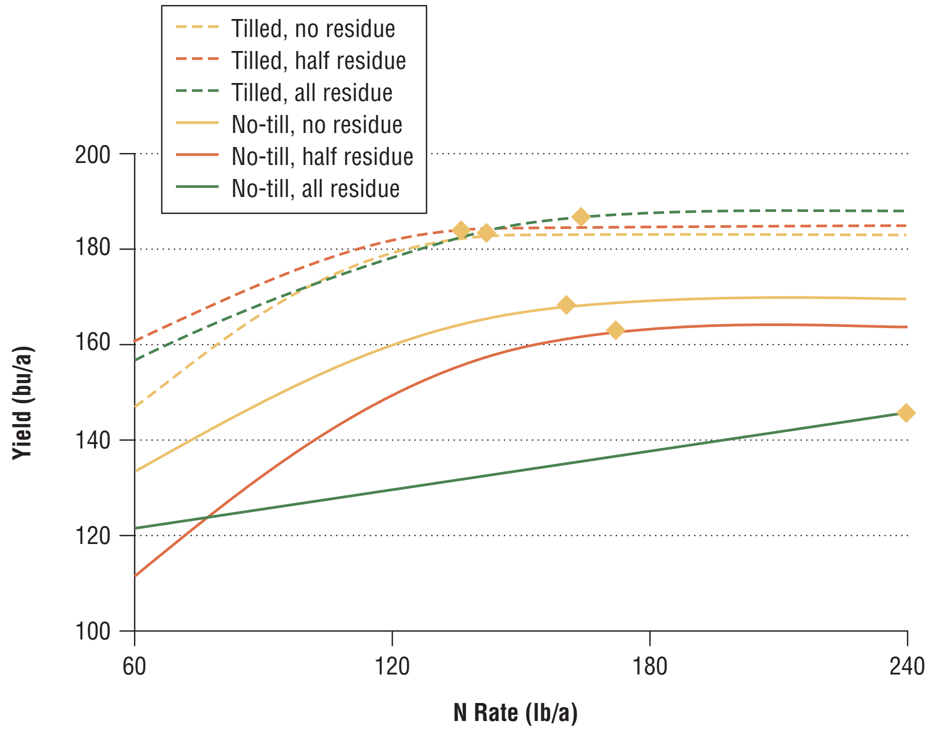

Figure 4 ■ Response to N for corn following corn with three levels of corn residue, with and without tillage. Data are from Urbana, 2006.

- *A "package" of practices, including high N rates, more tillage, and higher plant populations, might seem reasonable, but may not guarantee high CC yields. Continuous corn does not seem to "cure" its problems over time.*

Corn yield contest winners seem to have a number of factors in common, including high populations, a lot of tillage, and high fertilizer rates. Is it possible that university research is simply failing to "put together the package" needed to make continuous corn yields high, and increasing over time? Does continuous corn somehow "cure what ails it" if we just supply enough of the right inputs?

We now have three years of data from four sites in Illinois in which we have used two levels of tillage—conventional (chisel plow) and either deep ripping or a modified moldboard run at 12 to 14 inches deep—two levels of fertilizer (normal and normal plus 100 lb of N with additional P and K)—and both 32,000 and 40,000 plants per acre, with all eight combinations of these input levels. While CC yields have been variable, as expected, responses to inputs have not been very consistent (Table 3). Still, deeper tillage has increased yields in a number of sites, and higher fertilizer rates have increased yield about half the time, though the average effect is not enough to pay the cost of the extra fertilizer. Somewhat surprisingly, higher plant population has reduced yield in some cases.

The idea that growing continuous corn for a number of years in the same field tends to reduce yield losses and stabilize yields does not find much support in our data so far. In the N rate-rotation experiments described above, we tend to see no yield trend over time, either in CC by itself of in the difference between SC and CC. Neither does the N rate needed to maximize yield tend to decrease over time due to more N "cycling," as some have claimed happens with continuous corn.

- *While there may be no "easy answers" to the challenges of producing continuous corn, careful hybrid choice, along with management that provides good conditions for seed placement and root growth and that minimizes stress, can help move the crop toward higher and more stable yields.*

Table 2 ■ Nitrogen rate ranges for corn following corn and corn following soybean in northern, central, and southern Illinois, calculated using the N rate calculator located at http://extension.agron.iastate.edu/soilfertility/nrate.aspx. Data used for these calculations are from Illinois trials conducted through 2005.

Illinois region	Profitable N rate range Corn–Corn	Soy–Corn
	lb N/acre	
North	192–228	129–158
Central	166–204	161–196
South	163–195	149–187

Most evidence points to the advantage of managing continuous corn to maximize the chances that roots will grow well and stay healthy, in order to support water and nutrient uptake, and to keep plants well-anchored. We think that continuous corn undergoes stress slightly earlier and somewhat more severely than corn following soybean, but if we can "Think Roots" as we manage, we are confident that we will be able to keep yields at levels needed for high profitability.

Table 3 ■ Effects of deeper tillage, more fertilizer, and higher plant populations yield of continuous corn at four Illinois sites. Data are averages over three years, 2004-2006, except that DeKalb is only two years, 2005-2006.

Tillage	Fertilizer	Population	DeKalb	Monmouth	Urbana	Perry
			bu per acre			
Normal	Normal	Normal	202	166	223	184
Normal	Normal	High	206	158	224	189
Normal	High	Normal	199	161	223	178
Normal	High	High	205	140	208	170
Deep	Normal	Normal	213	179	226	174
Deep	Normal	High	208	175	225	181
Deep	High	Normal	207	173	215	175
Deep	High	High	207	166	206	178
Significant effects			None	Pop	None	None

Farm-Level Changes Resulting from a Switch to More Corn

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Changes in commodity price have increased the likelihood that corn production will be more profitable than soybean production in 2007. As a result, farmers are considering planting more corn and fewer soybeans. Planting more corn and changing rotations obviously will have agronomic impacts. Planting more corn also may cause other changes to the farm operation including 1) increasing a farm's costs, 2) increasing a farm's risk, 3) increasing planting timeliness concerns, 4) increasing harvesting demands, 5) increasing grain storage requirements, and 6) increasing field operation passes. These changes are discussed in the following sections.

Higher costs. Non-land costs are higher for corn than for soybeans. In northern Illinois, 2007 Illinois Crop Budgets indicate that non-land costs for corn-after-corn production are $313 per acre, whereas soybean costs are $202 per acre. Hence, corn-after-corn costs are $111 per acre higher than the costs for soybeans.

These higher costs could cause a farm to borrow more money. In general, the crop cost portion (i.e., fertilizer, pesticide, and seed) of non-land costs are paid before crop revenue is received. Many farmers finance these expenditures with operating loans. In northern Illinois, crop costs are estimated to be $170 per acre for corn, whereas soybean costs are $87 per acre. Hence, crop costs are $83 per acre higher for corn than for soybeans. The estimated $83 higher crop costs for corn could result in substantially larger operating loans if more corn is planted. As an example, consider a 1,500 acre farm with both owned and cash-rented farmland. Switching from 50% of the acres in corn to two-thirds of the acres in corn results in a cost increase of $20,750 (250 additional corn acres x $83 per acre). Besides higher crop costs, more corn acres could add more interest costs.

More Risk. Switching to more corn will increase the revenue risks a farmer faces for three reasons. First, corn yields traditionally have been more variable than soybean yields. In drought years, for example, corn often suffers much higher yield losses than soybeans. Second, a 50% corn/50% soybeans rotation blends risks. In years in which corn produces lower revenues, soybeans may produce higher revenues that partially offset revenue losses from corn, and vice versa. Moving towards a higher proportion of corn will reduce this "blending" feature. Third, agronomic research indicates that yields of corn-after-corn are more variable than yields of corn-after-soybeans. In adverse years, corn-after-corn likely will have higher yield losses than corn-after-soybeans.

To gauge increases in risk, we simulated revenues for 31 years using historical deviations from trends. Revenues were simulated for a farm having

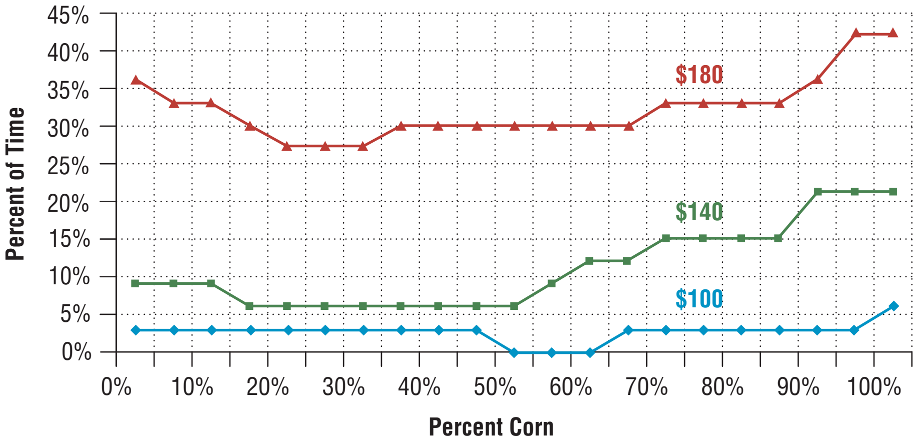

Figure 1 ■ Percent of Time Operator and Land Returns are Below Specified Levels for Different Percentages of Corn Planted, Central Illinois.

an average corn-after-soybean yield of 180 bushels per acre, a corn-after-corn yield of 170 bushels per acre, and a soybean yield of 53 bushels per acre. The average cash corn price used was $2.75 per bushel, and the average cash soybean price was $6.25.

This simulation compared operator and farmland returns for scenarios in which 0% of the acres were planted to corn (100% soybean acres) to 100% of the acres planted to corn (0% soybean acres). Operator and farmland return is a measure of return to both the farmland and the operator. A $210 return means that $210 can be used to provide the operator and farmland a return. If the farmland is cash-rented for $160 per acre, there would be a return of $50 remaining for the operator.

For a corn and soybean split of 50-50, the operator and farmland return averages $201 per acre over the 31 years of the simulation. The average return increases to $215 per acre when 100% of the acres are planted to corn because corn returns are projected to be higher than soybean returns.

Risk results are presented in Figure 1. The figure includes three lines labeled $180, $140, and $100. The $180 line gives the percentage of time revenue falls below $180 per acre. For 50% corn, revenues are projected to be below $180 thirty percent of the time. The percentage below $180 per acre increases to 33% when corn constitutes 70% of the acres, and to 40% when corn acres exceed 95% of the acres. For $140 of revenue, the probability of being below $140 per acre is 6% for 50% corn, increasing to 21% for 100% corn. Thus, increasing percentage of corn acres results in increases in revenue risks.

To a certain extent, increased risks from additional corn plantings can be managed. Increasing the coverage level on crop insurance polices could mitigate some of the risks associated with higher corn plantings.

Increasing planting timeliness concerns. Many farmers desire to have all of their corn planted relatively early. Increasing the amount of corn planted could decrease the probability of planting all corn acres within the desired time window.

This is illustrated in Table 1. Panel A shows the probability of completing planting between April 9 and April 30, the time frame during which many

Table 1 ■ Chance of Completing Work Between Specified Days, Given Differing Acres and Planter Sizes, Illinois.

Acres Planted	Planter Size 8-row	12-row	16-row	24-row	32-row
Panel A. Chance of Completing Work Between April 9 and April 30.					
500	46	65	82	93	98
750	6	46	65	82	93
1000	0	14	46	65	82
1250	0	2	14	65	82
1500	0	0	6	46	65
1750	0	0	2	28	46
2000	0	0	0	0	14
Panel B. Chance of Completing Work Between April 9 and May 15.					
500	96	99	99	99	99
750	73	96	99	99	99
1000	31	84	96	99	99
1250	11	59	84	99	99
1500	1	31	73	96	99
1750	0	20	59	92	96
2000	0	6	31	84	96
			Acres		
Acre per day	94	141	189	283	378

Source: Estimated using *Machinery Economics*, a Microsoft Excel spreadsheet available in the fast section of farmdoc.

farmers wish to have all corn acres planted. Panel B shows the probability of completing planting between April 9 and May 15, the time frame during which many farmers complete both corn and soybean planting.

A 16-row planter has a 65% chance of planting 750 acres between April 9 and April 30 (see Panel A). This probability is based roughly on a 30% chance of planting on any given day between April 9 and April 30 and planting 189 acres per day when able to work in the fields. These probabilities were estimated using a Microsoft Excel spreadsheet entitled *Machinery Economics*, available for download in the *FAST* section of *farmdoc*. A user can download this spreadsheet and modify the input to more accurately fit individual situations.

Adding more corn acres is illustrated for a 1,500 acre farm with a 16-row planter. This farm has a 73 percent chance of completing planting between April 9 and May 15 (Panel B). If the farmer in this example wishes to plant 50% of his acres to corn, or 750 acres, he has a 65% chance of completing corn planting between April 9 and April 30 (Panel A), which may be an acceptable percentage. Increasing corn acres to 1,000 acres, reduces the chance of completing corn planting to 46%, which may be a lower than desired probability.

Increasing harvest demands. On many farms, it takes longer to harvest an acre of corn than an acre of soybeans. To illustrate, the number of acres harvested were estimated for a combine with an 8-row corn head and a 30-foot grain platform, a fairly typical combine size in Illinois. Estimates were made using *Machinery Economics*, given that grain is unloaded from the combine into a grain cart while the combine is harvesting grain. For a speed of 4.5 miles per hour, 10.1 acres of corn can be harvested in an hour, whereas 15.1 acres of soybeans can be harvested in an hour (Panel A of Table 2). In this example, corn harvest is 5 acres an hour less than soybean harvest.

Besides being slower, corn harvest requires more grain to be moved away from the field. To illustrate, bushels harvested were estimated for a combine with an 8-row corn head and 30-foot grain platform described in the previous example, assuming that corn will yield 180 bushels per acre and soybeans will yield 55 bushels per acre. During an hour, 1,818 bushels of corn are harvested, whereas 831 bushels of soybeans are harvested (Panel B of Table 2). More than twice the number of bushels of corn can be harvested in an hour than the number of bushels of soybeans. Hence, transportation capacity must be larger for corn than for soybeans.

One means of increasing the speed of corn harvest is to increase the size of the corn head. In the previous example, a 12-row head could be used rather than an 8-row head. Doing so, however, exacerbates the challenges of keeping grain moving away from the field in order to keep the combine operating. For 180 bushels per acre corn, a combine operating at 4.5 miles per hour with an 8-row corn head has the capacity to harvest 1,818 bushels per hour, whereas a 12-row grain head has the capacity to harvest 2,718 bushels per hour (Table 2). In this case, switching from an 8-row to a 12-row corn head increases the bushels that will be harvested in an hour by 900 bushels, roughly the capacity of a semi-truck. To keep the combine harvesting, increasing combine size also requires increasing hauling capabilities and may require increasing the labor force. Not doing so may result in stops in the combine, thereby reducing the advantages of increasing corn head size.

Increased storage requirements. Usually, corn yields more than three times the number of bushels harvested than soybeans, which could influence

Table 2 ■ Potential Acres and Bushels Harvested for Different Sized Combines.[1]

Miles	Corn Head		Soybean Platform	
per Hour	8-row	12-row	30 foot	35 foot
Panel A. Potential Acres per Hour[2]				
3.5	8.0	11.9	11.9	18.1
4.0	9.0	13.5	13.5	15.8
4.5	10.1	15.1	15.1	17.6
5.0	11.1	16.6	16.6	19.4
5.5	12.1	18.2	18.2	21.2
Panel B. Potential Bushels Per Hour[3]				
3.5	1,440	2,142	655	765
4.0	1,620	2,430	743	869
4.5	1,818	2,718	831	968
5.0	1,998	2,988	913	1,067
5.5	2,178	3,276	1,001	1,166

[1] Estimated using the Efficiency tool in the Machinery Economics Microsoft Excel spreadsheet available in the FAST section of farmdoc.

[2] Estimated assuming 1/2 mile rows and .5 minute turning time on ends. Grain is unloaded into a grain cart while harvesting.

[3] Estimated assuming 180 bu. per acre yield for corn and 55 bu. per acre yield for soybeans.

Table 3 ■ Per Acre Primary Tillage Costs.

Operation	Total =	Tractor Overhead +	Implement Overhead +	Fuel & Lube +	Labor	Fuel Use
			$ per acre			*gal*
Chisel plow	13.40	4.50	3.10	3.70	2.10	1.3
Moldboard plow	23.80	8.00	5.60	6.50	3.70	2.4
Mulch tiller (disk, chisel)	17.00	6.30	4.10	4.70	1.90	1.7
Offset disk	11.80	3.60	3.60	2.90	1.70	1.1
V-ripper (shanks only)	16.90	6.50	1.90	6.80	1.70	2.5

Source: Machinery Cost Estimates, Department of Agricultural and Consumer Economics, University of Illinois, June 2006, available in management section of farmdoc (www.farmdoc.uiuc.edu).

decisions by farmers who have large amounts of on-farm storage. Planting more corn could result in shortages of on-farm storage. These shortages could increase reliance upon off-farm storage, thereby increasing commercial storage and drying costs. These higher costs could reduce the profitability of planting corn, thereby making corn less economically attractive than soybeans.

Increasing field operation passes. Planting more corn requires an additional field pass to apply nitrogen. Moreover, many farmers perform a primary tillage operation (e.g., chisel plowing) on corn stalks but do not perform a similar operation on soybean stubble. Hence, planting more corn requires additional field passes. These passes will place additional time demands on a farmer during the fall when many of these passes are performed.

In addition, some farms perform "deeper" primary tillage operations on corn-after-corn than on corn-after-soybeans. These tillage operations typically require more horsepower, which generally increases the per acre costs. Chisel plowing is estimated to cost $13.40 per hour (Table 3). V-ripping, which requires more horsepower, has a cost of $16.90 per hour. Costs are higher primarily because of higher depreciation and interest costs. These costs increase as more expensive implements or higher cost tractors are used in field operations. Because of their higher costs, "deeper" tillage operations generally require higher yields to justify their use from an economic standpoint.

Summary. The general result of increasing corn acres are 1) an increase in a farm's costs, 2) an increase ina farm's risk, and 3) an increase in time and machinery demands. In many situations, these additional challenges can be managed. On some farms, however, these concerns will influence the cropping decisions.

Fall Applied MAP and DAP Nitrogen: How Much is There Next Spring?

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Phosphorus (P) needs for corn (*Zea mays* L.) are typically met by the application of highly water-soluble diammonium phosphate (DAP, 18-46-0) or monoammonium phosphate (MAP, 11-52-0) fertilizers. These fertilizers are widely used because they represent a low-cost N-source and because the presence of ammonium can result in increased uptake of P. In most of the Midwest, P is commonly applied in the fall soon after soybean harvest when soil temperatures are warm (greater than 50 °F). Under such conditions, high biological activity can result in rapid nitrification, which is the transformation of ammonium (NH_4) to nitrate (NO_3). Mulvaney (1994) showed that nitrification occurred in the order of urea > DAP > $(NH_4)_2SO_4$ > NH_4NO_3 > MAP. Similarly, denitrification (transformation of NO_3 to N_2 gas) decreased in the order of NH_3 > urea > DAP > $(NH_4)_2SO_4$ > NH_4NO_3 > MAP (Mulvaney and Khan 1995). Using fertilizer materials that are more rapidly nitrified and/or applied for a prolonged period of time before plant uptake, i.e. fall, increases the risk of N loss from denitrification or leaching of NO_3 out of the root zone. These losses can be substantial in early spring when soils are extremely wet. The data from Mulvaney and Khan (1995) indicated that there is less potential for N loss from MAP than from DAP. Despite the potential for loss, all N from MAP and DAP is often assumed to be available for plant uptake, illustrated by the fact that N from these materials typically is taken into account when determining additional N fertilization for corn.

The objective of our study is to find out to what extent is fall-applied N from MAP and DAP available to the crop when compared to spring application of these products. A laboratory incubation study was conducted with three sources of MAP and one source of DAP at two N rates (20 and 40 ppm N) with two soil types (Cisne sil and Drummer sicl) and two moisture levels (80 and 120% field capacity) for 16 weeks. In addition, for the past three years (fall 2003 to fall 2006) a comparison study of two N sources (MAP, DAP) at two N rates (40 and 80 lb N $acre^{-1}$) and two times of application (fall and spring) was conducted at Urbana. Results from the 2006 season have not been compiled in time for inclusion in this paper.

Each year the same plots were planted to a final stand of 30,200 plants $acre^{-1}$ with corn variety Pioneer 34B24. Six-inch depth soil samples were collected every two weeks when possible until soils froze in the winter. Sampling resumed in the spring with samples collected from the 0–6 and 6–12 inch soil depth increments. All soil samples were analyzed for inorganic N concentration (Mulvaney 1996).

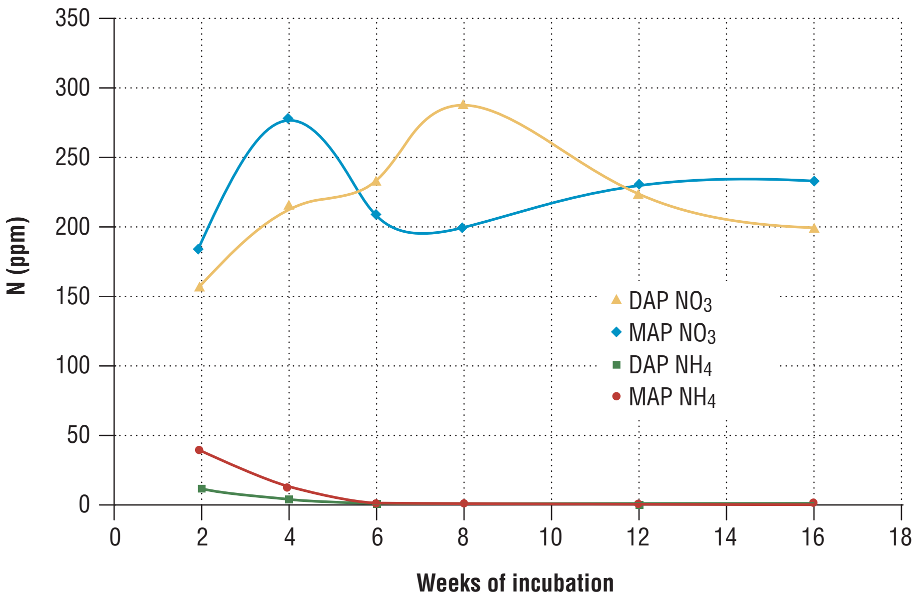

Figure 1 ■ Nitrification of DAP and MAP during a 16-week incubation period for a Drummer soil fertilized at a rate of 80 lb N acre^{-1} and maintained at a water content of 80% field capacity.

Incubation Study

After 2 weeks of incubation at room temperature, the differences in ammonium and nitrate recovery were relatively small between MAP and DAP (Figure 1), indicating that there was little difference in rate of nitrification between these two products. The differences that did exist agreed with previous work showing that MAP nitrifies slightly slower than DAP. At a moisture level below field capacity, the amount of nitrate present in the soil remained relatively constant over a long time (nearly 14 weeks), irrespective of N source (Figure 2). However, when moisture levels exceeded field capacity, the rate of nitrate loss was very rapid, with as much as 50% of the nitrate being lost in a 2-week period. These laboratory results clearly demonstrate that the ammonium in both MAP and DAP will nitrify rapidly at warm temperatures and that once nitrified, ammonium will rapidly denitrify at soil moisture levels above field capacity.

Field Study

Soils were very wet due to excessive precipitation during March and April 2004 (Table 1). In 2005, precipitation was close to or below normal every month except January and September. Air temperatures were near normal during 2004 and 2005 (Table 1).

Soil Nitrate, Ammonium, and Total Inorganic N

Within 3 weeks of application, nearly all the ammonium had been nitrified to nitrate in 2003 (Table 2). This rapid conversion occurred irrespective of rate or source of N. Nitrate concentrations in the soil remained relatively constant throughout the early part of the winter, but decreased substantially between December and March and even further between March and April. This decrease in nitrate concentrations in March and April was most likely due to denitrification that occurred while soils were saturated by the excessive precipitation received during these two months. The amount of inorganic N in the 0–6 inch soil zone was substantially higher through the May 25 sampling date for spring as compared to fall applications. For the most part, this differential was not affected by source or rate of application. The significant decrease in nitrate concentration between the May 25 and June 18 sampling dates was most likely the result of the rapid N uptake by the crop.

Even though average monthly temperatures were similar in the fall of 2003 and 2004, nitrification was more rapid in 2003 (tables 2 and 3). This differential carried through into early April, with more ammonium remaining in the soil in the spring of 2005 than in the spring of 2004. Neither source nor N rate influenced the nitrification rate. Unlike when nitrate concentrations

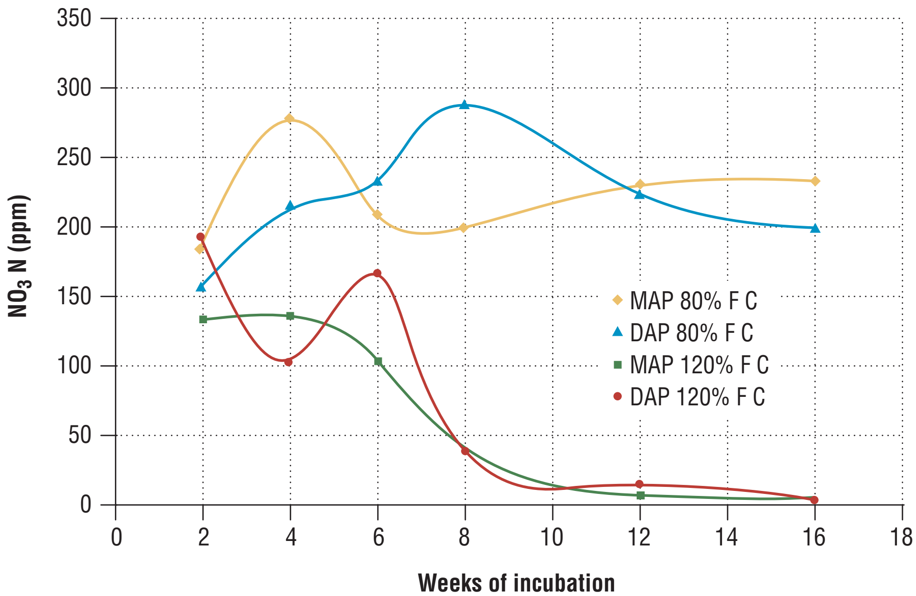

Figure 2 ■ Impact of soil water content—percent field capacity (%FC)— on N recovery from DAP and MAP during a 16-week incubation period for a Drummer soil fertilized with 80 lb N acre^{-1}.

decreased in March and April 2004, the levels of nitrate in 2005 continued to increase or remained constant into late May. This difference between years was most likely because precipitation levels remained at or below the 30-year average for all months, with monthly totals not exceeding 4 inches until July and September. Most of the 2004 growing season was characterized as being moisture deficient. In the two spring samples, there was little if any difference in nitrate concentration between fall and spring application, but there was significantly more ammonium present in the soil from spring application. The nitrate levels associated with spring application were higher than the nitrate levels associated with fall treatments in late May as a result of the nitrification of that ammonium.

Table 1 ■ Precipitation and average air temperature from October 2003 to September 2005.

	Precipitation (inch)			Air temperature (°F)		
Month	**2003–2004**	**2004–2005**	**30-yr. Avg.**	**2003–2004**	**2004–2005**	**30-yr. Avg.**
Oct.	1.31	3.71	2.81	54.5	54.5	54.5
Nov.	4.94	5.16	3.45	44.8	45.2	41.5
Dec.	3.11	2.02	2.76	33.1	32.0	29.8
Jan.	2.18	6.20	1.89	24	27.8	24.6
Feb.	0.56	2.00	2.01	30	34.7	29.9
Mar.	7.74	1.73	3.21	44.1	38.3	40.7
Apr.	10.88	3.98	3.65	53.9	54.7	51.7
May	4.38	0.97	4.80	65.7	61.3	62.9
Jun.	3.77	2.42	4.20	69.6	75.0	72.0
Jul.	5.73	4.3	4.67	72.6	76.1	75.2
Aug.	3.59	2.26	4.37	68.4	75.8	73.2
Sep.	2.19	5.66	3.22	68.6	70.9	66.3
Total	50.38	40.41	41.04			

Table 2 ■ Effect of source, time, and rate of N applied on inorganic N concentration in the 0–6 inch soil depth increment in 2003–2004.

N treatments			Nov. 21		Dec. 4		Dec. 19		Mar. 15		Apr. 3	
Source	Time	Rate	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4
		lb/A	*ppm*									
Contr.	—	0	13.3	2.5	13.1	4.6	9.8	3.9	10.1	2.1	5.3	2.7
DAP	Fall	40	26.1	3.3	26.9	4.9	22.4	4.2	15.0	1.5	7.2	3.0
DAP	Fall	80	36.0	5.3	37.5	5.1	37.8	4.4	18.3	1.6	9.1	2.6
MAP	Fall	40	25.2	5.1	25.5	5.4	23.2	6.2	15.4	1.8	8.5	3.1
MAP	Fall	80	30.9	5.5	43.3	7.1	33.5	10.0	22.7	3.7	11.2	3.0
LSD			4.6	2.4	7.4	ns	3.9	3.1	3.6	1.1	2.8	ns
			Apr. 16		May 5		May 25		Jun. 18			
Contr.	—	0	9.5	3.2	14.5	3.8	17.0	2.3	8.9	2.5		
DAP	Fall	40	11.3	3.4	16.5	3.9	19.1	2.9	8.2	2.6		
DAP	Spring	40	16.8	5.9	31.9	3.9	24.4	2.7	10.0	2.9		
DAP	Fall	80	12.8	4.4	18.8	3.5	19.9	3.0	9.1	3.2		
DAP	Spring	80	19.0	14.1	38.2	10.8	51.8	3.5	10.7	2.4		
MAP	Fall	40	11.8	3.5	18.3	2.9	20.1	3.1	8.3	2.8		
MAP	Spring	40	11.2	4.0	30.9	6.8	38.8	2.7	14.4	2.7		
MAP	Fall	80	14.9	3.5	22.2	3.7	22.4	2.0	12.2	2.6		
MAP	Spring	80	11.8	4.4	45.2	13.7	58.6	3.9	16.6	2.6		
LSD			3.5	3.8	6.4	3.5	9.1	0.8	3.4	ns		

Percentage recovery of applied N was estimated by subtracting the total inorganic N in the control plot from the total inorganic N in the treated plots and dividing by the applied N rate. In 2004, recovery of fall-applied N averaged 11%, compared with 40% in the 2005 season. In early May, more than 85% of the spring-applied N was recovered in the soil, irrespective of rate or source of N. The difference in recovery of fall-applied treatments between years was attributed to denitrification that likely occurred in the spring of 2004.

Grain Yield

In the 2004 and 2005 growing seasons, increasing the N rate from 40 to 80 lb N acre^{-1} resulted in increases from 20–25 bushels acre^{-1}, depending on the year. Source of N applied had no impact on grain yield at the end of the season. Fall-applied N reduced yield in 2004 but not in 2005 (Figure 3). We might have expected the opposite; the 2004 spring was characterized by excessively wet soils for extended time periods, which, based on the fact that we found less nitrate in the soil than from spring applications, seemed to have increased denitrification. In 2005, there appeared to be little loss of N and there was little difference in the amount of nitrate in the soil in the spring. Seasonal weather was generally more favorable in 2004, and yields were higher, indicating that both water and N availability might have been less limiting in that environment.

Summary

Source of N (MAP and DAP) had little influence on soil inorganic N concentration or on grain yield. However, time of application and N rate affected both of these parameters. Because N rates as low as 40 or 80 lb

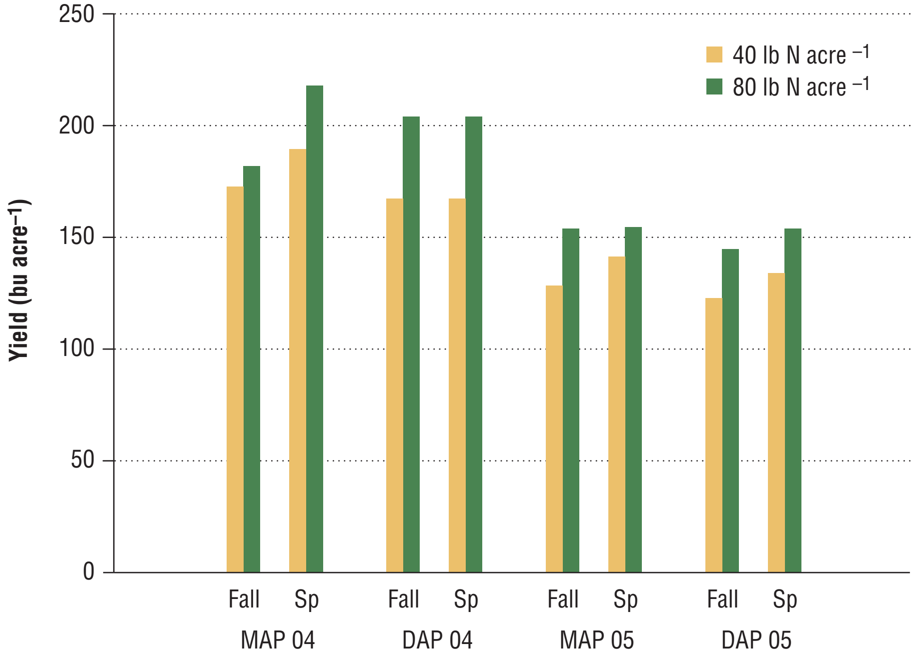

Figure 3 ■ Effect of time, rate, and source of N on corn yield. 2004–2005.

acre^{-1} typically are lower than that needed to optimize yield in Corn Belt soils, we expected that increasing the N rate from 40 to 80 lb acre^{-1} would result in the observed increase in grain yield. In the past, most agronomists have assumed that there should be little if any loss of N associated with fall applied ammoniated phosphates, at least if application is delayed until soil

Table 3 ■ Effect of source, time, and rate of N applied on inorganic N concentration in the 0–6 inch soil depth increment in 2004–2005.

N treatments			Nov. 20		Dec. 1		Mar. 15		Apr. 1	
Source	Time	Rate	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4
		lb/A				*ppm*				
Contr.	—	0	7.2	3.4	4.6	3.8	5.4	2.8	5.7	6.2
DAP	Fall	40	12.7	14.4	9.8	14.5	9.4	4.5	13.0	7.4
DAP	Fall	80	14.8	35.9	11.4	31.1	14.2	21.2	23.9	13.4
MAP	Fall	40	13.9	13.8	9.3	13.8	9.3	5.4	12.8	7.3
MAP	Fall	80	13.0	31.6	10.3	26.1	12.8	16.2	21.7	16.0
LSD			1.9	6.2	0.8	7.0	1.6	4.3	2.4	5.6
			Apr. 18		May 1		May 25		Jun. 15	
Contr.	—	0	10.0	2.9	11.2	5.2	15.4	5.3	11.9	3.8
DAP	Fall	40	17.2	2.8	18.5	6.3	21.5	5.0	15.7	3.6
DAP	Spring	40	19.2	14.5	18.8	10.4	30.8	6.6	27.3	5.7
DAP	Fall	80	30.9	8.7	24.9	6.7	33.6	7.0	22.2	5.2
DAP	Spring	80	20.0	29.4	24.1	23.6	41.9	13.5	35.2	8.9
MAP	Fall	40	18.8	3.4	15.1	7.6	22.0	5.9	20.5	4.6
MAP	Spring	40	17.9	9.5	22.4	12.9	33.4	11.6	28.4	8.5
MAP	Fall	80	29.0	7.0	25.9	7.0	32.6	7.3	19.8	4.4
MAP	Spring	80	20.0	16.5	26.5	28.1	41.9	18.0	38.6	13.1
LSD			3.9	4.0	3.7	5.0	5.1	4.7	7.2	2.4

temperatures are low enough to slow nitrification. Based on our results, we conclude that such an assumption is not accurate in most years. We found that as much as 70 to 80% of fall-applied N as DAP or MAP might be lost in years in which nitrification of the ammonium is completed before the heavy rains and warmer soils in the spring create conditions that can result in denitrification.

Do the results of these studies indicate that farmers who have used fall-applied ammoniated phosphates have likely experienced significant yield loss in many years? The answer is probably not. The yield losses that were recorded in the study were at the low end of the response curve, i.e., 40 or 80 lb N $acre^{-1}$. In farmers' fields, any loss experienced from the use of fall-applied MAP or DAP would reduce N supply at the higher, less N responsive portion of the N response curve, where some loss in N supply would be expected to have minimal impact on yield. To the extent that excessive spring moisture, which results in denitrification, is followed by good soil moisture throughout most of the rest of the growing season, more N released from the soil in such favorable conditions might well compensate in part for some of the N that was lost.

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Resistance to Soybean Cyst Nematode Resistance

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There is a lot of resistance out there—and not just resistance to soybean cyst nematode (SCN). There is a lot of resistance to using SCN-resistant soybean varieties. SCN-resistant varieties earned a bad reputation early by not providing yields acceptable for general use, that is, for planting in areas that did not have a severe SCN problem. That is no longer the case, as we can demonstrate using data from the Illinois Soybean Variety Trials (SVT). Average yields of all susceptible varieties (All S), all resistant varieties (All R), the top 10 susceptible varieties (Top 10 S), and the top 10 resistant varieties (Top 10 R) are presented in figures 1 through 5. The SCN egg count for each location is presented in Table 1.

Using SCN-resistant varieties on a regular basis

No one suggests that SCN-resistant varieties be planted all the time in every soybean field. Having said this, though, remember that SCN is the primary yield-reducing pathogen of soybean in Illinois, and SCN can be found in more than 8 of 10 soybean fields. Based on data from research plots and the SVT, average yield losses caused by SCN ranged from 4% to 12% in 2006, with losses in individual fields reaching 35%. For the state, SCN cost us between $104.3 million and $312.9 million. It may well be that the actual losses were higher, due to the interactions between SCN and other diseases, but we have no data to support an estimate.

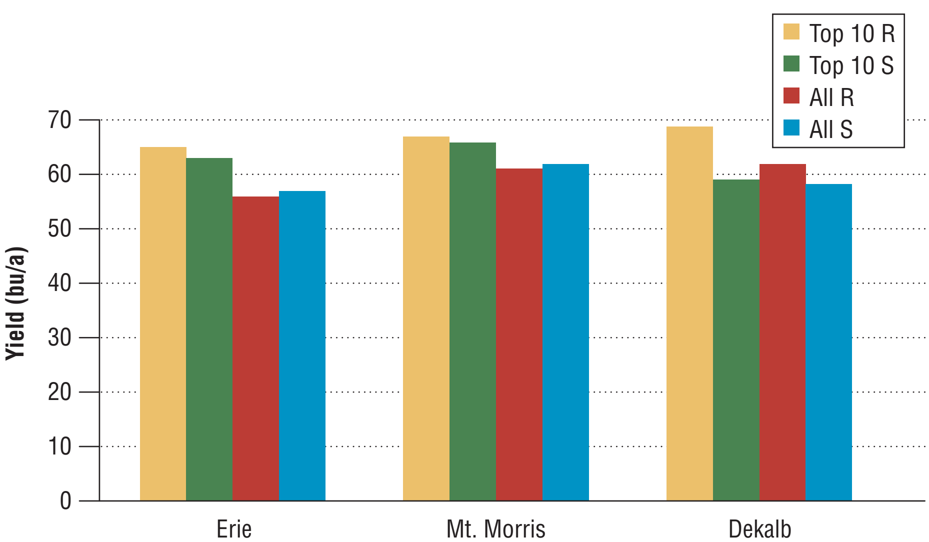

Figure 1 ■ 2006 soybean variety trials, region 1.

Table 1 ■ SCN eggs counts for 2006 Illinois Soybean Variety Trials locations, sampled in August. *(Please note that yield loss is NOT related to SCN egg counts in August. For predictive purposes, sampling should be done in the fall or spring preceding soybean planting. These data are presented simply to show the presence of SCN).*

Location	Eggs/100 cm^3 soil
Belleville	0
Brownstown	40
Elkville (Carbondale)	960
Dekalb	5,120
Dwight	2,480
Erie	8,000
Goodfield	1,080
Harrisburg	120
Monmouth	1,440
Mt. Morris	320
New Berlin	2,560
Perry	280
Urbana	3,040

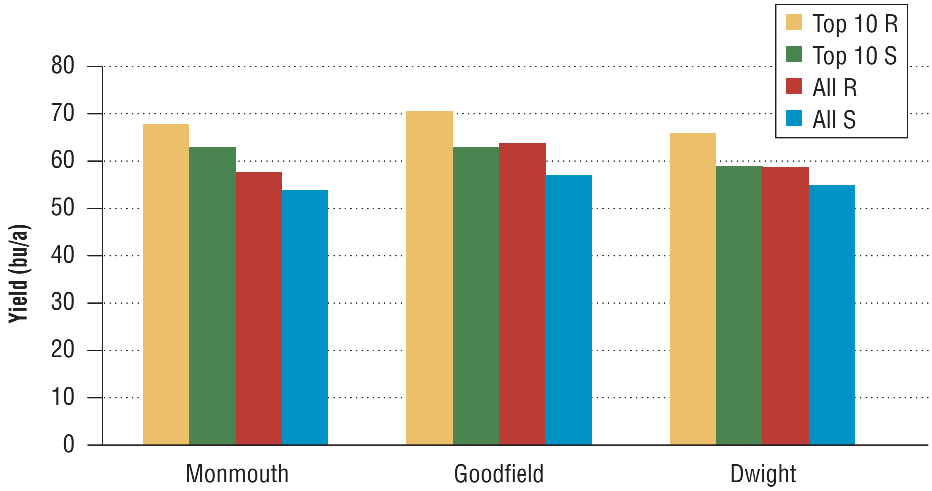

Figure 2 ■ 2006 soybean variety trials, region 2.

The least you can do to minimize losses to SCN is to know two simple things:

- the population density (egg count) in the field, and
- the yield potential of the resistant varieties available.

Because this information is readily accessible, and because SCN management with resistant varieties is not costly, producing high soybean yields in SCN-infested fields is an achievable goal. Remember that the threshold for using SCN-resistant varieties is *one cyst*.

Using SCN-resistant varieties in "problem" fields

In some SCN-infested soybean fields, using a SCN-resistant variety may not be enough because the SCN population may have adapted to resistance. For these fields, you need an additional piece of information—SCN Type. (The Illinois SCN Type test has been discussed at the *Classics* before; for review,

Table 2 ■ General recommendations based on SCN egg counts and SCN Types. *(Please note that an egg count of 5,000 is high. Yield losses are measurable at lower counts).*

SCN eggs/100 cm^3 soil	SCN Type	Recommendation
up to 5,000	1	Use a high-yield SCN-resistant variety with resistance from PI 88788.
over 5,000	1	Nonhost (corn) for 1 additional year, followed by a high-yield resistant variety with resistance from PI 88788.
up to 5,000	2 or 1.2	Use a high-yield highly resistant variety that is different from any that has been planted in the field before.
over 5,000	2 or 1.2	Nonhost (corn) for 1 additional year, followed by a SCN-resistant variety with resistance from PI 437654 (also called Hartwig or CystX®).
up to 5,000	4	Nonhost (corn) until the SCN egg count is reduced to the detection limit (very low), then use a high-yield SCN-resistant variety with resistance from PI88788.
over 5,000	4	Nonhost (corn) for several years, or a nematicide.

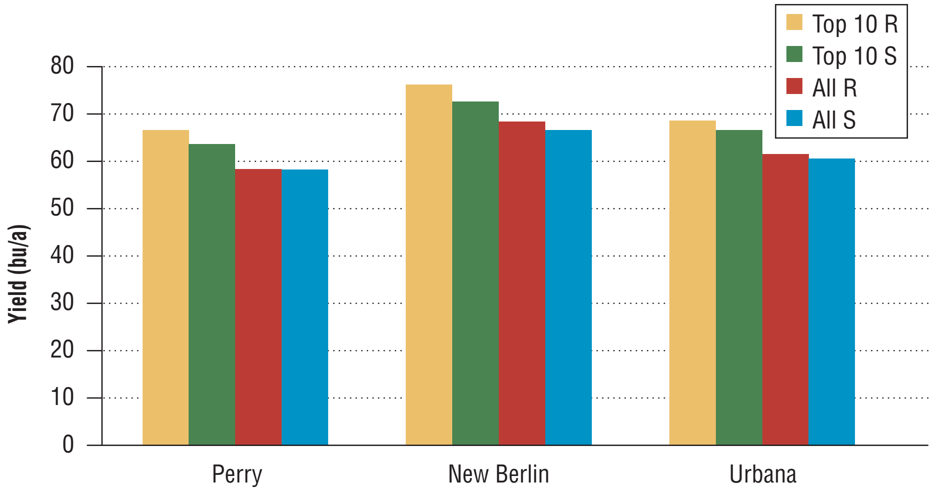

Figure 3 ■ 2006 soybean variety trials, region 3.

go to the SCN web site accessible through the Department of Crop Sciences Web site.) The SCN Type test can take up to 3 months to complete because it is a greenhouse test, so plan ahead for this option.

Based on experience—not data—we have developed a set of general recommendations for using SCN-resistant varieties in fields where some of the nematodes have adapted to resistance (Table 2). These recommendations must be considered in light of other characteristics unique to a particular field.

Reassess the SCN population in each field once every 4 to 6 years with at least an egg count. The number of SCN eggs and the field history will tell you whether further steps should be taken.

Conclusions

Although we have nearly 50 years of experience with SCN in Illinois, yield losses due to the nematode do not seem to be decreasing as much as we would like. The proper use of SCN-resistant varieties will preserve their effectiveness for the future. Soybean producers should be encouraged to stop being resistant to SCN-resistance and enjoy the benefits of resistant varieties—higher yields and lower SCN egg counts.

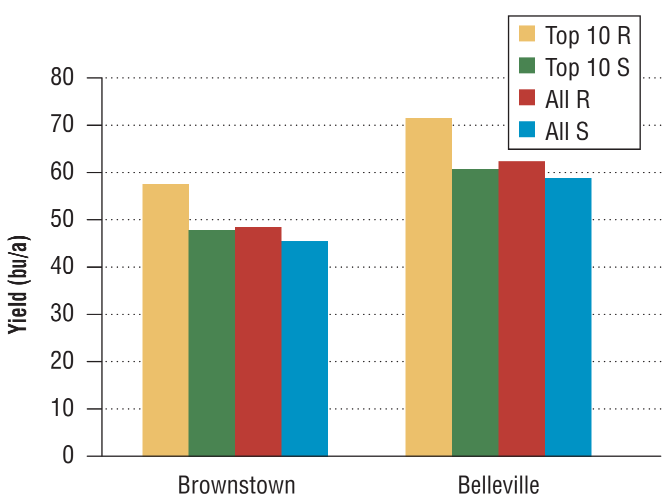

Figure 4 ■ 2006 soybean variety trials, region 4.

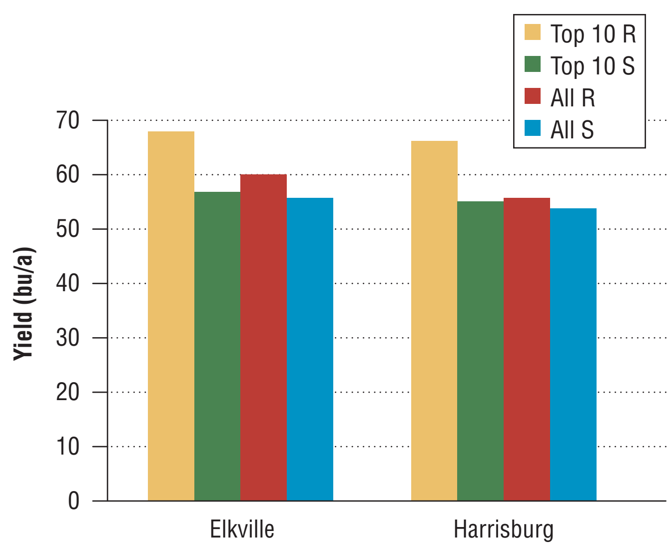

Figure 5 ■ 2006 soybean variety trials, region 5.

Preparing for Soybean Aphids in 2007

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Pest management in soybeans will be a major focus for soybean producers in Illinois and elsewhere in the Midwest in 2007. The primary concern likely will be whether Asian soybean rust will show up in soybean fields. Many people also will keep their eyes on weed populations in Roundup Ready soybeans. Last, but not necessarily least, based on information gathered through 2006, soybean aphids should be included in pest management plans for 2007.

Since 2000 when soybean aphids were first discovered in North America, populations of soybean aphids have reached outbreak levels (i.e., widespread economic infestations) in the odd-numbered years 2001, 2003, and 2005. The most significant outbreak occurred in many states in the Midwest and in Canada in 2003, although less widespread outbreaks in 2001 and 2005 had noteworthy economic impacts in affected areas. Much more localized outbreaks of soybean aphids have occurred in the even-numbered years, but the economic impact of soybean aphids during those years was limited.

So, what's in store for us in 2007? Hopefully the discussion in this paper will shed some light on the question. Regardless, soybean producers should be prepared to manage soybean aphids in 2007.

Do We Have the Ability to Forecast Soybean Aphid Populations?

Based upon his extensive knowledge of aphids, David Voegtlin, entomologist with the Illinois Natural History Survey, suggested the use of suction traps to sample for winged soybean aphids. Suction traps have been used for decades to sample for winged aphids in other areas of the world. In 2001, David was able to garner funding to support the placement of suction traps at seven locations in Illinois—Brownstown, DeKalb, Dixon Springs, Freeport, Monmouth, Perry, and Urbana. The suction traps (Figure 1) are ~25 ft PVC pipes placed vertically and secured to the ground. A fan at the base of the trap draws air down through the pipe, directing the insects captured into a collection vial. The traps, which are usually operated only during daylight, sample populations of flying aphids traveling in the vicinity of traps.

Since 2002, suction traps have been established at two more locations in Illinois—Joliet and Metamora (formerly Eureka)—and in several locations in other states—Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, South Dakota, and Wisconsin. Data gathered from this "suction trap network" can be viewed on the North Central IPM Center Web site at http://www.ncipmc.org/traps.

Initially we entomologists had hoped that captures of soybean aphids flying from their overwintering host, buckthorn, to soybeans in the spring would provide some indication of the onset, and possibly intensity, of infestations in soybeans. However, because numbers of soybean aphids in the spring are relatively low (compared with their numbers later in the season), the suction traps captured very few, if any, soybean aphids in the spring. Somewhat unexpectedly we learned that captures of soybean aphids flying from soybeans to buckthorn in the fall might provide some insight about the potential for infestations in soybeans the following year. The numbers of winged soybean aphids captured in suction traps in the fall typically have been large in the year preceding an outbreak.

What Did We Learn in 2006?

With the exception of a localized outbreak in South and North Dakota and part of Minnesota, densities of soybean aphids were subeconomic throughout the Midwest in 2006. Regardless, sampling for soybean aphids in soybean fields throughout a growing season provides valuable information about the population dynamics of this invasive species whether their numbers are small or large. With funding from the Illinois Soybean Association (ISA) and in cooperation with entomologists at Purdue University and the University of Minnesota, we initiated a sampling program for soybean aphids in soybean fields in Illinois in 2006. Similar sampling programs were initiated in Indiana and Minnesota. The ultimate goal is to correlate in-field densities of soybean aphids during the season with numbers of winged aphids captured in nearby suction traps. If a correlation exists, we may be able to refine our forecasts of infestations of soybean aphids.

We began sampling for soybean aphids in mid-June, 2006, in 26 soybean fields. Ten of the fields were located in Woodford County and ten of the fields were in Stephenson County. The other six fields were roughly along a transect from Woodford County to Stephenson County, with one field in each of the following counties—Bureau, Lee, Marshall, Ogle, Putnam, and Whiteside. Soybean aphids were counted on 20 plants in each of the fields approximately once per week until mid-September. Surveyors recorded the stage of soybean development on each sampling date and noted the presence or absence of natural enemies.

Densities of soybean aphids in all 26 fields sampled remained very small through July 2006, but the numbers of soybean aphids began to increase noticeably in August and September. With only one exception (field 1 [Marshall County] in the transect), the average density of soybean aphids was below the economic threshold (250 aphids per plant) in all fields all season long. Interestingly, the numbers of soybean aphids in field 1 in the transect increased from late August to mid-September from 100 aphids per plant to 255 and 302 aphids per plant on 7 and 18 September, respectively (Figure 2). With occasional exceptions, densities of soybean aphids were greater in Stephenson County than in the transect counties or in Woodford County.

Also worthy of note was the general lack of natural enemies (e.g., predators such as the multicolored Asian lady beetle) in almost all fields throughout the season.

As we concluded sampling for soybean aphids in soybean fields, we turned our attention to the numbers of soybean aphids captured in suction traps.

Figure 1 ■ Suction trap used to monitor for winged soybean aphids.

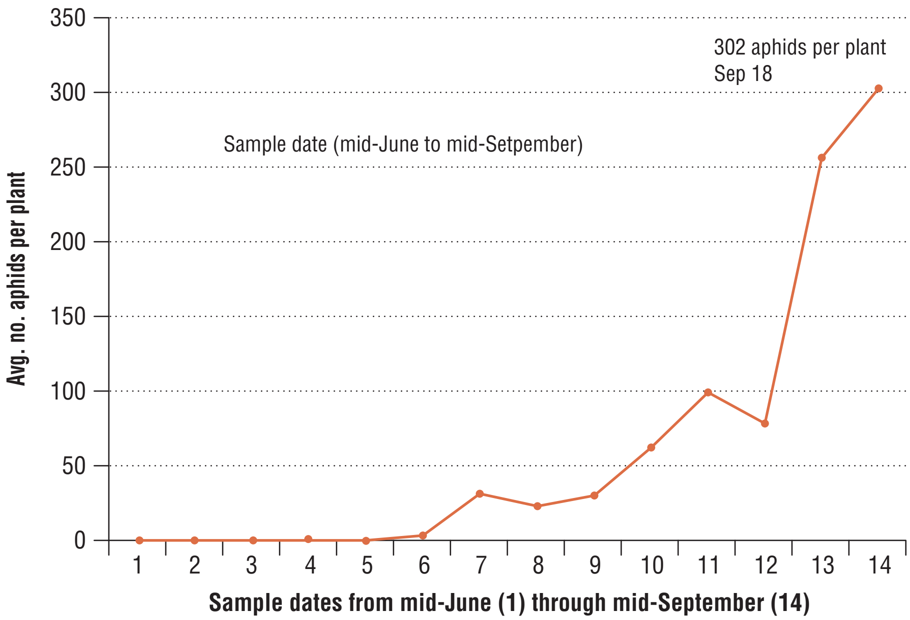

Figure 2 ■ Densities of soybean aphids in transect field 1, Marshall County, Illinois, 2006.

With only a couple of exceptions, the numbers of winged soybean aphids captured in nine suction traps in Illinois from mid-September through October 2006 were noticeably greater than the numbers of winged soybean aphids captured in suction traps during any other year of their operation, including 2002, the year preceding the widespread outbreak in 2003. The numbers of winged soybean aphids captured in suction traps in Indiana in the fall of 2006 were even larger than the captures in Illinois.

To end the season, David Voegtlin and Bob O'Neil, entomologist at Purdue University, began searching for soybean aphids and their eggs on buckthorn plants in October and November 2006. The numbers of soybean aphid eggs they found on buckthorn were the largest they had ever observed.

What Will Happen with Soybean Aphids in 2007?

The relatively low numbers of soybean aphid predators in 2006, the unprecedented numbers of winged soybean aphids captured in suction traps in 2006, and the numbers of soybean aphid eggs overwintering on buckthorn (2006–2007) all suggest the potential for a significant outbreak of soybean aphids in 2007. However, there are many unknowns regarding our ability to forecast soybean aphid populations based upon current information:

- The percentage of soybean aphid eggs that survive over the winter cannot be determined at this time. Some eggs undoubtedly will perish, but we currently do not have enough information to assess percentage survival.
- *Orius insidiosus*, the insidious flower bug, is an important early-season predator of many arthropods that appear in soybean fields in the spring. *Orius* feeds on arthropods such as thrips before soybean aphids arrive, after which *Orius* begins preying on the aphids. Entomologists at Purdue University have determined that the presence of large numbers of insidious flower bugs in the spring can slow down the population growth of soybean aphids and delay the onset of economically threatening numbers.
- The multicolored Asian lady beetle is an important predator of soybean aphids when the numbers of aphids begin to increase during the summer. However, there typically is a lag time between the buildup of soybean aphid numbers and the buildup of numbers of lady beetles.
- The real wild card may be temperatures during the growing season in 2007. The optimal temperature for soybean aphid maturation is 80°F. At temperatures greater than 86°F, development of soybean aphid populations slows down. At temperatures greater than 90°F, mortality of soybean aphids occurs. Consequently, if temperatures during the 2007

growing season are relatively cool, the potential for a soybean aphid outbreak may be realized. If temperatures are relatively hot, economically threatening populations of soybean aphids may not develop.

Managing Soybean Aphids in 2007—Do's and Don'ts

Before soybean seed is planted, some growers may want to consider planting seed that has been treated with a neonicotinoid insecticide (e.g., Cruiser, Gaucho). The labels for both of these products indicate suppression of soybean aphid populations early in the season. The hypothesis is that suppression of soybean aphid populations will delay the onset and eventual buildup of threatening numbers. However, results from insecticide efficacy trials in several Midwestern states over the years have not verified this hypothesis consistently.

Regardless of whether soybean seed is treated with a neonicotinoid insecticide, the key to managing soybean aphids during the summer is to begin scouting regularly (at least weekly) early in the season (mid-June to mid-July). The frequency of scouting should increase when numbers of aphids begin to increase and soybeans are in susceptible reproductive growth stages (R1–R5). The numbers of soybean aphids should be counted on a representative sample of soybean plants and expressed as an average number of aphids per plant. The widely accepted economic threshold for soybean aphids is 250 aphids per plant, with at least 80% of the plants infested and few natural enemies observed. This economic threshold is relatively conservative; the economic injury level (cost of control = value of yield loss) is thought to be 1,000 aphids per plant.

If numbers of soybean aphids reach or exceed the economic threshold in a soybean field, treatment with an insecticide is warranted. Several foliar-applied insecticides are very effective for controlling soybean aphids. A "snapshot" of the efficacy of selected insecticides in an experiment in Whiteside County in 2006 (Figure 3) shows that the numbers of soybean aphids in plots treated with Asana XL, Baythroid 2, Dimethoate 4EC, Lorsban 4E, and Warrior 1CS were smaller than the numbers of soybean aphids in the untreated check 22 days after the insecticides were applied. The numbers of soybean aphids in the plots treated with Dimethoate 4EC, Lorsban 4E, and Warrior 1CS were significantly smaller than the numbers of soybean aphids in the untreated check. Average yields from these treatments were not statistically different (Figure 4).

A few don'ts regarding management of soybean aphids in 2007 also are worth noting. Because of the potentially negative impact on populations of *Orius insidiosus* in soybeans early in the season, we strongly discourage tank-mixing

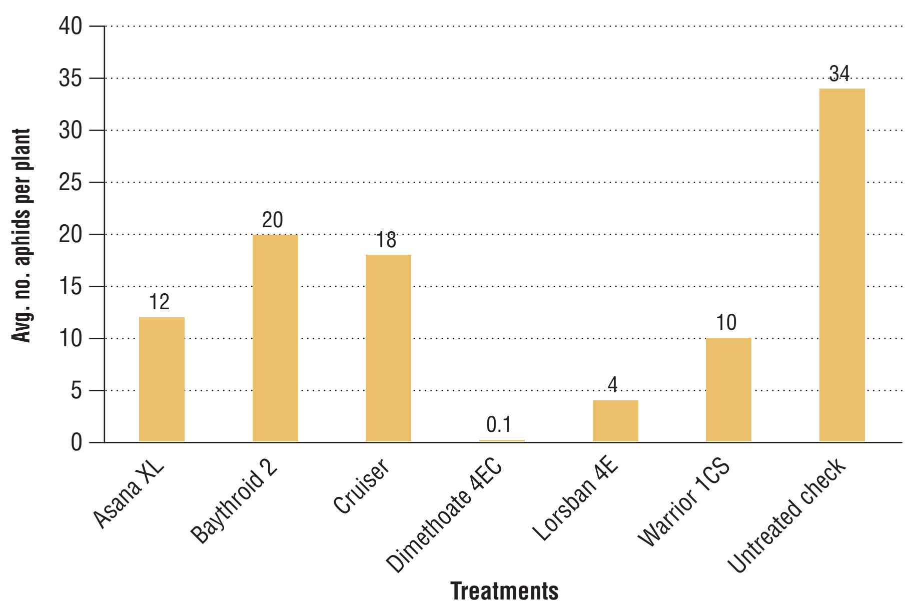

Figure 3 ■ Efficacy of insecticides against soybean aphids 22 days after treatment, Whiteside County, Illinois, 2006.

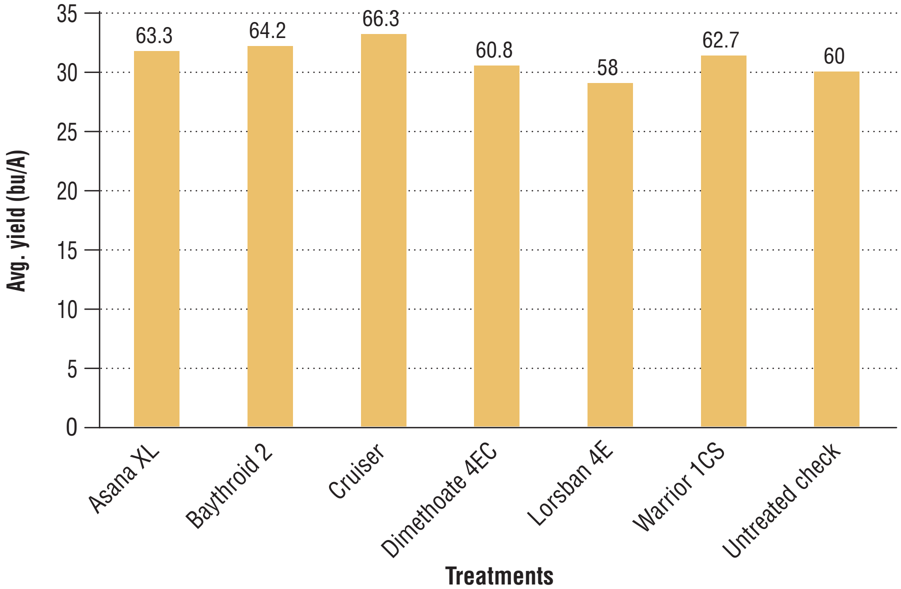

Figure 4 ■ Yields from plots in a soybean aphid insecticide efficacy trial, Whiteside County, Illinois, 2006.

an insecticide with a herbicide in June. Insecticides applied in June will eliminate *Orius* and will have little impact on soybean aphid populations. In addition, we discourage application of a fungicide or a fungicide + insecticide tank mix later in the summer if neither the fungicide nor the insecticide is warranted. Although there have been claims of plant health benefits and yield improvements associated with the application of a fungicide + insecticide to soybeans, the data associated with such applications are inconsistent. Additionally, application of a pesticide when the target pest is not present is in conflict with some principles of pest management. Finally, there is some evidence suggesting that fungal organisms that help regulate populations of soybean aphids are killed by fungicides.

Is There Anything New on the Horizon for Management of Soybean Aphids?

Efforts to import specific natural enemies (i.e., parasitoids) from Asia and release them in North America are underway. However, there are many unknowns associated with this classical biological control approach, so the benefits of such a program probably won't be realized for a few years. The contribution of biological control of soybean aphids will be discussed during a short course delivered in many north central states on March 6, 2007, via distance education technology. For more information about this short course, visit the Soybean Aphid Biological Control Web site, http://www.entomology.wisc.edu/sabc/resources.htm. The short course is sponsored by the North Central Soybean Research Program (NCSRP).

Fortunately there are near-future expectations for soybean varieties with resistance to soybean aphids. With support from both the ISA and the NCSRP, several entomologists in the Midwest established experiments to determine the efficacy of some resistant varieties developed at land-grant universities, including the University of Illinois (Brian Diers, Department of Crop Sciences, and Glenn Hartman, USDA-ARS). The results from the experiment established in Whiteside County, Illinois, in 2006 suggest that at least two varieties developed at the University of Illinois show considerable promise for further development into commercially available varieties. There also was limited evidence from the experiment suggesting that the addition of Cruiser to the seeds of resistant varieties further suppressed soybean aphids.

Conclusion

Soybean producers in Illinois should be prepared for economic infestations of soybean aphids in 2007. If an outbreak begins to occur, we'll see it develop first in northern states and northern counties in Illinois. Soybean producers in central and southern counties in Illinois should be able to "see it coming" by keeping apprized of the situation through publications such as *the Bulletin* (http://www.ipm.uiuc.edu/bulletin), the weekly newsletter published by the University of Illinois. Entomologists at other land-grant universities in the Midwest also publish articles in their weekly newsletters. A soybean aphid outbreak in 2007 is not guaranteed because extenuating circumstances (discussed previously) may dictate otherwise. Regardless, vigilance is the key, and we advocate respect for ecological balance in soybean fields.

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Waterhemp—What have we learned?

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Sometimes to have a better idea of where we're going, it helps to step back and review where we've come from. During the early days of January 1994, the Illinois Agricultural Pesticides Conference convened to address the most relevant and contentious issues facing production agriculture in Illinois. Among the topics presented was a discussion by Dr. Loyd Wax, a weed scientist with the USDA/ARS in Urbana, of the expanding problem of herbicide-resistant weeds. Two significant quotes from Dr. Wax's proceeding paper are reproduced here; the first provides a reference to the status of herbicide-resistant weeds in Illinois during the early years of the 1990s, whereas the second provides a then-ominous, but now-obvious mention of a weed species soon to become more problematic for Illinois farmers.

First, the statement about the status of herbicide-resistant weeds in Illinois: "Herbicide resistant weeds, while becoming a significant problem worldwide and in some areas of the United States, are minimal at this time in Illinois. However, there is potential for development of resistant weed biotypes with several classes of herbicides." By the end of 1993, researchers in Illinois had documented herbicide resistance in only three weed species biotypes (common lambsquarters, smooth pigweed, kochia), and resistance was to only one herbicide family (triazines). A decade later, the list of herbicide-resistant weed biotypes in Illinois had grown to include 10 species (eight broadleaf and two grass species), and resistance had expanded to include four herbicide families (triazines, ALS inhibitors, PPO inhibitors, ACCase inhibitors).

Next, the forward-looking statement (again, published in 1994) of problems and challenges soon to be faced by Illinois farmers: "To date, we have not documented any weed biotypes in Illinois that are resistant to ALS inhibitors. In other greenhouse work, and based on field observations, we have identified substantial differences in tolerance of the various pigweed species, including the water hemps, to postemergence applications of the herbicides Classic and Pursuit." This might have been one of the earliest references to the forthcoming problems with waterhemp, a weed species unfamiliar to and unrecognized by many Illinois farmers in1994. Fast-forward 12 years to 2006, and this once obscure weed species is considered the most problematic broadleaf weed species with which weed control practitioners in Illinois (and many other states) must contend.

Although a species indigenous to Illinois, waterhemp was not considered much of a problem weed species in agronomic crops until it began to spread across the state beginning in the late 1980s or early 1990s. Today, waterhemp populations continue to infest additional acres of farmland in central and northern Illinois annually, aided by several adaptations (some of which are unique to this weed species) that allow the species to thrive in contemporary agronomic crop production systems. Waterhemp has become perhaps the most recognized example of how a weed species is able to adapt to man-made "environments". One particularly important adaptation that has allowed waterhemp to flourish is its ability to thwart attempts at control with herbicides.

Figure 1 ■ Waterhemp has become the most problematic broadleaf weed species in many Illinois soybean and corn fields.

The story of waterhemp management in agronomic crops has been anything but static, and even today the story continues to be written. No other weed species in Illinois has demonstrated more unique instances of herbicide resistance than waterhemp. In 1994, Dr. Wax alluded to the forthcoming possibility of selecting waterhemp biotypes resistant to ALS-inhibiting herbicides. By 2002, we reported how pervasive herbicide resistance in waterhemp had become across Illinois. Over a two-year period, we made approximately 60 waterhemp collections from 30 counties to examine the extent of herbicide resistance in the Illinois waterhemp population. We randomly selected individual female waterhemp plants from corn and soybean fields (we had no knowledge of herbicide use history for any field we sampled), grew seedling plants in the greenhouse, and treated them with a triazine herbicide (atrazine) or an imidazolinone herbicide (imazethapyr).

Greenhouse results indicated approximately 25 percent of the samples produced progeny resistant to atrazine, whereas approximately 90 percent of the populations demonstrated resistance to ALS-inhibiting herbicides. Within the atrazine-resistant populations, there seemed to be at least two different mechanisms of resistance, along with variation in patterns of cross-resistance to other triazine herbicides and inheritance of the resistance trait(s). Similarly, within the ALS-inhibitor resistant populations, there were different mechanisms of resistance that affected patterns of cross-resistance to the various ALS-inhibiting herbicides. Intermingled with their reports of herbicide-resistance screening research, Illinois weed scientists also reported the confirmation of a waterhemp biotype from Bond county that was resistant to both ALS-inhibiting herbicides and triazine herbicides, the inaugural report of multiple herbicide resistance in waterhemp. But the story continued to evolve.

Weed control practitioners know there are only four active ingredients for postemergence waterhemp control in soybean, and three of these belong to one chemical family. The diphenylether herbicides (PPO-inhibitors) acifluorfen (Ultra Blazer), fomesafen (Flexstar), and lactofen (Cobra/Phoenix) were once used extensively for waterhemp control in soybean, until being largely displaced by glyphosate. These products were often applied alone to control waterhemp, but frequently they were used as tank-mix partners with one or more of the postemergence ALS-inhibiting broadleaf herbicides. For many years, diphenylether herbicides were the primary weapons against waterhemp in soybean, and we learned that the most consistent control of waterhemp with these herbicides was achieved when applications were made to plants less than 6 inches tall. However, during the 2001 growing season, several reports from around Illinois indicated that waterhemp control was much less than expected following applications of diphenylether herbicides. We began investigating a population of waterhemp from western Illinois that was not controlled by postemergence applications of diphenylether herbicides during the 2001 growing season, nor with lactofen (Cobra at 20 fluid ounces plus crop oil concentrate) under greenhouse conditions. Given these observations from the field and our results from greenhouse research, we began experiments to determine how this waterhemp population responded to various soil-applied and postemergence herbicides under field conditions.

It soon became obvious that this waterhemp biotype demonstrated resistance to various PPO-inhibiting herbicides. After several years of extensive field, greenhouse, and laboratory research, in 2005 we reported the confirmation that this waterhemp biotype was resistant to three herbicide families: ALS inhibitors, PPO inhibitors, and triazines. This was the first report of three-way herbicide resistance in a summer annual weed species in the United States. Additionally, we recently published the results of research that identified a unique mechanism of resistance that this waterhemp biotype uses to survive exposure to PPO herbicides. And so, the story of waterhemp management in agronomic crop continues to evolve.

The fourth postemergence herbicide option for waterhemp control in soybean is glyphosate. Glyphosate has been a very effective herbicide against waterhemp since its in-crop utilization rapidly escalated following the commercialization and adoption of glyphosate-resistant soybean varieties. Many soybean farmers rely exclusively or near exclusively on glyphosate for waterhemp control in lieu of a more integrated waterhemp management approach. For many years, glyphosate seemed to be the remedy for all of the problems and challenges presented by waterhemp. However, during the past several growing seasons, we have received an increasing number of reports of glyphosate having failed to provide adequate control of waterhemp and a few other weed species. Other states have reported similar observations. Although lack of control does not always satisfy the criteria for a weed being designated “resistant” to glyphosate, lack of control for whatever reason presents a problem. The story, however, continues to unfold.

The moniker “glyphosate-resistant” now has been attached to a waterhemp population. Weed scientists from the University of Missouri reported that at least one waterhemp population has consistently survived either in-field (Table 1) or greenhouse applications of glyphosate, and this resistance characteristic is successfully passed on to succeeding generations. Not surprising, the field from which this population was identified had received numerous applications of glyphosate since 1996. In essence, what some people had considered “unlikely to occur” or “less likely to occur than resistance

Table 1 ■ Influence of preemergence and postemergence programs on glyphosate-resistant waterhemp control three months after planting (University of Missouri[a])

Preemergence treatments	Postemergence treatments[b]					
	Phoenix	Ultra Blazer	Roundup Original Max	Roundup Original Max + Phoenix	Roundup Original Max + Ultra Blazer	None
	% Waterhemp control 3 months after planting					
Valor	68	81	66	86	85	58
Spartan	89	94	91	95	95	80
IntRRo	76	85	73	86	88	45
Boundary	88	88	81	95	94	80
None	23	23	0	5	3	0
LSD (0.05)	12					

[a] Data courtesy Dr. Kevin Bradley, University of Missouri
[b] AMS added to all Roundup treatments; NIS added to Phoenix and Ultra Blazer treatments when applied alone.

to other herbicide families" now is reality. The occurrence of glyphosate-resistant waterhemp in Missouri begs the question: "Can it happen in Illinois?" Although we have yet to confirm any glyphosate-resistant biotypes of waterhemp from Illinois, we have no evidence to suggest that glyphosate-resistant waterhemp will not occur in Illinois.

Will the incidence of glyphosate-resistant waterhemp be sufficient to persuade changes to weed management programs in Illinois, especially in soybean production? Only time will provide an accurate answer. However, we continue to stress several points related to glyphosate-resistant weeds and glyphosate stewardship:

1. A selection pressure for herbicide-resistant weeds occurs each time the same herbicide is applied to a particular field.
2. Increased adoption of glyphosate-resistant corn hybrids, with a concomitant use of glyphosate to the exclusion of other weed management tools, will speed the selection of glyphosate-resistant weeds.
3. Rotating herbicides (sites of action) or tank-mixing herbicides will help slow the selection of glyphosate-resistant weeds but is unlikely to completely prevent their selection. Keep in mind that it's nearly impossible to make blanket statements about how effective a particular alternative herbicide or tank-mix partner will be in slowing the selection of glyphosate-resistant weeds.
4. Stewardship of glyphosate herbicide is an easy concept to discuss but more difficult to implement. Different herbicide manufacturers often have different messages about stewardship, but it may be wise to ask why a particular manufacturer seems to be concerned with stewardship of glyphosate.

In summary, this historical perspective of waterhemp's notorious expansion across Illinois has been provided to illustrate an important point. Waterhemp is a very diverse plant species, as is evidenced by the selection of biotypes resistant to ALS-inhibitors, triazine herbicides, PPO-inhibitors, and glyphosate. It's become somewhat "old news" that much of the Illinois waterhemp population is resistant to ALS-inhibiting herbicides or that many populations are resistant to triazine herbicides. Resistance to PPO-inhibiting herbicides is perhaps more widespread in Illinois than many people assume, but the near-ubiquitous utilization of glyphosate on Illinois soybean acres likely has masked the full extent of PPO-resistant waterhemp. The preponderance of evidence suggests it is only a matter of time until glyphosate-resistant weeds (waterhemp, in particular) begin to occupy places in the Illinois agronomic landscape.

In years past, many new herbicide active ingredients were commercialized regularly for the soybean market, but that has changed. It is unlikely that many (if any) new active ingredients with good postemergence efficacy on waterhemp will be introduced into the soybean market during the next few years. If the effectiveness of currently available postemergence soybean herbicides for waterhemp control continues to decline, waterhemp management may reach a new level of difficulty; there may not be any new solutions that come to market, at least for the foreseeable future.

One way to reduce the selection of herbicide-resistant waterhemp biotypes is to integrate multiple control tactics, such as use of soil-applied and postemergence herbicides, mechanical cultivation, or all three. Research conducted by weed scientists at the University of Illinois in the mid-1990s indicated that many soil-applied corn and soybean herbicides demonstrated good waterhemp control, but few consistently provided season-long waterhemp control. Our recommendation has been, and will continue to be, that the most consistent programs for waterhemp management include soil-applied and postemergence herbicides, along with mechanical cultivation where feasible. Experience has shown that continued heavy reliance on a single herbicide active ingredient, to the exclusion of other management tactics, ultimately speeds the selection of herbicide-resistant weeds. Glyphosate will not be an exception.

The Fungi Among Us: Why the Rot, and Where's the Rust?

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As we wrapped up the 2006 growing season, the soybean disease picture for 2006 was probably best characterized as average, at least until October. No sooner had we wrapped up and begun writing annual summary reports than the situation exploded. As I have said before, fungi just don't care about what we think they should do. They don't care about funding reports or project deadlines; they've got their own agenda. So although I had originally intended to talk about rots such as Phytophthora and the fascination of soybean stem disease, instead let's talk about where's the rust—because it's here (Figure 1).

Soybean rust was positively diagnosed in eight Illinois counties in 2006. It was first confirmed on October 13, 2006, on a sample collected from a soybean research plot at the University of Illinois Dixon Springs Agricultural Research Center in Pope County. University of Illinois Plant Clinic director Nancy Pataky and USDA-ARS soybean plant pathologist Dr. Glen Hartman observed the sample and sent it to the national mycologist at USDA-ARS in Beltsville, Maryland, for positive confirmation and species verification, as indicated by the national protocol for handling of first soybean rust samples in a state. Soybean rust was then confirmed in seven additional counties: Massac, Hardin, White, Alexander, Johnson, Pulaski, and Jefferson.

So as not to test anyone's geography memory too much, for the most part the counties with confirmed soybean rust are the southernmost counties in Illinois. The distribution of rust in Illinois and other states can be seen in season on the national soybean rust Web site (Pest Information Platform for Extension and Education, PIPE), http://www.sbrusa.net. To review what happened in late 2006, select a date, such as November 17, 2006, on the side menu of the site (Figure 2).

Figure 1 ■ Soybean rust pustules erupting on a 2006 leaf sample from southern Illinois, D. Epplin photographer.

Detection of soybean rust in southern Illinois counties in October 2006 was a serious reminder that the disease isn't going to hang out only on the Gulf Coast. Additionally, only one weather event was required to move the pathogen up the Mississippi River Valley, not only to southern Illinois, but also as far north as Lafayette, Indiana.

The finding of soybean rust in southern Illinois was not

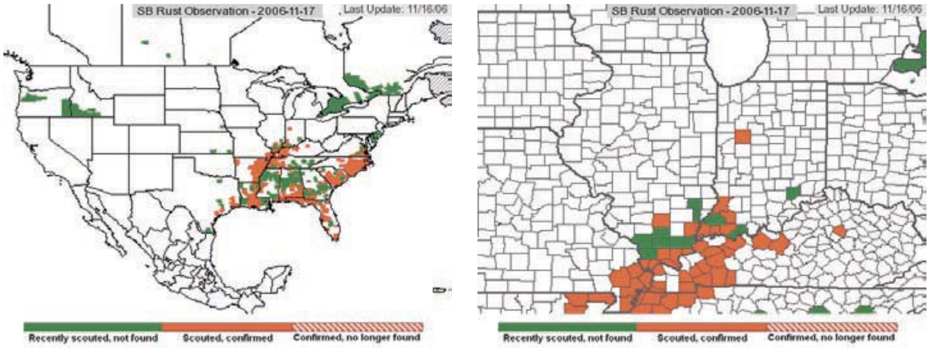

Figure 2 ■ 2006 map of USA counties with positively diagnosed soybean rust infections as reported on the Pest Information Platform for Extension Education (PIPE), www.sbrusa.net

unexpected. In September, spore deposition models indicated the distinct probability of development of soybean rust in Illinois (Figure 3). Infection by soybean rust in Illinois so late in the season had no impact on our 2006 soybean crop. Information that was collected on the extent of this outbreak, however, greatly facilitates research on soybean rust and aids in the refinement of predictive models for soybean rust (Table 1).

Again in 2006, Illinois had sentinel plots throughout the state to aid in the early detection of soybean rust. Thirty-nine sentinel soybean rust plots were established in the state. Most plots were soybean, but kudzu (*Pueraria lobata*), field pea (*Pisum sativum*), dry beans (*Phaseolus vulgaris)*, and mung beans (*Vigna radiata*) also were observed and sampled. Double-cropped soybean sentinel plots also were planted in southern Illinois. Cooperators were the University of Illinois, University of Illinois Extension, and Southern Illinois University. Plots were located throughout Illinois on research stations and on commercial and private fields. Plots were sampled weekly during the season and analyzed by personnel at the University of Illinois Plant Clinic.

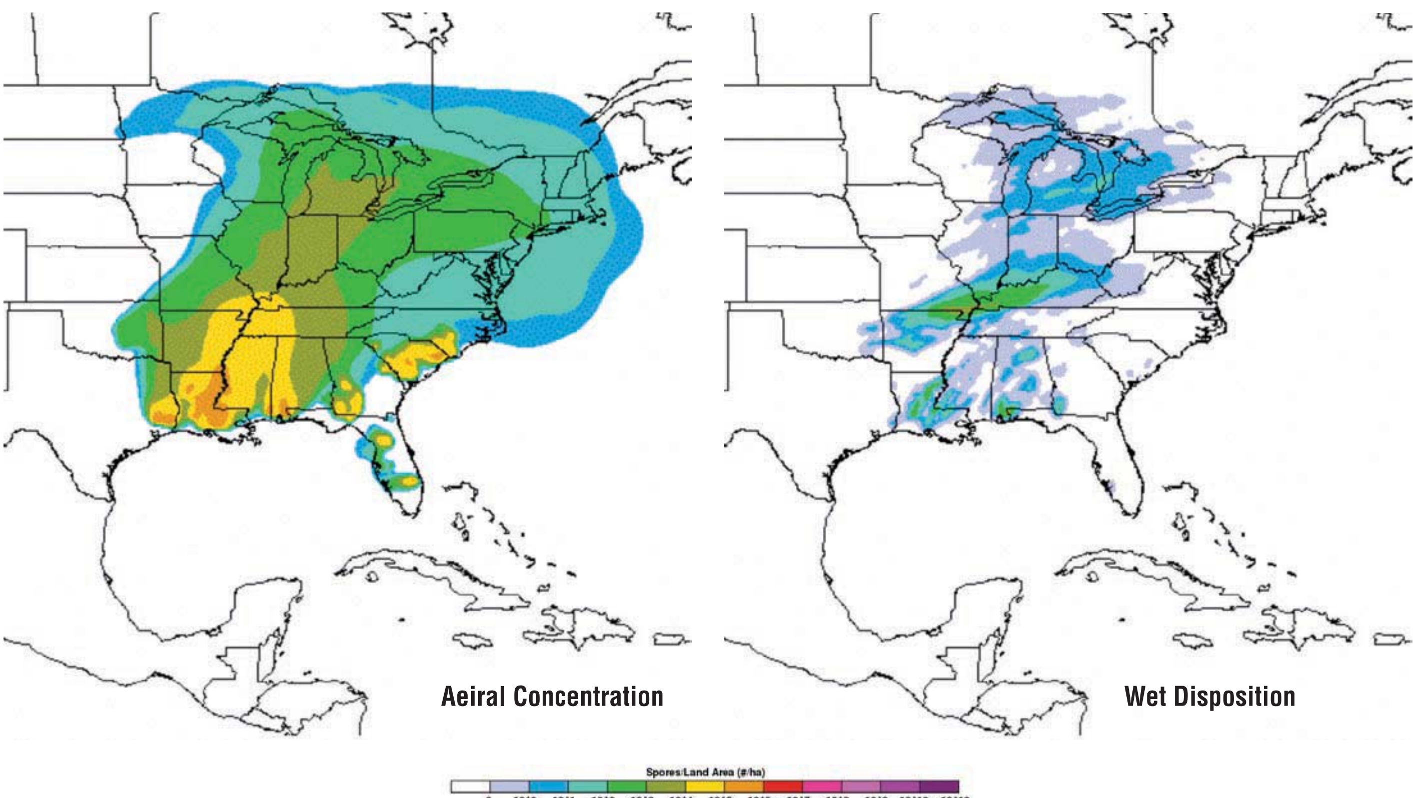

Figure 3 ■ Out put of Aerial rust spore concentration and leaf wet deposition models September 23, 2006, Integrated Aerobiology Modeling System, CSREES APHIS.

Table 1 ■ Rust survey from Illinois counties, starting with samples taken from 10–22 October, 2006.

Source G. Hartman, Proceedings of the 2007 Illinois Crop Protection Technology Conference.

County	No. of fields sampled[1]	Percentage of fields with rust[2]	No. of leaves sampled[2]	No. of leaves with rust[4]	Percentage of leaves with rust[5]
Alexander	7	43	279	2	0.7
Edwards	2	0	59	0	0
Franklin	1	0	68	0	0
Gallatin	7	0	181	0	0
Hardin	2	100	61	15	25
Hamilton	1	0	24	0	0
Jackson	1	0	45	0	0
Jasper	2	0	89	0	0
Jefferson	3	33	50	11	22
Johnson	9	78	238	14	6
Knox	1	0	45	0	0
Madison	5	0	100	0	0
Massac	7	14	216	15	7
Pope	6	50	119	28	24
Pulaski	5	20	179	6	3
Saline	1	0	25	0	0
Union	2	0	78	0	0
White	5	20	148	1	0.7
Williamson	3	0	172	0	0
Totals/Means[6]	70	30	2176	93	4

[1] Two of these fields represent kudzu sites (Madison and Massac Counties), one represents a clover (Jasper County) site, and two represent experimental plots (Pope County).
[2] Percentage of fields in a county with rust (number of fields positive/total number of fields sampled*100).
[3] Total number based on sporulating uredinia.
[4] Total number of leaves (leaflets) sampled in each county.
[5] Percentage of leaflets with rust (leaflets positive/total leaflets sampled*100).
[6] Total number of fields, leaflet samples, and number with rust; mean percentage of fields and leaflets with rust.

Results of samples and crop progress were reported on the PIPE national Web site. The plots were funded by a combination of grant monies from the USDA Risk Management Agency (RMA), Illinois Soybean Association, Illinois Department of Agriculture, and the North Central Soybean Research Program.

Anticipation of soybean rust and participation in the sentinel plot program resulted in documentation of the disease progress of other foliar soybean diseases in the state, as well. Several foliar diseases were observed, including Septoria brown spot, frogeye leaf spot, bacterial blight, bacterial pustule, and downy mildew. Samples were incubated and verified at the University of Illinois Plant Clinic. These other foliar diseases are not new to Illinois; however; documentation of trends and the spread of foliar diseases was eye opening, particularly with regard to the extent of bacterial blight this season.

Information about soybean rust, rust management, fungicide recommendations, and monitoring can be found through our soybean rust Web sites, http://soyrust.cropsci.uiuc.edu and http://www.soybeanrust.org, as well as through the national USDA Web site, http://www.sbrusa.net/, which

Table 2 ■ Illinois Asian soybean rust fungicide information—Fungicides for soybean rust in Illinois*

EPA Soybean Rust Section 3 Fungicides

Common Name	Trade Name	Manufacturer	Rate/Acre	Application (GPA)	Labeled no. Applications	PHI (days)	Chemical class	Strategy
Azoxystrobin	Quadris	Syngenta	6.2-15.4 fl oz	Adequate coverage & penetration. Include NIS with low fungicide use rate.	1-2	14	Strobilurin (FRAC 11)	Preventative
Chlorothalonil	Bravo Weather Stik,	Syngenta	16-36 fl oz	20-150 (5-10 by air)	1-3	42	Benzonitriles(FRAC M5)	Preventative
	Echo 720	Sipcam Agro	16-40 fl oz	20-150 (5-10 by air)	1-3	42		
	Echo 90DF	Sipcam Agro	14-32 oz	20-150 (5-10 by air)	1-3	42		
	Echo Zn	Sipcam Agro	1.5-3.5 pts	20-150 (5-10 by air)	2-3 (14 day interval)	42		
	EQUUS 720 SST	Farmsaver.com	1.37-2.25 lbs	10-20	3 (14 day interval)	42		
	EQUUS DF 3 (14 day interval)	Farmsaver.com 42	1.25-2.2 lbs	10-20				
Pyraclostrobin	Headline	BASF	6-12 fl oz	Thorough coverage of foliage. Adjuvants allowed.	1-2 (7-14 day interval)	21	Strobilurin (FRAC 11)	Preventative

EPA Soybean Rust Section 18 Fungicides

Common Name	Trade Name	Manufacturer	Rate/Acre	Application (GPA)	Labeled no. Applications	PHI (days)	Chemical class	Activity
Cyproconazole (exp. 4/19/09)	Alto 100SL	Syngenta	4-8 fl oz.	10-15 (5 by air)	1-2 (14-21 day interval)	30	Triazole (FRAC 3)	Curative
Myclobutanil (exp. 11/10/07)	Laredo EC	Dow AgroSciences	4-8 fl oz	15-20 (5 by air)	1-2 (14-21 day interval)	28	Triazole (FRAC 3)	Curative
	Laredo EW		4.8-9.6 fl oz	15-20 (5 by air)	1-2 (14-21 day interval)	28		
Propiconizole (exp. 11/10/07)	Bumper 41.8EC	Makhteshim-Agan	4-8 fl oz	15 (5 by air)	1-2 (12 day interval)	28 (do not apply later than R6)	Triazole (FRAC 3)	Curative
	Propimax EC	Dow AgroSciences	4-8 fl oz	15-20 (5 by air)	1-2 (14-21 day interval)	28 (do not apply later than R6)		
	Tilt	Syngenta	4-8 fl oz	10 (5 by air). Adjuvant allowed	1-2 (14 day interval)	28 (do not apply later than R6)		

Tebuconazole (exp. 11/10/07)	Folicur 3.6F	Bayer CropScience	3-4 fl oz	10 (5 by air). Adjuvant allowed.	1-2 (10-21 day interval)	30	Triazole (FRAC 3)	Curative
	Orius 3.6F	Makhteshim-Agan	3-4 fl oz	10 (5 by air). Adjuvants allowed.	1-2 (10-21 day interval)	30		
	Uppercut	DuPont	3-4 fl oz	10 (5 by air).	1-2 (10-21 day interval)	30		
Tetraconazole (exp. 11/10/07)	Domark 230ME	Valent	4-6 fl oz	20-150 (5-10 by air)	1 (under review for 2 applications in IL)	21 (do not apply after R5)	Triazole (FRAC 3)	Curative
Cyproconazole + Azoxystrobin (exp. 4/19/09)	Quadris Extra SC	Syngenta	(Not yet available)	—	1-2 (14-21 day interval)	30	Triazole (FRAC 3)	Curative
Azoxystrobin + Propiconizole (exp. 11/10/07)	Quilt	Syngenta	14-20 oz	(apply w/ 0.5% COC)	1-2 (14-21 day interval) than R6)	21(do not apply later (FRAC 3,11)	Triazole + Strobilurin	Curative + Preventative
Propiconizole + Trifloxystrobin (exp. 11/10/07)	Stratego	Bayer CropScience	5.5-10 fl oz	10 (5 by air). Certain adjuvants allowed.	1-2 (10-21 day interval)	(do not apply later than R6)	Triazole + Strobilurin (FRAC 3,11)	Curative + Preventative
Pyraclostrobin + Tebuconazole (exp. 11/10/07)	Headline SBR	BASF	5.9-7.8 fl oz	15 (5 by air). Apply 0.125-0.2% v/v NIS.	1-2 (14-21 day interval)	30 (may apply up to R6)	Triazole + Strobilurin (FRAC 3,11)	Curative + Preventative

* Fungicide EPA approvals as of 07/06. Please check the Environmental Protection Agency Web site for most current Section 3 and Section 18 registrations and listings of allowed states. http://www.epa.gov/oppfead1/cb/csb_page/updates/soybean_rust.htm. The Illinois Department of Agriculture maintains a list of soybean rust fungicides as well, http://www.agr.state.il.us/Environment/soybeanrust/fungicide.html.

has additional information about good farming practices documentation and insurance documentation requirements through RMA.

Numerous other online and printed resources are available to aid in soybean scouting and disease management, including

- fungicide spray recommendations fact sheet, updated on our crop science Web site, http://soyrust.cropsci.uiuc.edu/index.cfm
- the news release series at http://www.ipm.uiuc.edu/fieldcrops/soybeans/diseases.html;
- in-season articles in the Bulletin, http://www.ipm.uiuc.edu/bulletin;
- North Central IPM Center's soybean rust fact sheets, http://www.ncipmc.org/alerts/soybeanrust.cfm; and
- NCR 504 scouting brochure, http://www.aphis.usda.gov/publications/plant_health/content/printable_version/SBR_IDcard_11-04.pdf.

Scouts and producers should have:

- a field crop scouting guide (Field Crop Scouting Manual, U of I Extension publication number X880d); and
- the reprinted and updated soybean disease pocket guide (Pocket Guide to Soybean Diseases, U of I Extension publication number C1380).

Also, new and specifically for soybean rust are:

- a disease assessment tool (Soybean Rust Assessment Tool, U of I Extension publication number X881); and
- a hand lens for soybean rust scouting endeavors (folding pocket magnifier, 20X, U of I Extension item number X882).

(University of Illinois Extension resources for soybean rust can be ordered online at http://www.PublicationsPlus.uiuc.edu or by calling 800-345-6087.)

Also, a new Extension Report on Plant Disease #1002, "Characteristics of Fungicides for Field Crops" (http://www.ag.uiuc.edu/~vista/abstracts/a1002.html) is an excellent resource when making decisions about using fungicides.

As you make your scouting and management plans for next season, remember that part of our early detection plan in Illinois includes pre-screening of soybean foliar samples for rust. In Illinois, a specialized section of our University of Illinois Digital Distance Diagnostics Imaging (DDDI) system to aid in early detection of Asian soybean rust has been in place since 2004 for you to take advantage of quick sample pre-screening. Our DDDI system is an online plant clinic, and, with regard to soybean rust, our goal is rapid pre-screening and early detection of rust-infected plants. Samples can be submitted to the University of Illinois DDDI system at your county Extension unit office. The results of soybean rust pre-screening via DDDI are available within a few hours. If the sample submitted to DDDI pre-screening appears suspect, a plant sample is submitted to the U of I Plant Clinic for verification.

So, our best plant disease lesson from the 2006 growing season was that preparation, training, pre-screening, and vigilance really did work to detect soybean rust. Let's keep in perspective that rust is a disease that can be managed with appropriate and timely fungicide applications. And remember that monitoring does take a more diligent effort than we have been accustomed to for soybean production.

Fungicide selection, application, and regulatory issues will continue to be issues as soybean rust progresses. As of November 2006, our recommended fungicides for the management of soybean rust were those listed in Table 2. Continuation of in-depth training for competent and legal selection and application of fungicides for the management of soybean rust by clientele will continue to be a key component of our educational effort to manage soybean rust in Illinois.

Bt, ECB, ISTs, WCR, IRM, IPM: Sorting it All Out

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We are in the midst of an agricultural revolution regarding the management of pests in the corn and soybean agroecosystem of the United States. This revolution in pest control is perhaps even more significant than the post-World War II over-use of chlorinated hydrocarbons to control agricultural, veterinary, ornamental, and urban pests worldwide. The current paradigm shift in pest control is so significant that the foundation and pillars of integrated pest management (IPM) are beginning to "shake" in the corn and soybean fields of the Corn Belt. Provided are some facts concerning the biotechnology revolution gleaned from a USDA Economic Research Service report published in 2006.

Biotechnology Adoption Facts

Excerpted from Fernandez-Cornejo, J., and M. Caswell. 2006. The first decade of genetically engineered crops in the United States. USDA Economic Research Service, Economic Information Bulletin, Number 11. Washington, DC:

- "Since 1987, seed producers have submitted nearly 11,600 applications to USDA's Animal and Plant Health Inspection Service for field testing of GE varieties. More than 10,700 (92 percent) have been approved. Approvals peaked in 2002 with 1,190. Most approved applications involved major crops, with nearly 5,000 for corn alone, followed by soybeans, potatoes, and cotton. More than 6,000 of the approved applications included GE varieties with herbicide tolerance or insect resistance."
- "By 2005, herbicide-tolerant soybeans accounted for 87 percent of total U.S. soybean acreage, while herbicide-tolerant cotton accounted for about 60 percent of total cotton acreage."
- "Insect-resistant corn accounted for 35 percent of the total acreage in 2005, following the introduction of a new variety to control the corn rootworm."
- "In the United States, foods containing GE ingredients currently available in the U.S. market do not require labels, since the U.S. Food and Drug Administration has determined that these foods are "substantially equivalent" to their non-GE counterparts. Thus, U.S. consumers have been eating foods that contain GE ingredients (corn meal, oils, sugars) for the past 10 years while remaining largely unaware of their GE content."

- "The U.S. commercial seed market is the world's largest—with an estimated annual value of $5.7 billion per year in the late 1990s—followed by China at $3 billion and Japan at $2.5 billion."
- "An estimated 200 million acres of GE crops with herbicide tolerance and/or insect resistance traits were cultivated in 17 countries worldwide in 2004, a 20-percent increase over 2003. U.S. acreage accounts for 59 percent of this amount, followed by Argentina (20 percent), Canada and Brazil (6 percent each), and China (5 percent)."
- "Bt corn, originally developed to control the European corn borer, was planted on 35 percent of corn acreage in 2005, up from 24 percent in 2002. The recent increase in acreage share may be largely due to the commercial introduction in 2003/04 of a new Bt corn variety that is resistant to the corn rootworm, a pest that may be even more destructive to corn yield than the European corn borer."

IPM in a Biotechnology Corn and Soybean Landscape: Does it Fit?

Does integrated pest management (IPM) in the traditional sense of scouting for insect pests, using economic thresholds, and applying a rescue treatment to prevent an increasing pest population from reaching the economic injury level have much relevance across an expanding Bt corn landscape? Many, including the author of this paper, have significant concerns that IPM in the corn and soybean landscape is being tossed aside. With the surging interest in the use of "stacked" transgenic corn hybrids that feature herbicide tolerance and insect protection against lepidopteran pests and corn rootworms, insect pest management is viewed by many as complete when the planter is put back in the shed. Furthermore, because all Bt corn seed is treated with a neonicotinoid insecticide (Poncho [clothianidin] or Cruiser [thiamethoxam]), secondary insects (white grubs, wireworms, seedcorn maggots) also are targets of insecticide applications even though their densities may be below economic levels. The time savings and ease of planting Bt corn seed treated with neonicotinoids are very appealing, and we shouldn't be surprised as the adoption rate of this technology continues to climb. However, there are a few clouds on the horizon.

Thus far, the lack of any confirmed field-level development of resistance to Bt by European corn borers has been a success story. The agribusiness sector and producers throughout the Corn Belt are to be congratulated for the implementation of non-Bt corn refuges designed to prevent the development of resistance by European corn borers to the high dose events (MON 810, Cry1Ab, YieldGard hybrids; TC1507, Cry1F, Herculex hybrids) in the market place. However, a decade has elapsed since the commercialization of Bt corn hybrids for the control of European corn borers. Selection pressure for resistance development will increase as more and more acres are planted to Bt corn hybrids. It is imperative that refuges be properly deployed and that producers, the ag industry, and land grant university entomologists cooperate to ensure that stewardship of Bt corn continues. So, although fewer traditional IPM approaches are being implemented for insect pests in cornfields, IRM (insect resistance management) through the use of refuges is mandated for Bt corn hybrids by the U.S. Environmental Protection Agency. Yet, there are no insect resistance management requirements for neonicotinoid insecticidal seed treatments applied to every Bt corn seed planted in the Corn Belt. Why? In

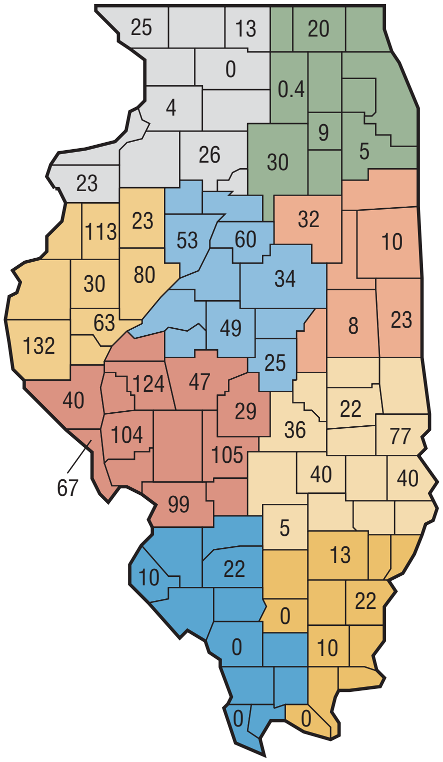

Figure 1 ■ Results from the 2006 survey of European corn borers. State average of borers per 100 plants = 33.

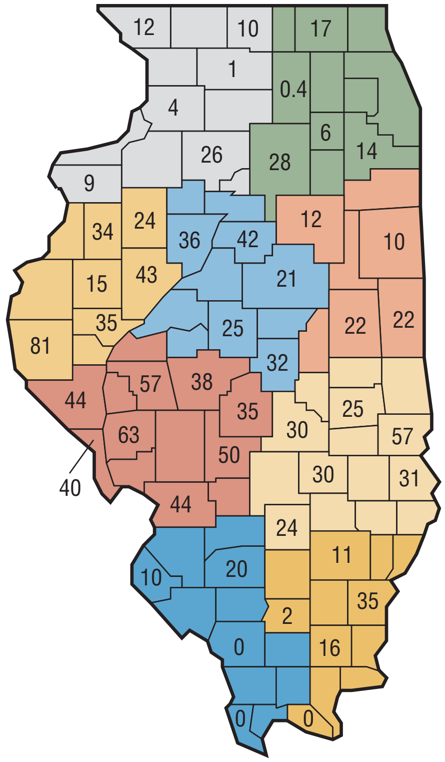

Figure 2 ■ Results from the 2006 survey of European corn borers. State average percentage infestation = 23%.

time, it seems likely that resistance to these systemic insecticides will develop among one or more species of secondary insect pests.

European Corn Borer Densities in 2006

There seems to be little doubt that the use of Bt corn hybrids in Illinois continues to diminish the economic impact of European corn borers. In 2006, the average number of European corn borers per 100 plants was 33 (Figure 1), and the percentage of plants infested was 23 (Figure 2). Both of these population parameters were slightly below the 2005 estimates. Similar to the results from our 2005 annual survey of European corn borers, densities of this insect pest were greatest in western and west central counties in Illinois in 2006. Increasingly, this survey has become a good way to estimate where Bt corn is planted and where it is not, so striking are the differences in stalk quality as measured by lodging and stalk breakage. As the western bean cutworm becomes more established in Illinois, there will be an even greater incentive to plant more Bt corn hybrids, "dialing up" the selection pressure for resistance development. Although cornfields can be scouted for European corn borers and rescue treatments can be applied as needed, more and more producers will continue to accept the use of Bt corn hybrids as a standard crop production input to control multiple insects. The use of Bt corn hybrids for the control of European corn borers has been a striking success story to date—excellent control and lack of resistance development!

Bt and Corn Rootworm Control

There have been a few more "potholes in the road" with regard to Bt corn hybrids and control of corn rootworms. In 2006 for the first time, we were able to make head-to-head comparisons of the root protection afforded by transgenic corn rootworm hybrids with different events from Monsanto (MON 863, Cry3Bb1, YieldGardRW), Pioneer Hi-Bred International, Incorporated (DAS-59122-7, Cry34Ab1/Cry35Ab1, HxXTRA), and Mycogen (DAS-59122-7, Cry34Ab1/Cry35Ab1, HxRW, HxXTRA). In general, the root protection provided by these transgenic corn rootworm hybrids was very good to excellent. In July, the average node-injury ratings for HxXTRA (Pioneer 34A18) were 0.08, 0.24, and 0.47 in DeKalb (Figure 3), Monmouth (Figure 4), and Urbana (Figure 5), respectively. Considering the level of root injury in the untreated check plots (non-Bt corn), these node injury ratings represented acceptable levels of root protection. For

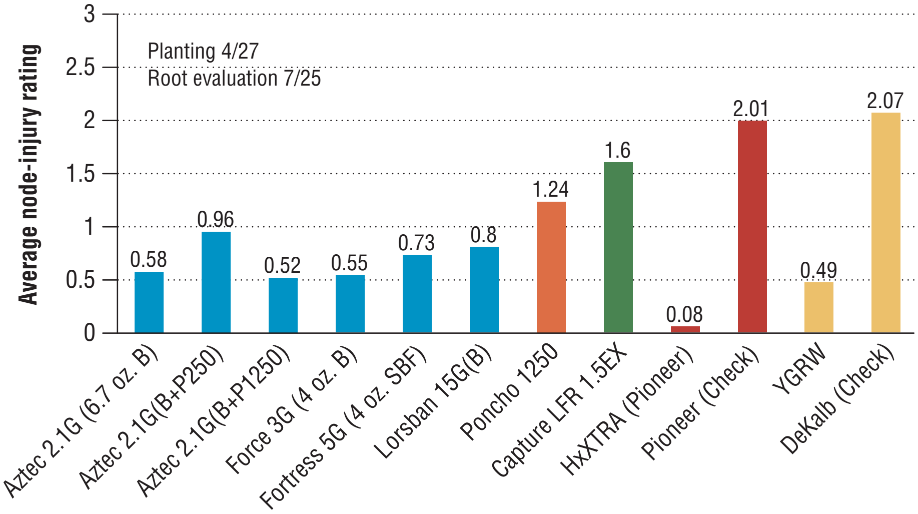

Figure 3 ■ Node injury ratings from a corn rootworm control trial, DeKalb, Illinois, 2006.

HxXTRA (Pioneer 34A18), comparison of root injury should be made with the appropriate non-rootworm Bt control—Pioneer 34A16, which also was treated with Poncho 250. HxRW (Mycogen 2G777) and HxXTRA (Mycogen 2P788) also provided very good (½ node or less of roots pruned) root protection at the Monmouth (node injury ratings: HxRW, 0.22; HxXTRA, 0.40) and Urbana (node injury ratings: HxRW, 0.55; HxXTRA, 0.44) locations. These node injury ratings should be compared with the node injury ratings for the appropriate non-rootworm Bt control—Mycogen 2784, which was not treated with a seed-applied insecticides. Due to late shipments of seed, the Mycogen Bt corn rootworm hybrids were not planted until May 6 at the Urbana site. In July, YieldGard RW (DK 61-68) had node injury ratings of 0.49, 0.39, and 0.96 at the DeKalb, Monmouth, and Urbana experiments, respectively. These node injury ratings should be compared with the node injury ratings for the appropriate non-rootworm Bt control—DK 61-72, which was not treated with a seed-applied insecticide. The level of root injury to YGRW (nearly one node of roots pruned) at the Urbana location

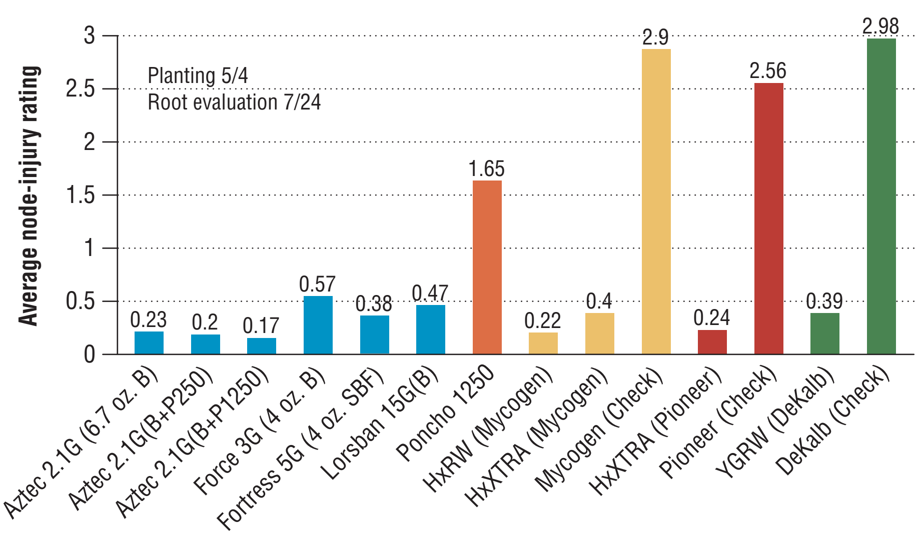

Figure 4 ■ Node injury ratings from a corn rootworm control trial, Monmouth, Illinois, 2006.

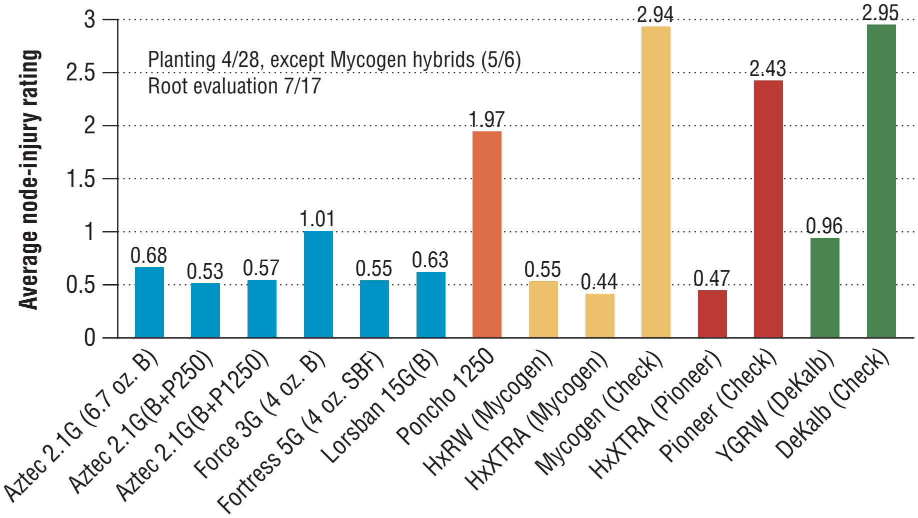

Figure 5 ■ Node injury ratings from a corn rootworm control trial, Urbana, Illinois, 2006.

was much greater than anticipated for mid-July. In addition, the planting date for this treatment was April 28, later than the planting date of corn for most producers in east central Illinois. How severe would the root injury have been if planting had occurred during the first week of April?

Late-Season Control of Corn Rootworms with Bt Corn

A subset of treatments from our standard corn rootworm efficacy trials in DeKalb, Monmouth, and Urbana were evaluated for late-season rootworm larval injury (figures 6, 7, and 8, respectively). As in previous years, the amount of pruning by rootworm larvae to the YGRW hybrid (DK 61-68 + Poncho 250) at the Urbana experimental site increased from mid-July (0.96) to early August (1.46). By mid-July, nearly one full node of roots of the YGRW hybrid was pruned; by early August, approximately 1½ nodes of roots were destroyed (Figure 8). Rootworm larval injury to YGRW at the DeKalb (Figure 6) and Monmouth (Figure 7) sites was much less, with node injury ratings in August of of 0.41 and 0.59, respectively. Why was the node-injury rating of YGRW corn at the Urbana site greater than at the two other locations? In August, the levels of root injury in the untreated checks (DK 61-72) at Monmouth (2.82) and Urbana (3.0) were similar. So, a difference in corn rootworm pressure doesn't seem to be a satisfactory explanation. We suspect that greater densities of the variant western corn rootworm at the Urbana site may be partially responsible for the greater severity of root injury at this location. The average node injury ratings for Aztec 2.1G in mid-July and early August suggested fair (DeKalb, 0.58 to 0.78; Urbana, 0.68 to 0.63) to very good (Monmouth, 0.23 to 0.41) protection of roots. The root protection offered by Poncho 1250 was poor by August 8 at the DeKalb, Monmouth, and Urbana sites—1.42, 1.72, and 2.35, respectively.

Concluding Remarks

On October 4, 2006, the U.S. Environmental Protection Agency granted registration approval for Syngenta's transgenic corn rootworm event (MIR604, mCry3A, Agrisure RW). For the 2007 growing season, three Bt corn rootworm events (MON863, DAS-59122-7, MIR604) will be available among many corn hybrids. In 2006, we evaluated the new corn rootworm Bt

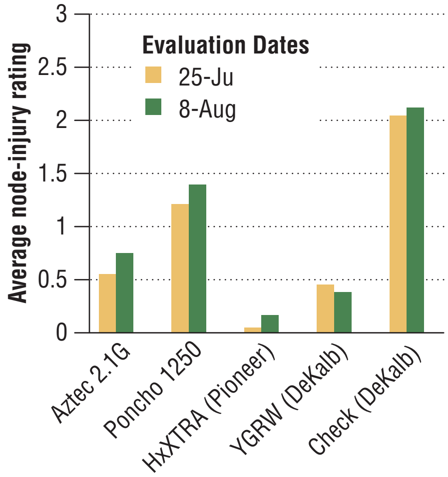

Figure 6 ■ Node injury ratings, first and second evaluations, DeKalb, Illinois, 2006.

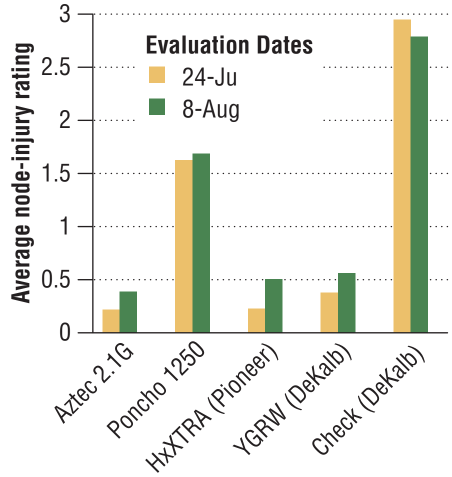

Figure 7 ■ Node injury ratings, first and second evaluations, Monmouth, Illinois, 2006.

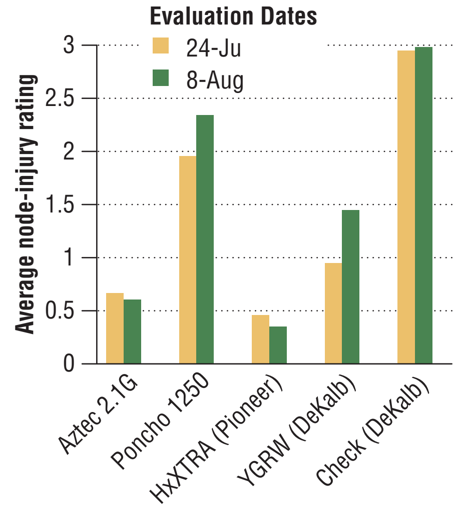

Figure 8 ■ Node injury ratings, first and second evaluations, Urbana, Illinois, 2006.

event from Syngenta in a trial located near Urbana. The plot (late-planted corn interplanted with pumpkins in 2005) in which the experiment was planted (May 23, 2006) had intense corn rootworm larval pressure (untreated non-Bt check = 3 nodes of roots destroyed). The MIR604 treatment had an average node injury rating of 1.04 (one node of roots destroyed) on July 17. As previously evident, this new event is not the only transgenic Bt event for corn rootworms that has experienced performance challenges at this test site. We have reported that some YGRW hybrids also sustain greater levels of root injury in experiments located near Urbana. We will continue to evaluate the hypothesis that variant western corn rootworms may be able to inflict more feeding injury than the non-variant populations to certain Bt hybrids. Results from the 2006 growing season reinforce the fact that we have much to learn about the performance and reliability of transgenic Bt corn rootworm hybrids across a wide range of environments. One thing seems certain—the Bt corn rootworm story already has had more twists and turns than the Bt corn saga with European corn borers.