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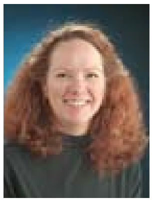
College of Agricultural, Consumer and Environmental Sciences
Department of Crop Sciences

New Information on the Distribution and Management of Corn Nematodes in Illinois



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Nematodes are the most frequently overlooked cause of disease in corn in Illinois. Nematodes cause above-ground symptoms similar to those caused by almost any stress (especially stunting and yellowing; Fig. 1), and can intensify expression of specific symptoms due to nutrient deficiency, herbicide injury, and other causes. Until recently, the occurrence and activity of corn nematodes in Illinois has mostly been ignored because the symptoms are usually nonspecific (Fig. 2) and typical production practices kept pathogenic nematode populations in check.

Nematode injury to corn is not rare—it is simply difficult to identify. Adding to the difficulty of diagnosing problems due to nematode feeding is the probability that few corn nematode species cause direct injury on their own; nematodes interact with other problems to intensify symptoms. They also occur in polyspecific communities, meaning that several potentially plant pathogenic species are usually found in the same fields, and corn nematologists believe that corn injury due to nematodes is not often a one nematode—one disease situation. The practical implication of corn injury as an "interaction disease" is that it requires highly trained people to diagnose and supply management recommendations. There is no easy fix for the problem of diagnosing corn nematode problems.

Densities and distributions of corn nematodes in Illinois

In 1994, the last year for which estimates are available, nematodes were responsible for corn yield losses values at $81 million dollars in Illinois alone (1). Losses have probably increased dramatically in the last 15 years, but there are no published estimates. According to older literature, the nematodes responsible for suppression of corn yields in Illinois were *Hoplolaimus galeatus* (lance nematode), *Longidorus breviannulatus* (needle nematode), *Pratylenchus* spp. (lesion nematodes), and *Xiphinema americanum* (dagger nematode).

Figure 1 ■ Stunting and Chlorosis of corn plants caused by high population densities of plant parasitic nematodes.

Figure 2 ■ Typical appearance of corn in fields with high population densities of plant parasitic nematodes.

Interest in developing new management recommendations for corn nematodes led to the proposal of a survey of corn nematodes in Illinois by Jim Morrison and Dave Feltes, Extension Educators in northern Illinois. They conducted a pilot study during 2008 in 19 northern Illinois counties in order to test protocols that will be used in a 2009 study to include 80 additional counties. Preliminary results for the 2009 study will be presented but cannot be included here.

For the 2008 study, eight cooperators were each assigned randomly-generated coordinates along a pre-determined route in two to four counties per cooperator. A total of 76 soil samples were collected from corn fields at or near the assigned coordinates from corn plants at the V3 to V6 growth stage. Samples comprised 10 to 20 soil cores (2.5-cm-diam) taken to a depth of 25 to 30 cm within the rows. A 100 cm^3 soil subsample was washed through a series of sieves including 20-, 60-, and 400-mesh (850, 250, and 38-µm-apertures, respectively). Material collected on the 20 and 60 mesh sieves was placed on Baermann funnels for 48 hrs. Material collected on the 400-mesh sieve was processed by centrifugal flotation for extraction of vermiform nematodes. Data collected from each sample included numbers of nematodes in each of five trophic groups: microbivores (bacterial feeders), fungivores, plant parasites, omnivores, and predators. Plant parasites were identified to morphological group or to genus, and individuals were collected, fixed, and mounted to facilitate species identification.

Overall, the nematode communities were composed of about 50% bacterivores and 50% plant parasites; very few fungivores, omnivores, or predators were observed (Fig. 3). This type of nematode community in thought to reflect an "unhealthy" situation because there is a high level of parasitism occurring, relative to the level of nutrient cycling reflected by the bacterial feeding nematodes.

The most frequently (97%) occurring group of nematodes was the "tylenchid," a group whose effects on plant growth and yield is mostly unknown (Fig. 4). Many of these nematodes are thought to be fungivorous, or

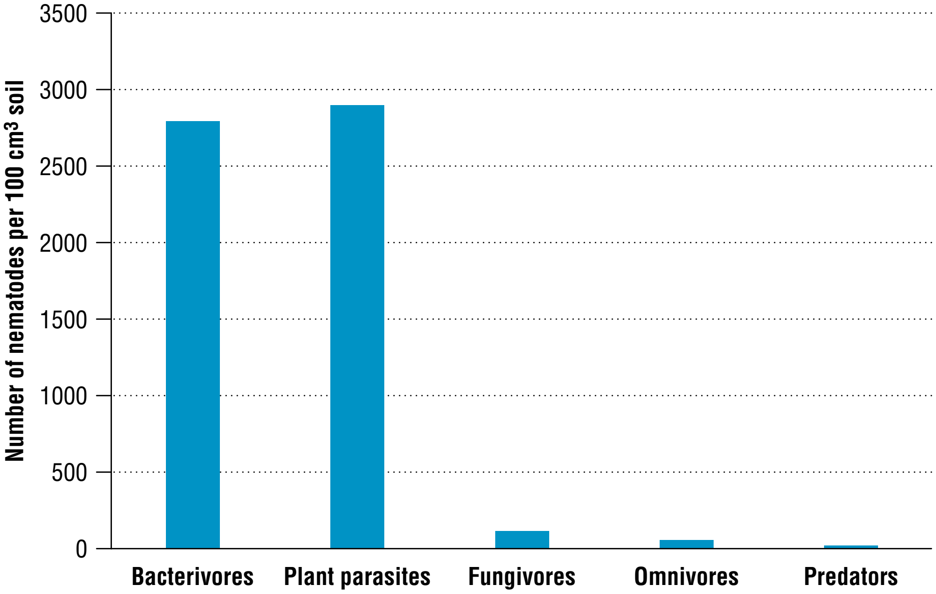

Figure 3 ■ Abundance of five trophic groups ("feeding groups") of nematodes in corn fields in 19 counties in northern Illinois, 2008.

Figure 4 ■ Typical nematode of the "tylenchid" group, with a delicate stylet and long, pointed tail. Members of this group may be either plant feeders, fungal feeders, or both. Specific information for most members of this group is unknown.

possibly able to feed on both plants and fungi, although there are few good examples of this type of behavior among soil nematodes. Genera and species of animals in this group were not determined, but they were counted as plant parasites rather than fungivores.

The second most frequent (94%) group was the spiral nematode complex, consisting mostly of *Helicotylenchus* species (Fig. 5; Table 1). Certain species of spiral nematodes can be pathogenic, but fairly high numbers of nematodes are required (Table 1).

The most frequent (92%) genus of possibly corn-pathogenic nematodes was *Pratylenchus*, commonly known as lesion or root-lesion nematodes (Fig. 6; Table 1). Molecular analysis was used to identify at least five different *Pratylenchus* species: *P. crenatus*, *P. hexincisus, P. neglectus, P. penetrans,* and *P. scribneri.* All but one of these has been reported as a pathogen of corn. Work is continuing to verify the numbers of each species.

Other genera of potential corn pathogens observed were *Hoplolaimus* (lance nematode, 36%), *Xiphinema* (dagger nematode, 18%), and *Paratylenchus* (pin nematode, 11%) (Table 1). The stunt nematode group was found in 24% of the samples, and comprises at least three species in two genera. Juveniles of *Heterodera* were observed in 57% of the samples (Table 1). Species

Table 1 ■ Distribution and population densities (numbers of nematodes per 100 cm^3 soil) of common plant-parasitic nematodes in 19 counties in northern Illinois in 2008.

	Spiral	Lesion	Cyst	Lance	Dagger
Frequency	94.7%	92.1%	56.5%	35.5%	18.4%
Threshold (severe)	300	50	n/a	75	50
Threshold (moderate)	150	25	n/a	40	25
Mean	127.8	40.4	8.9	19.6	5.3
Standard deviation	138.7	48.8	16.5	—	—
Min	0	0	0	0	0
Max	690	284	96	126	18

identification will provide additional insight into the potential for any or all of these groups or genera to reduce corn growth or yield.

Seed treatment tests 2008, 2009

Several companies are currently developing products for corn nematode management. We have evaluated experimental products in the greenhouse for their effects on lesion nematodes, and we have evaluated products in various stages of the labeling process for their effects on corn yields and nematodes in the field. The relative yields we obtained from our field plots in 2009 are illustrated (Fig. 7). Significant differences among treatments will be discussed.

Figure 5 ■ A female spiral nematode, member of one of the most common plant parasitic nematodes that occur in corn fields.

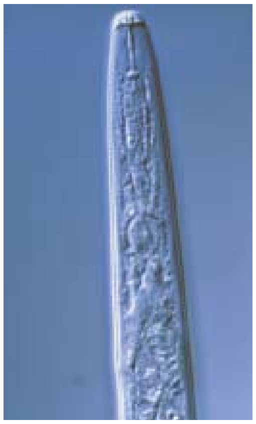

Figure 6 ■ The head of a female lesion nematode, member of one of the most common pathogenic nematodes that occur in corn fields.

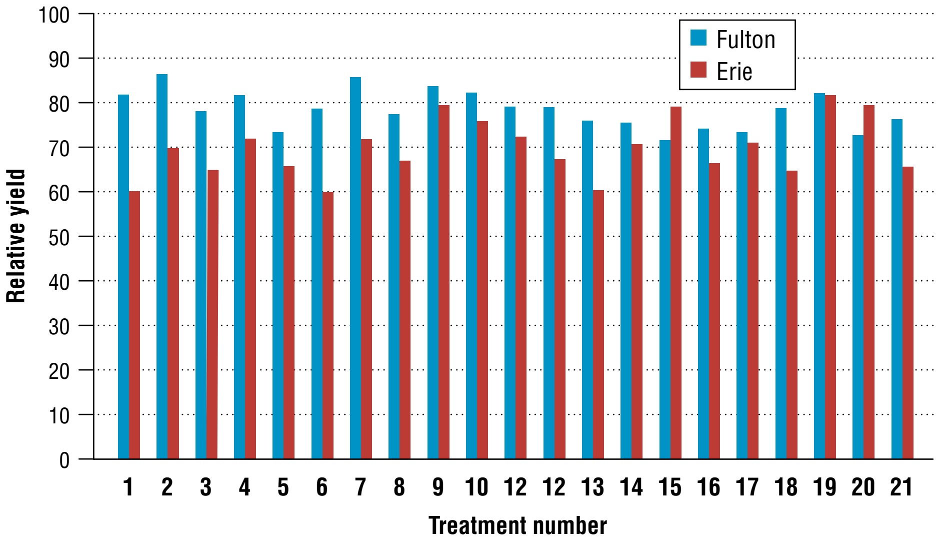

Figure 7 ■ Relative corn yields for 21 treatments at two locations in Illinois in 2009. Treatment number 21 is Counter; Treatment numbers 10 and 20 are nontreated checks of two different hybrids.

Summary

All corn fields have plant parasitic nematodes, some of which may be pathogenic under certain circumstances. It is time to reassess the impact of corn nematodes on corn production, and determine whether our research and development efforts are what they should be given the current value of corn yield losses and the expected future increases.

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Sulfur for Corn Production in Illinois

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Sulfur (S) is an essential nutrient for corn production because this nutrient is involved in many important physiological functions in the plant. Some of these functions are formation of amino acids, protein and enzyme synthesis, plant respiration, seed production, and chlorophyll synthesis. This nutrient has been classified as secondary, even though it is required in amounts somewhat similar to those of phosphorus (0.19 lb elemental P vs. 0.07 lb elemental sulfur per bushel of corn). The reason this nutrient is described as secondary is that in the past, it was rarely limiting, and more rarely added to soils as fertilizer. Sulfur is the 13th most abundant nutrient in the earth's crust, but most of it is inorganic or organic forms unavailable to plants. In the past, this nutrient has not been considered a problem for corn production in Illinois. However, more recently the frequency of reports of suspected and/or actually confirmed deficiency symptoms has increased.

Typically, sulfur availability is dependent on the amount of soil organic matter. Most often, deficiencies are observed in low organic matter soils and soils with coarse texture with high leaching potential. Sulfur undergoes transformations similar to nitrogen. In fact, the sulfur cycle (Figure 1) is similar to the N cycle. Warm, moist, and well drained conditions accelerate the formation of sulfate (SO_4^{2-}) which is the plant-available sulfur form. Similar to nitrate, in the sulfate form, sulfur is easily leachable in the soil. However, unlike nitrogen, once sulfur is taken up by the plant it is not mobile. For this reason deficiency symptoms appear in the younger leaves, often as interveinal chlorosis, (Figure 2) rather than in the older leaves as in nitrogen.

Sulfur deficiency in corn was first reported in the 1920's in Minnesota. Later, in the early 1950's it was reported in Nebraska. During the late 60's to early 70's Missouri, Wisconsin, Iowa and other states observed sulfur deficiency in corn. In Illinois, studies on corn response to sulfur were conducted in a total of 82 site-years over a three-year period (27 sites in 1977, 26 in 1978, and 29 in 1979) (Hoeft, et al., 1985). In that study 40% of the sites were either low in organic matter, coarse in texture, or sulfur deficiency had been observed. The treatments were 50 lb sulfur acre^{-1} from gypsum and

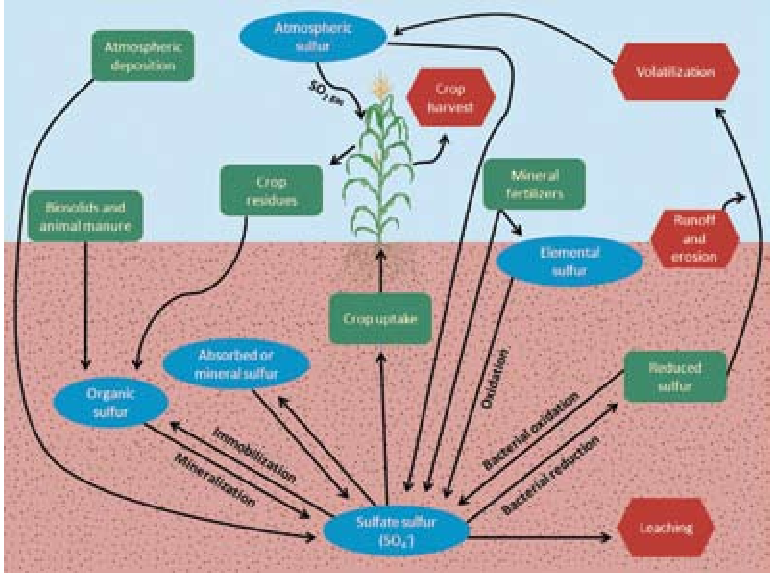


Figure 1 ■ Sulfur cycle.

Figure 2 ■ Sulfur deficient corn in a Onarga sandy loam soil receiving no sulfur in Fulton County, Illinois. Picture taken on July 9, 2009 by Earl Allen.

a control with no sulfur application. They collected whole plant samples at V6 development stage and ear leaf samples at silking. They also collected 9-inch soil depth samples at the end of May, and grain yield at harvest. In that study, sulfur increased yield at 5 of the 82 locations. The average yield increase over the check was 11.2 bu acre^{-1}. The five locations were: 2 sites in northwestern Illinois on an eroded silt loam and on an irrigated sand, 1site in central Illinois on a silty clay loam soil, and 2 sites in southern Illinois on a silt loam and on a sandy loam soil. Only two of the 5 responsive locations had shown increase sulfur tissue concentrations with applied S. Averaged across all 82 sites, the yield increase was 0.5 bu acre^{-1} compared to the check, but it was not a statistically significant increase. In terms of plant tissue sulfur levels, only one of the 82 locations had sulfur below the critical level. Sulfur application increased sulfur tissue concentrations at 13 sites at V6 and 20 sites at R1. Half of the sites where this occurred were sandy loam or coarser in texture. A follow up study in the greenhouse using the top 9 inches of soil depth from each of the field locations showed corn response to sulfur was much greater and frequent than in the field. The difference in response between the field and greenhouse studies was likely related to greater sulfur supply to the crop under field conditions from atmospheric deposition and/or subsurface soils.

Historically, sulfur application for corn has not been recommended in Illinois because soil supply, manure applications, and/or atmospheric deposition were sufficient to supply sulfur needs for this crop and because work conducted during the late 70's (described previously) suggested very little chance for sulfur fertilizer response. However, soil sulfur levels or supply may have diminished since that earlier study due to several factors. Since the Clean Air Act of 1970, strict air pollution standards have cleaned the air of gaseous sulfur compounds resulting in less sulfur atmospheric deposition (Figure 3). In general many agronomic inputs such as fertilizers, insecticides and fungicides are "cleaner," having less incidental sulfur in them. For instance MAP and DAP have replaced superphosphate fertilizers and organic fungicides have replaced copper sulfate fungicides. Also, less livestock operations across the state are leading to less manure applications, which also reduce the amount of sulfur being applied with this fertilizer source. At the same time less incidental sulfur is being applied or deposited, there is greater removal of sulfur by increasing crop yields (Figure 4). Fitting a function to the yield data in Figure 4, starting in 1980 (the year after the last corn response to sulfur study was

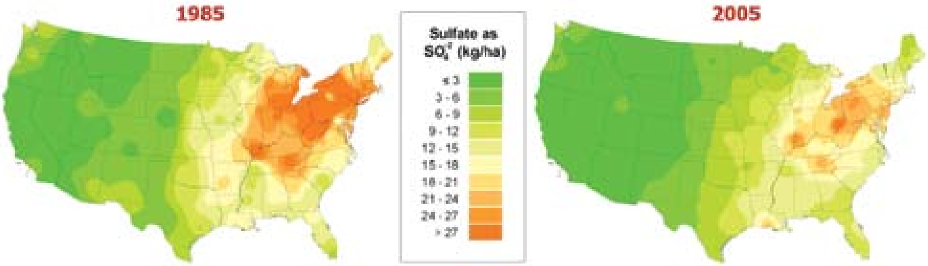


Figure 3 ■ Isopleth atmospheric sulfate deposition map of the United States in 1985 (three-year average 1984-1986) and in 2005 (three-year average 2004-2006). Adapted from the National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu

conducted in Illinois), indicates that since then, corn yields have increased 1.96 bu acre^{-1} year^{-1}. This yield increase represents an increase in sulfur removal in corn grain of 0.14 lb sulfur acre^{-1} year^{-1}. On average, in 1980 corn in Illinois was removing 7.7 lb sulfur acre^{-1}, in 2008 the mean removal was 11.6 lb sulfur acre^{-1}. These changes warrant taking a new look at corn response to sulfur in Illinois. A study was started in 2009 to assess the potential for corn response to sulfur across the state. Due to delays in planting in the spring and harvest in the fall of that year, there are no data available to include in this publication, but preliminary results will be shared during the conference. Some visual responses observed during the growing season, such as those in Figure 2, indicate that indeed it might be important to revisit the topic of sulfur availability for corn production in Illinois.

In order to truly quantify the potential for a yield response to sulfur application, sulfur trials throughout the state and across several years will be needed. Following is a call for volunteers who would like to participate in an on-farm research study to measure corn response to sulfur application.

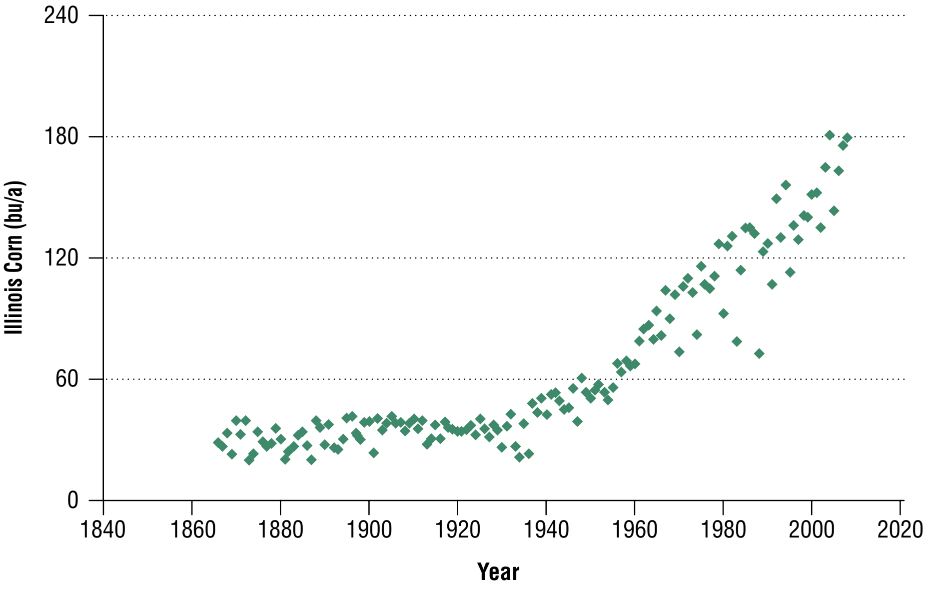


Figure 4 ■ Historic mean corn grain yield for Illinois. Source: http://www.nass.usda.gov

Sulfur Research: We Need Your Help

Contact

If you are interested in participating (even if you are not sure whether your particular field would fit the conditions for this study), or if you have question about how to find sulfur fertilizer or have the fertilizer applied please contact Fabián Fernández: fernande@illinois.edu; phone, 217-333-4426; Department of Crop Sciences, N-315 Turner Hall MC-046, 1102 South Goodwin Ave., Urbana, IL 61801.

Soil conditions

We are interested in light color soils (less than 2% organic matter, coarse texture, or both) and soils with an eroded phase. However, we would like to characterize sulfur response across the State, so we will consider other "more traditional" soils in Illinois as well. Fields that will not be considered in the study are those that have received manure or sulfur applications within the last 5 years.

Equipment

Volunteers conducting these trials will follow a simple design applying 0 and 30 lb S/acre as a broadcast application in a uniform portion of the field. A minimum of three replications or as many as 8 replications are needed for each field. Figure A shows a layout of the treatments randomly assigned within each replication for an 8 replication study. It will be important to georeference or clearly mark each strip with different color flags or markers in the center of each strip. Strips can be anywhere from 8 to 16 rows wide by 300 to 1,000 feet long. What is important is that the size of the strip allows accurate application of the rate, accurate measure of yield, and if possible that the strips are wider than the harvest strip. However, if the combine is at least 12 to 16 rows wide it is possible to harvest the strip without having boarder rows.

Sulfur sources

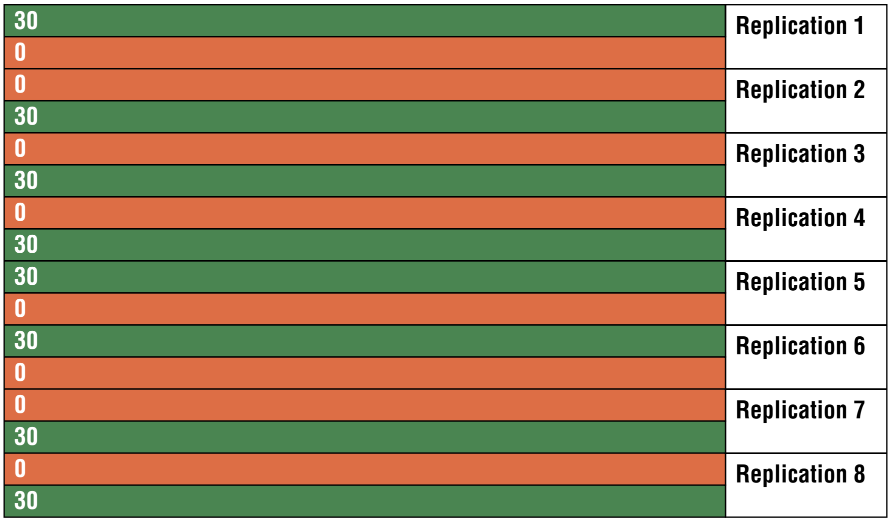
Sulfur sources will be limited to either ammonium sulfate $(NH_4)_2SO_4$ (21-0-0-24); MicroEssentials^{TM} sulfur (ME S) ME S15 (13-33-0–15); and elemental sulfur (0-0-0-90). If the sulfur source contains other accompanying nutrients, the corresponding rates of those nutrients will need to be applied to other treatment strips to avoid a differential response to nutrients other than sulfur. If you use ammonium sulfate you would need to apply 26 lbN/acre to the other strips and if you use ME S15 you would need to apply 145 lb DAP (18-46-0)/acre (for more details see section below "How to apply the treatments").

Time of application

The preferred application time is the spring, but if the only time available is the fall, we can certainly accommodate it. What is most important is to try to have as many locations as possible throughout the state to be able to characterize the potential for corn response to sulfur in Illinois.

Measurements for data collection

The only data volunteers will have to provide is the yield for each strip. This information can be collected by yield monitor or from a weigh wagon. Volunteers will not be required to take plant or soil samples, but would need to allow the researcher to visit the strips approximately two to three times during the growing season.



30	**Replication 1**
0	
0	**Replication 2**
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0	**Replication 3**
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0	**Replication 4**
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30	**Replication 5**
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30	**Replication 6**
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0	**Replication 7**
30	
0	**Replication 8**
30	

Figure A ■ Layout of treatments randomly assigned within each replication for an 8 replication study.

How to apply the treatments

Listed below are three sulfur sources to choose from:

Using ammonium sulfate (21-0-0-24)

The strips with 30 lb sulfur/acre: Apply 125 lb ammonium sulfate /acre.

The strip with 0 lb sulfur/acre: Apply 26 lb nitrogen/acre. This application is to balance the nitrogen that was applied along with the sulfur in the sulfur strip. Those 26 lb of nitrogen/acre can be applied as either:

57 lb urea/acre, 94 lb UAN (28%)/acre (8.7 gallons/acre), or 82 lb UAN (32%)/acre (7.4 gallons/acre).

Do not use anhydrous ammonia because it would be difficult to apply only 32 lb of product/acre.

Using micro essentials MES–15 (13-33-0–15)

The strips with 30 lb sulfur/acre: Apply 200 lb MES–15/acre.

The strip with 0 lb sulfur/acre: Apply 145 lb DAP (18-46-0)/acre. This application is to balance the nitrogen and phosphorus that was applied along with the sulfur in the sulfur strip.

Using elemental sulfur (0-0-0-90)

(I would use this only as the last resort because often it does not become all available in the year of application).

The strip with 30 lb sulfur/acre: Apply 33 lb elemental S/acre.

The strip with 0 lb sulfur/acre: No need to apply any product since the sulfur source is not accompanied by any other nutrient.

Additional N, P, K, or any other input

If the field needs additional nutrients or other inputs (insecticide, herbicide, etc.) to optimize production, make sure those inputs are applied at the same rate across the entire study site.

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Evaluation of Corn and Soybean Yield Forecast Models for 2009

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Introduction

The size of the U.S. corn and soybean crops is one of the major factors determining the price of those crops. Crop size is determined by the magnitude of planted and harvested acreage and the U.S. average yield. The U.S. Department of Agriculture's National Agricultural Statistics Service (NASS) generates crop production forecasts based on estimates of planted and harvested acreage and two sources of yield indications, a farmer-reported survey and objective measures. (for a more detailed description of the methodology used, see Good and Irwin) The USDA releases a *Prospective Plantings* report at the end of March and an *Acreage* report at the end of June. Yield and production forecasts are released in August, September, October, and November and the final production estimate is released in January.

Information about potential yields and production is available beginning early in the growing season. This information is in the form of reports on the timeliness of planting, precipitation and temperature observations, and USDA reports of crop conditions. There is a fairly long history of efforts to incorporate this type of information into formal models to forecast yields prior to the release of USDA yield forecasts and/or to augment USDA yield forecasts. Yield forecasts combined with acreage estimates provide the basis for anticipating crop size as the growing season progresses. The purpose of this article is to report on recent efforts to model corn and soybean yields and the use of the models to forecast U.S. yields in 2009.

Crop Weather Model

Crop weather models have been developed to explain state average corn and soybean yields in Illinois, Indiana, and Iowa. Based on the work of Thompson and Tamara, Irwin, and Good these models explain state average corn yield as a function of the following factors: annual time trend; percent of the crop planted late; amount of pre-plant precipitation; amount of monthly precipitation in April, June, July, and August; and monthly average temperature in July and August. Monthly precipitation is modeled as a quadratic to recognize that yields are negatively impacted by excessive precipitation. The model for soybeans is similarly specified, with the exception that April precipitation and June temperatures were not found to have explanatory value and are not included in the model.

Except for the late planting variable, all of the variables in the model are straightforward and values are easily obtained. The amount of pre-plant precipitation is included as a proxy for soil moisture levels at planting time and is specified as the total amount of precipitation from September through March preceding the year of planting. For corn, the late planting variable is specified as the percent of the crop planted after May 30 from 1960 through 1985 and after May 20 from 1986 forward. For soybeans, late planting is defined as the percentage of the crop planted after June 10 from 1960 through 1985 and after May 30 from 1986 forward. The shift to an earlier data after 1985 acknowledges the general trend toward earlier planting and recent agronomic research that implies a larger penalty for late season soybean planting than earlier believed.

The models are estimated using observations from 1960 through 2008. For corn, the models explained 95 percent of the annual variation in state average yield in Indiana and 96 percent of the variation in annual yields in both Illinois and Iowa. For soybeans, the model explained 88 percent of the annual variation in yields in Iowa, 91 percent in Illinois, and 93 percent in Indiana. The estimated coefficients for each of the variables in each state are presented in Table 1.

Crop Condition Model

A second model to explain U.S. average corn and soybean yields has also been developed based on the USDA's weekly report of crop conditions. This report has been available since 1986 and reports subjective observation on the percent of the crop rated very poor, poor, fair, good ,and excellent each week through the growing season in each of the major producing states and a weighted average (based on planted acreage) for all of the states. The yield models specify the U.S. average yield as a function of annual time trend, percent of the crop planted late, and percent of the crop rated good or excellent in the last report of the season. The model is estimated based on observations over the period 1986 through 2008. The corn model is estimated as:

$$\text{U.S. corn yield} = 66.3855 + 2.2851 \times \text{time} - 0.179 \times \text{percent planted after May 20} + 0.6207 \times \text{percent rated good or excellent}$$

The soybean model is estimated as:

$$\text{U.S. soybean yield} = 21.5971 + 0.4239 \times \text{time} - 0.00684 \text{ percent planted after May 30} + 0.1912 \times \text{percent rated good or excellent}$$

The models explain 97 percent of the variation in U.S. average corn yields and 92 percent of the variation in U.S. soybean yields over the period 1986 through 2008.

2009 Yield Forecasts

For any particular year, the crop weather model can be used to forecast state average corn and soybean yields as early as one is willing to make assumptions about the value of the variables included in the model. An initial forecast, for example, could be made assuming average values for all the variables. Once observations on actual variables are available, those values along with assumptions about the value of the remaining variables can be used to update forecasts. A final forecast would be based on actual observations through August. To forecast the U.S. average yield, the acreage-weighted three state average yield forecast is divided by the average ratio of the three state weighted average yield to the national average yield over the previous 10 years. That ratio is 1.0976 for corn and 1.158 for soybeans.

The crop condition model can be used to make an initial forecast of U.S. average yield with the release of the first crop condition rating of the season. The value of the late planting variable would also be known at that time. Forecasts can be updated based on weekly crop condition ratings and/or assumptions about final crop condition ratings.

Since the standard error of the models are relatively large (10.7 bushels for the corn weather model, 4.1 bushels for the soybean weather model, 6.45 bushels for the corn condition model, and 1.9 bushels for the soybean condition model) forecast errors are also expected to be large. Some reduction in forecast error was noted with the use of an average of the two models.

Forecast results for the various models in 2009 are compared to USDA forecasts in Tables 2 and 3. The crop weather model for corn was first estimated in early June based on observations through May and the assumption of average summer weather. The initial yield forecast was relatively low due to the historically late planting in Illinois and Indiana. Subsequent forecasts were much higher due to the extremely favorable summer weather conditions (cool and wet). The yield forecasts based on crop condition ratings in the first report of the month changed very little during the season as crop ratings were very consistent. The lowest ratings were in November, reflecting the impact of the very wet fall weather. The average of the two forecasts was larger than the USDA forecast, but very close in October. The difference widened in November as the USDA lowered its average yield forecast. The October comparison seems to be the most relevant since the crop weather models do not incorporate weather effects beyond August and the fall weather in 2009 was very unusual. It is generally believed that the USDA November forecast would have been larger if weather conditions had been more favorable.

Both the crop weather model and crop condition model for soybeans consistently forecast the US average yield above the USDA forecast. The average of the two forecasts was 2.2 to 2.5 bushels above the USDA forecast through October. However, the difference narrowed to 1.1 bushels in November as the USDA again raised its forecast of average yield.

The experience of yield forecasting in 2009 was very encouraging. Modeling efforts have the potential to identify likely yield levels prior to the release of USDA forecasts.

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Table 1 ■ Regression Estimates of Crop Weather Models for Corn and Soybean Yields in Illinois, Indiana, and Iowa, 1960–2008

	Corn			Soybeans		
Variable	**IL**	**IN**	**IA**	**IL**	**IN**	**IA**
Constant	261.05	227.49	228.17	28.31	10.87	29.10
Time Trend	1.90	1.73	2.01	0.42	0.43	0.49
Late Planting	–0.29	–0.18	–0.38	–0.04	–0.07	–0.07
Preseason Precipitation	1.32	3.36	6.48	1.84	0.67	2.12
Preseason Precipitation^2	–0.02	–0.07	–0.21	–0.04	–0.01	–0.06
April Precipitation	13.21	9.58	12.05	—	—	—
April Precipitation^2	–1.42	–1.04	–1.45	—	—	—
June Precipitation	12.46	14.41	9.17	0.96	4.64	2.01
June Precipitation^2	–1.34	–1.50	–0.80	–0.06	–0.45	–0.17
July Precipitation	19.97	15.62	17.41	3.86	3.90	3.19
July Precipitation^2	–1.77	–1.25	–1.66	–0.33	–0.35	–0.32
August Precipitation	0.93	10.69	0.60	1.84	3.96	2.99
August Precipitation^2	0.00	–1.24	0.03	–0.11	–0.38	–0.21
July Temperature	–1.75	–2.04	–2.16	–0.01	–0.07	–0.37
August Temperature	–2.42	–2.13	–1.85	–0.55	–0.25	–0.19

Table 2 ■ 2009 U.S. Corn Yield Forecasts

Month	Weather Model[1]	Condition Model[2]	Average	USDA
June	148.6	159.0	153.8	—
July	150.4	160.1	155.2	—
August	165.3	158.2	161.7	159.5
September	170.2	158.8	164.5	161.9
October	170.2	159.5	164.8	164.2
November	170.2	157.6	163.9	161.9

[1] Based on observed values through previous month and average values for unobserved variables

[2] Based on ratings in the first report of the month

Table 3 ■ 2009 U.S. Soybean Yield Forecasts

Month	Weather Model[1]	Condition Model[2]	Average	USDA
July	42.2	44.1	43.1	—
August	43.6	44.3	43.9	41.7
September	45.2	44.5	44.8	42.3
October	45.2	44.3	44.7	42.4
November	45.2	43.6	44.4	43.3

[1] Based on observed values through previous month and average values for unobserved variables

[2] Based on ratings in the first report of the month

High Yielding Soybeans: What is High? What is the Challenge?

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There is a lot of desire by the entire agriculture industry to find ways to significantly increase soybean yields. Soybean yields have increased in Illinois by an average of 1.1% per year as a linear trend between 1950 and 2005. However, in the most recent half decade (2003 to 2008), the average soybean yields have seemed to level off, causing frustration and concern. In addition, soybean yields greater than 150 bushels per acre were achieved by Kip Cullers, a soybean yield contest participant in Southwest Missouri in 2007. There have been other reports of yields greater than 100 bushels per acre, which is more than twice our typical state average yield.

This perceived lagging trend and these high contest yield reports have raised questions among soybean producers and academic researchers alike regarding the management needed to produce higher soybean yields. One approach to find the best combination of management practices to increase soybean yields is to challenge the best soybean producers in the world—Illinois' farmers. Therefore, a soybean 'Yield Challenge' has been designed to start in 2010. In approaching the Yield Challenge, however, it is important to understand a historical perspective of soybean yields and what levels are considered high to evaluate practices and set goals.

Historical perspective: The idea that there is a 'yield barrier' or 'yield plateau' in soybean is not a new one. It is interesting to note that in the 1969 Illinois Fertilizer Conference Proceedings is a title "*Can we break the soybean yield barrier?*" by Dr. R. L. Cooper, a USDA soybean geneticist then working at the University of Illinois. He wrote "The answer is easy. Yes. The question of just how is more difficult." Now, forty years later, we're still intrigued by the same question and faced with the same difficulties. In 1968, Illinois set a new record for an average state yield of 32 bu/acre; however, Dr. Cooper reported that only rarely had the 70 bu/acre barrier been surpassed. Furthermore, there were at that time only five instances in the United States of reported farmer contest plot yields above 90 bu/acre. Today, there have been numerous farmer contest yield reports above 100 bu/acre including the 2007 world record of 154 bu/acre produced in Southwest Missouri. Evaluation of progress in yield via contests is challenging, and a little arbitrary, but contest yields do provide a reference about the maximum potential a crop can produce. Interestingly, in that 1969 report, Dr. Cooper said the barrier was 100 bu/acre. While we know that the crop can surpass that barrier, the national or state average soybean yield levels have yet to consistently reach half that level.

Illinois soybean yields for the nine USDA NASS crop reporting districts (CRDs) graphed as a two-year running average, and the average Illinois state yield is graphed as a linear trend presented in Figure 1. Differences among CRDs are relatively stable over years, and are as much as 10 to 15 bu/acre. These differences point to the importance of geography and soil type when assessing yield potentials. Overall, average Illinois soybean yields have increased at about one-third a bushel per year since 1989 (Figure 1).

High yielding soybeans, what is considered 'high'? While the quest for increasing soybean yields seems to be a relatively simple one, there are really several questions: 1) what limits the production of 'ultra-high' soybean yields (i.e. what is needed to provide unlimited resources), and 2) what keeps below-average or average yields from being high or better-than-average yields? The

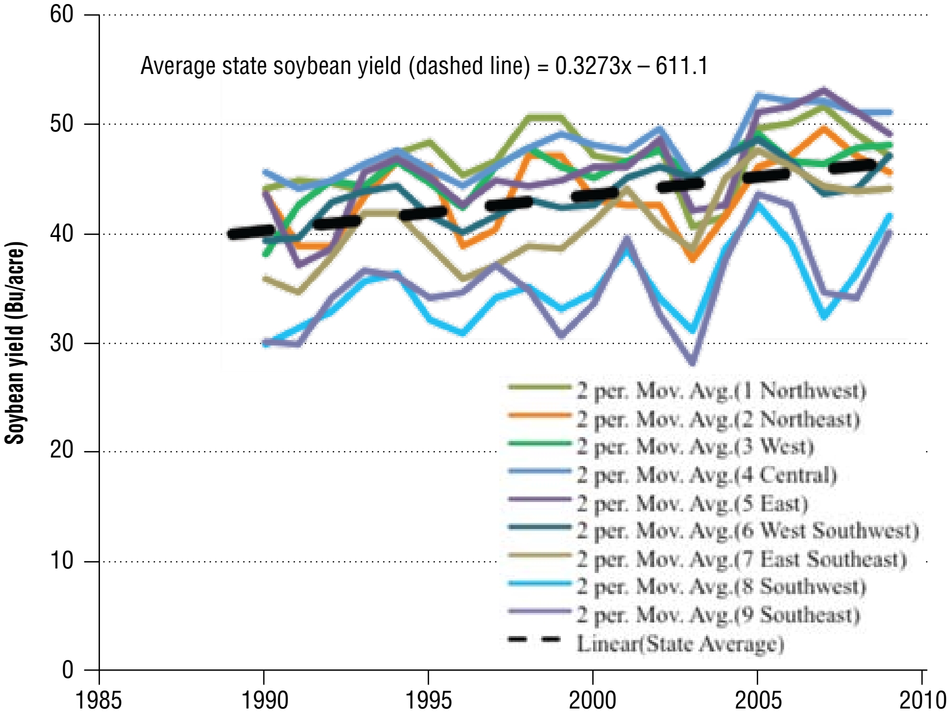

Figure 1 ■ Soybean yields for the nine Illinois USDA NASS crop reporting districts from the last twenty years graphed as a two/year moving average and the average state yield graphed as a linear trend (dashed line). Data were accessed from http://www.nass.usda.gov/.

answer to these questions depends on the definition of 'high' soybean yields, and that answer can be either simple or complex. Simply stated, if yield levels are above county and district averages, then they might be considered "high" yields because they are better than average. However, if soils are also more productive than average county or district soils, then more care must be taken into the evaluation. As more conditions are considered, it quickly becomes an arbitrary decision as to what constitutes 'ultra-high' soybean yields for a given soil type and annual environmental conditions. For now, we might consider high or ultra-high yields to be somewhere around 150% of the typical average county yields as a basis. However, opinions will vary.

University 'High-Yield' Experiments: To address the first component of yield limitations, a study was designed to examine the effects of irrigation, nutrient treatments, pesticides, and high planting densities toward the production of 'ultra-high' soybean yields. The study was first conducted at two Illinois sites—Dixon Springs and Urbana—in 2008. None of the treatments at Dixon Springs, including irrigation, affected yield. One reason for this was likely an unusually high amount of natural rainfall at Dixon Springs in August 2008. At Urbana, there were no affects of additional inputs when irrigation was not supplied. There were also no yield differences observed for the addition of a seed treatment which included fungicide, insecticide and *Bradyrhizobium japonicum* inoculant. There were also no differences observed for foliar applied micronutrients or cytokinin growth hormones. However, yields were increased 7% by irrigation, 15% by irrigation+fungicide, and 20% by irrigation+nitrogen, but irrigation+fungicide+nitrogen did not further increase yields. These data were included in the recently published, 24th edition of the Illinois Agronomy Handbook (p. 36).

This study was conducted, with some minor changes, at four sites in Illinois in 2009: Dixon Springs, Carbondale, Brownstown, and Urbana. To date, only data from the Urbana location are available, and are summarized, in Figure 2. At this site, Pioneer 93M70® seeds were treated with CruiserMax® + Optimize® and planted on May 12. Main plots were with and without irrigation, subplots were low (125,000 seeds/acre) and high (250,000 seeds/acre) seeding rates, and six sub-subplot treatments were: untreated (U); 6 fl oz/acre Headline® fungicide applied at R3, R5, and R6 (F); F plus 3.2 fl oz/acre Warrior® insecticide at all application timings (FI); nitrogen applied as 100 lb/acre urea (45-0-0) plus 3 gal/acre CoRon® 25-0-0 at R2 and R5 (N); N plus Manni-Plex for Beans® complete micronutrients at 2 qt/acre plus X-Cyte® cytokinin growth hormone at 1 pt/acre (NM); and the combination of all the previously mentioned treatments (NMFI).

There were no significant differences at P < 0.1 for any main plot or subplot treatments, and there were only differences to sub-subplot treatments at the P < 0.1 level. Soon after planting, the study received 6" of hard rain which created a crust and limited emergence. The trial was rotary hoed at 7 days after planting to try to break the crust. The June plant stands were 62,000 and 85,000 plants/acre and harvested plant stands were 52,000 and 74,000 plants/acre for the 125,000 and 250,000 seeding rates, respectively. Seeding rate did not influence yields with 80.2 and 78.9 bu/acre, for the low and high seeding rates, respectively; averaged across all other treatments. Natural rainfall was above average all season long in Urbana and no differences were observed between the non-irrigated and irrigated treatments with 80.2 and 78.9 bu/acre, respectively; averaged across all other treatments. All sub-subplot treatments provided greater yield than the untreated check except the NM treatment; however, there were no differences among the other sub-subplot treatments (Figure 2). In 2010, we will repeat these studies again,

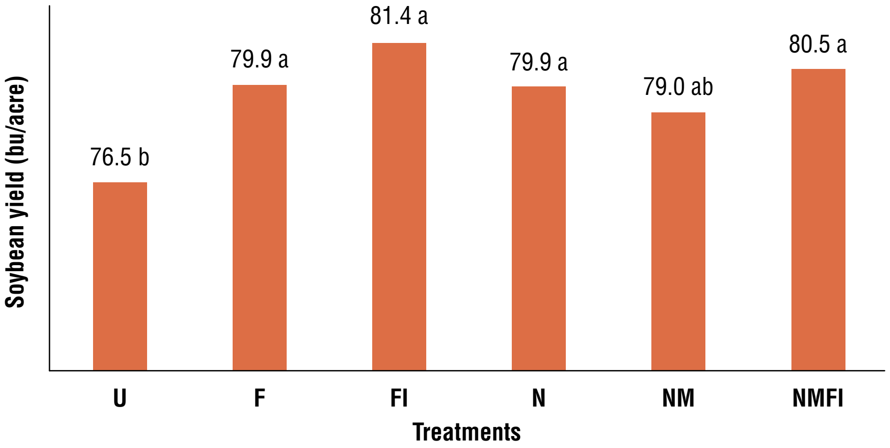

Figure 2 ■ Soybean yields for six sub-subplot treatments: untreated (U); fungicide (F); fungicide plus insecticide (FI); nitrogen (N); nitrogen plus micronutrients (NM); and the combination of all previously mentioned (NMFI). Sub-subplot treatments were averaged over two irrigation main plots (with and without) and two seeding rate subplots (low; 125,000 seeds/acre and high; 250,000 seeds/acre) each replicated four times for a total of 16 replications represented and letters that are same indicate there are no significant differences at the alpha=0.1 level.

and in addition, implement some of our findings in a large-plot, side-by-side University Yield Challenge plot. This will be one of four University Yield Challenge plots in the state.

What is the 'Challenge'? One approach to address both components of the question is the creation of the Illinois Soybean Yield Challenge starting in 2010. The Yield Challenge will be different from typical yield contests in that each on-farm participant will pair an 'investigative plot' with a 'normal practices' plot. The Illinois Soybean Association, the University of Illinois Crop Sciences faculty, and the National Soybean Research Laboratory are cooperating to build a unique, systematic way of harnessing the power of on-farm research to improve soybean yields through farmer teamwork in Illinois. Competition yields will be an average of five fields, and Yield Challenge teams will be grouped according to the nine USDA National Agriculture Statistics Service (NASS) crop reporting districts in the state. This approach helps even out the effects of different soil types and environments across Illinois, and allows us to compare yields with official crop reports. No overall state Yield Challenge winners will be named.

Teams can be sponsored by a company or they can form independently. We hope that many different sectors of the agriculture production industry get involved since many different crop production sectors are advancing technology and products in ways that should enhance yield or improve our ability to manage soybeans. This challenge will contribute to science by providing us hypotheses to test like in the 'high-yield' experiment described above. Hopefully, in the long term, we can validate and refine results for the benefit of all Illinois soybean farmers. For more information about the program, visit www.soyyieldchallenge.com, or contact ISA at 309-663-7692. Registration will continue until April 1, 2010.

Summary: Soybean yields have been increasing in Illinois at about 1/3 bu per year over the last twenty years. It will be a challenge to accelerate soybean yields through additional inputs. Management approaches for high yielding soybean must be constructed in a holistic approach using sound agronomic and pest management recommendations. Research must continue to investigate the factors that limit the highest possible yields; however, on-farm research of both 'contest plots' and 'normal practices' plots will help provide information to increase yields from both the below-average to above-average categories, and the above-average to 'ultra-high' or near maximum yield categories.

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ILLINOIS SOYBEAN ASSOCIATION

Determinants of Grain Farm Profitability

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In this paper, grain farms enrolled in Illinois Farm Business Farm Management were divided into three groups based on per acre operator and farm management returns averaged over four-years. The low group contained one-third of the farms with the lowest returns, the mid group included farms in the middle, and a high one-third group contained one-third of the farms in the highest productivity group. For each group, average yields, prices received for grain, revenues, and costs were calculated. By comparing these averages, some feel for the determinants of profitability can be obtained.

Farms Included in the Study

Farm data came from the Illinois Farm Business Farm Management (FBFM) associations. Within Illinois, acreage on farms enrolled in FBFM account for approximately 25 percent of the acres in corn and soybean production. To be included in results, a farm had to meet the following criteria:

1. Data had to be complete for the years between 2005 through 2008. Results were averaged for four years so as to gain a longer run view of profitability. In any one year, a farm's profit is influenced by weather, pest problems, and other random events. By taking an average over multiple years, impacts of these events are minimized.
2. The FBFM field staff had to certify that the farm records were complete and usable in each year.
3. The farm had to have at least 90% of the acres in corn and soybeans. This criterion focused attention on farms that predominately produce corn and soybeans.
4. Farms had to have to be located in northern or central Illinois and have high productivity farmland. This criterion was included so that results were not impacted by land productivity. Similar results have been generated for lower productivity farmland and for southern Illinois farms producing corn, soybeans, and wheat. These results are not presented here but are available from the author.
5. The farm had to have little livestock revenue (less than $10 per acre) and little custom work revenue (less than $20 per acre). These criteria were meant to focus attention on corn and soybean production.

A total of 583 farms met the above criteria and were included in this study.

Operator and Farmland Returns

Farms were sorted into productivity groups based on operator and farmland returns. Operator and farmland returns measures profitability and equals gross revenue minus non-land costs. Not include in costs are charges for farmland. Farmland charges vary depending on whether farmland is owned, share rented, or cash rented. For farms that are cash rented, cash rent can be subtracted from operator and farmland return to arrive at the return to the farmer. Take, for example, an operator and farmland return of $281 per acre which is cash rented and the cash rent of $200. The famer received returns of $81 per acre ($281–$200).

Operator and farmland returns were averaged for the four years between 2005 and 2008. The farms then were divided into three profit groups. The one-third farms having the lowest returns—i.e., the low group—had an operator and farmland returns of $224 per acre (see Table 1). The mid one-third group has an operator and land return of $281 per acre while the high group had a return of $338 per acre, yielding a $114 per acre difference in returns across the high and low groups. Obviously, this difference is significant and has impacts on overall wealth and financial position.

Revenues and Costs by High and Low Returns Group

The $114 difference in returns between the high and low group was split between revenue and costs (see Table 1). Gross revenue for the high group was $639 per acre, $71 higher than the $567 per acre revenue for the low return group. Higher revenue of $71 accounted for 62 percent of the differences in operator and farmland return from the high and low returns group. Costs for the high group were $301 per acre, $43 higher than the $344 costs for the low returns group. The $43 in lower costs accounted for 37 percent of the difference in profitability between the high and low returns group.

Costs were further broken out into three categories: 1) direct costs include fertilizer, seed, pesticides, drying, and storage; 2) power costs include machinery repairs, depreciation, and hire along with fuel; and 3) overhead costs include hired labor, building repairs and deprecation, insurance, misc, and interest (see Table 1). The high returns group had statistically lower costs in all three cost categories:

1. Direct costs for the high returns group was $8 lower than the low returns group ($156 for the high returns group versus $164 for the low returns group). While these costs were statistically different across the high and low groups, they were the smallest difference across any of the three major cost groups. Direct costs were further broken down into fertilizer, seed, pesticide, and other categories (see Table 1). The high returns group had lower average costs than the low returns group in all these categories; however, the cost differences were not statistically significant. For fertilizer, for example, the high group had $62 per acre of costs, $3 lower than the $64 costs for the low group. This difference, again, is not statistically significant.
2. Power costs for the high return group is $17 lower than for the low returns group ($63 for the high returns group versus $81 for the low returns group).
3. Overhead costs for the high returns group was $17 lower than for ht low returns group ($82 for ht high returns group versus $99 for the low returns group).

The power and overhead costs generally related to long-term decision. For example, equipment purchases influence machinery depreciation in the power category and interest costs in the overhead category.

Yields and Prices

To further examine revenue difference, average yields were calculated for the three return groups (see Table 2). Both yields and prices differed across the three return groups. First take corn. Corn yields for the high group averaged 187 per acre from 2005 through 2008 (see Table 2). The yield for the low

Table 1 ■ Revenue, Costs, and Operator and Farmland Returns by Profit Group, Northern and Central Illinois Grain Farms Enrolled in Illinois Farm Business Farm Management, Averages for 2005 through 2008.

		Return Group[1]		Statistical
	Low	Mid	High	Difference[2]
		$ per Acre		
Gross revenue	567	591	639	*
Costs				
Direct	164	157	156	*
Power	81	69	63	*
Other	99	84	82	*
Non-land costs	344	310	301	*
Operator and farmland return	224	281	338	*
Direct cost categories				
Fertilizer	65	62	62	
Seed	45	44	44	
Drying	37	36	34	
Other	17	15	16	
Total direct costs	164	157	156	*

[1] Divided into three-groups based on operator and farmland return. The low group has one-third of the farms with the lowest returns, the mid group had one-third of the farms in the middle, and the high group had one-third of the farms with the highest returns.

[2] Stars indicate statistically significant differences between high and low group at a 5% test level.

Table 2 ■ Yields, Prices, Acres, and Percent Corn, Northern and Central Illinois Grain Farms Enrolled in Illinois Farm Business Farm Management, Averages for 2005 through 2008.

			Return Group[1]		Statistical
	Unit	Low	Mid	High	Difference[2]
Yield					
Corn	bushels/acre	177	181	187	*
Beans	bushels/acre	52	53	55	*
New-crop price					
Corn	$/bushel	3.06	3.10	3.22	*
Bean	$/bushel	7.63	7.78	7.95	*
Old-crop price					
Corn	$/bushel	2.93	2.93	3.02	*
Bean	$/bushel	7.31	7.36	7.46	*
Tillable acre		877	1,095	1,197	*
Percent tillable acres in corn		55%	54%	57%	

1 Divided into three-groups based on operator and farmland return. The low group has one-third of the farms with the lowest returns, the mid group had one-third of the farms in the middle, and the high group had one-third of the farms with the highest returns.

[2] Stars indicate statistically significant differences between high and low group at a 5% test level.

return group was 177 bushel per acre, or 10 bushels lower than the high returns group.

Prices are divided out into new-crop price and old-crop price. New and old-crop prices relate to the timing of grain sales relative to production. In 2008, for example, the new crop price relates to grain produced in 2008 and sold in 2008. The 2008 old crop price relates to grain produced prior to 2008 but sold in 2008. The prices shown in Table 2 are averaged over the four years from 2005 through 2008.

Farms in the high group had an average new-crop corn price of $3.22 per acre, compared to $3.06 for the low returns group. This is a difference of $.16 per bushel. The old-crop price also differed. The high group averaged a $3.02 per bushel corn price compared to $2.93 for the low group. This is a difference of $.09 per bushel between the high and low returns group.

Similar results occur for soybeans. Soybean yields for the high group averaged 55 bushels per acre, compared to 52 bushels for the low return group. The high group averaged $7.95 for a new-crop soybean prices as compared to a $7.63 new-crop price for the low group.

Farm size

Farms in the high returns group have more tillable acres than farms in the low returns group. Tillable acres average 1,197 for the high return group compared to 877 for the low returns group (see Table 2). This reflects some economies of size in grain farm production. However, some smaller farms have high returns and some larger farms have low per acre returns. Size is not automatically related to profitability.

Percent Acres in Corn

Recently, corn production has been more profitable than soybean production. In general, farms in the high returns group have slightly higher percent of their tillable acres devoted to corn production; however, differences were not statistically significant. Farms in the high returns group had 57 percent of their acres in corn production as compared to 55 percent for the low production group (see Table 2).

Figure 1 contains a scatter plot showing operator and farmland returns for different percent of tillable acres in corn. As can be seen, there may be a slight increasing trend for farms growing a higher percentage of their acres in corn; however, there is a great deal of variability.

Summary

Over four years from 2005 through 2009, operator and farmland returns varied considerable across grain farms included in this study. Farms with higher returns have statistically higher yields, received higher prices, and had lower costs. While high return farms had higher yields, the higher return farms did not spend any more than low return farms on fertilizer, seed, and chemicals. Hence, the results do not suggest that high return farms spend any more on production inputs.

None of the differences shown in this study would necessarily be observable. For example, a 10 bushel difference in yields over a four year

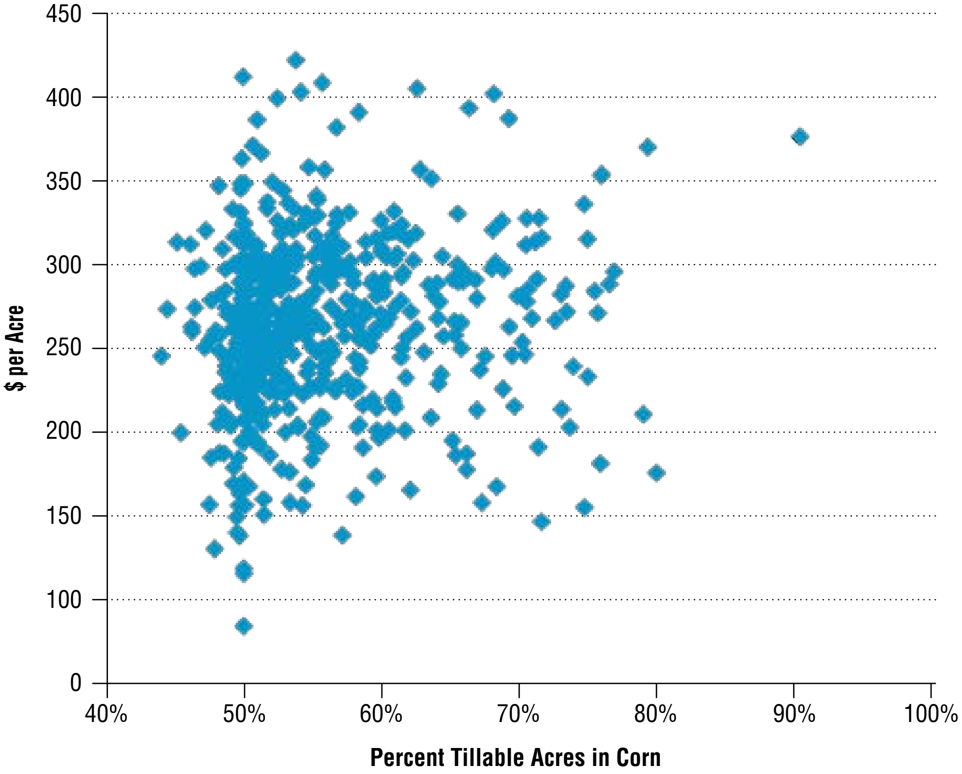

Figure 1 ■ Operator and Farmland Returns by Percent Tillable Acres in Corn, Illinois FBFM Grain Farms in Northern and Central Illinois, Averages for 2005–2008.

periods would not be observable without finding averages across all fields over a field records. In other words, detailed records are needed are needed to detect differences. This fact illustrates the competitiveness within the grain farm industry and that finding additional profits is not an easy process. Note also that high profit farms had better performance in most categories. This fact points out that generating profits within the grain industry requires attention to all details and is not a simple process.

Corn Traits and Hybrid Performance

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Forty or fifty years ago, we had insecticides—some (rightly) under attack at the time for causing environmental and health problems due to widespread and careless use—for most of the major insect pests of corn. At that time, herbicides developed for corn had to be safe (or mostly safe) for corn, and we didn't give too much thought to the idea that we could instead make crops safe for the herbicides we might have.

After glyphosate appeared as a very effective and environmentally safe herbicide in the 1970s, we began to dream about the possibility of developing crops on which we could use this herbicide. As a graduate student in the early 1980s, I helped screen chemically mutated soybean seeds for their tolerance to glyphosate. That didn't work out, but we did have some cultured plant cells that could grow after addition of glyphosate at levels that stopped growth of normal cells. Finding such a genetic difference made it seem possible that we might one day have crop plants that could survive this herbicide.

The Bt toxin against produced by the *Bacillus thuringiensis* bacterium had been known as an insecticide for more than 100 years, and was in use many years ago as a granular material (produced by the bacterium) against various caterpillars. This material was known to be effective against European corn borer larvae, but its cost and difficulty of getting it on young ECB caterpillars made it a less-than-ideal control method.

When scientists learned how to cut up genetic material (chromosomes) and to transfer pieces of them (genes) into other organism in the 1980s, plants were a primary target for this process, called "transformation." The "product" of a gene is a protein, often an enzyme that enables other processes in the plant. Moving a gene usually involved taking plants down to single cells or clumps of cells, shooting the desired gene into these cells or letting a tumor-forming bacterium do that job, growing the cells into plants, then testing the small plants to see which ones have the new, working gene. This is rather crude, and usually requires making huge numbers of attempts for only a few successes. New methods such as "zinc finger nucleases" are helping make this process more precise, but it still is a hit-or-miss process.

New "transgenes" not only have to be moved to the "target" plant, but they also have to work correctly, with controls in place so they don't produce too little or too much of their product. This means that along with the gene we want, we usually have to move one or more "control" genes or gene sequences. The gene we want plus the genetic material that helps to control its activity are commonly referred to as an "event."

Once we have moved a gene into a corn seedling and grown up a plant that contains the gene in its DNA, the new plant is almost never a very good plant from which to start breeding better hybrids. Moving the gene from this "donor" plant into top hybrids initially involved (and in some cases still involves) a "backcrossing" process, with high-yielding lines crossed with the line that contains the new gene, and with offspring screened to find which ones have the gene. These offspring are again crossed with the high-yielding line and screened, and this process is repeated in order end up with high-yielding lines that still contain the new gene but not many other genes from the donor plant. Half the genes from the donor line are lost with each cycle. After ten cycles of backcrossing, 99.9% of the genes are from the high-yielding parent line. Corn has an estimated 30,000 to 50,000 genes, so the 0.1% of genetic material left over from the donor line might be as many as 30 to 50 genes. In addition, the new gene might carry along some "bad" genetic material that might affect the new hybrids in unpredictable ways.

The first genetically modified (GM) corn for which a registration was granted was Event 176 from Mycogen and Syngenta (then Ciba Seeds), for which licensing was granted in 1995. It was a European corn borer (CB) Bt event that included glufosinate tolerance, whose gene was inserted along with the Bt gene so the herbicide could be used to screen for plants that had Bt (plants without Bt, which were also without glufosinate resistance, died.) Different CB Bt events appeared over the next few years, including ones from Monsanto (MON 810, or YieldGard), Syngenta (Bt 11, or Agrisure), and Dow/Pioneer (TC 1507, or Herculex I). In 2003 the first registration was granted for corn rootwork Bt events, which included MON 863 (YieldGard RW), in 2003 and Dow (then Pioneer) 591227-7 (Herculex RW) in 2005. During this period "stacks"—combinations of different Bt events, such as MON 810 + MON 863 (YieldGard Plus)—were developed and approved. Other events were developed that had activity against caterpillars besides ECB; for example, DAS-06275-8 from Dow listed activity against some 20 insects, including corn earworm and some cutworms. In recent years some of these different traits have been incorporated into single hybrids; for example, "SmartStax" hybrids, approved in 2009, have six different Bt events.

The development and transfer of genetic events for herbicide tolerance took off after the approval of glyphosate tolerant (Roundup Ready) corn (event MON 802 from Monsanto and GA21 from Syngenta, at the time Zeneca) in 1997. Soon these events were being stacked with different Bt events, and "triple-stack" hybrids, with Bt events for CB and RW along with glyphosate tolerance forming the combination of traits most common since 2005-2006. More recently, Pioneer has applied for approval of its GAT trait, which has both glyphosate and ALS inhibitor herbicide tolerance. New genes for glyphosate tolerance have also been found, and work continues to identify different Bt genes for control of more insects, and to find and develop more herbicide tolerance traits.

To date the only commercial traits we have in corn are plant-produced insecticides (Bt) and herbicide tolerance. Several others—like drought tolerance, high lysine, and heat-tolerant alpha-amylase (which helps break down starch to start ethanol production)—are in various stages of development or approval in corn. Other transgenes, including ones for disease resistance, improved quality, and improved nitrogen use efficiency are also on the drawing board. While it is possible that some of these may contribute to yield, it seems likely that most increases in genetic yield potential over the next decade will come from "conventional" plant breeding. This will be aided by genetic markers and techniques used in developing transgenes, but it will still require large amounts of crossing and finding higher-yielding hybrids using the genetic variability present in corn.

Do transgenes increase corn yields?

There is no question that Bt genes that effectively prevent insect damage, especially in the case of European Corn Borer where chemical controls are not very effective, and in some cases in corn rootworm, have helped to increase yields of corn. As an example, RW Bt corn hybrids grown following corn at

Monmouth in 2006 yielded 73 bushels per acre more than did non-RW Bt hybrids in the same trial, even though both sets of hybrids yielded about the same when they followed soybean (Figure 1.) Soil-applied insecticide was used in both trials, but was clearly inadequate to fully protect against yield loss in corn following corn for those hybrids without rootworm Bt.

Since 2006, hybrids entered into the trials at Monmouth have been increasingly those with rootworm Bt; as early as the next year (2007), 50 of the 55 entries in these trials were RW Bt, and the five that weren't RW Bt performed about as well in corn after corn as in corn following soybean (Figure 2.) This reflects the fact that corn rootworm pressure was not very high, or at least that rootworm could be controlled by use of soil insecticide that year. In 2008, we saw virtually the same thing as in 2007, but the average of the hybrids in the corn following corn trial was 8 bushels higher (236 versus 226) than in the trial where the same set of hybrids followed soybean. In 2009 at this location, all hybrids were triple-stacked, and the average for corn following corn was about 8 bushels less than corn following soybean.

The question about whether current GM traits by themselves (that is, in addition to their effect on protecting the crop) affect yield is a difficult one to answer. To answer it would require sets of hybrids that differ only in the presence or absence of individual GM traits: hybrids that differ in only one gene are called *isolines*. Because during the backcross process we generally end up with hybrids that are at least slightly different genetically from the hybrid we started with, getting true isolines is usually not possible. And, with such a high percentage of the hybrids today sold as "traited" (GM) versions, very few non-GM isolines are available for sale even if they exist.

There is no known physiological reason why we would expect available GM traits by themselves to affect grain yield. Bt genes equip the plant to

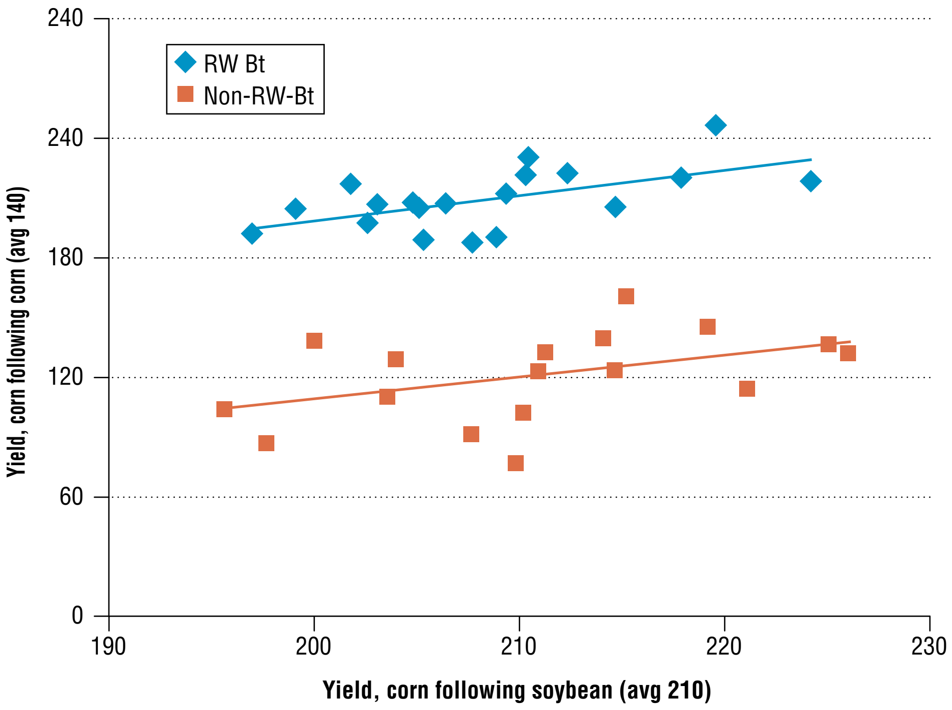


Figure 1 ■ Yields of the same hybrids in the 2006 corn hybrid trials in which corn followed soybean and corn followed corn at Monmouth, Illinois.

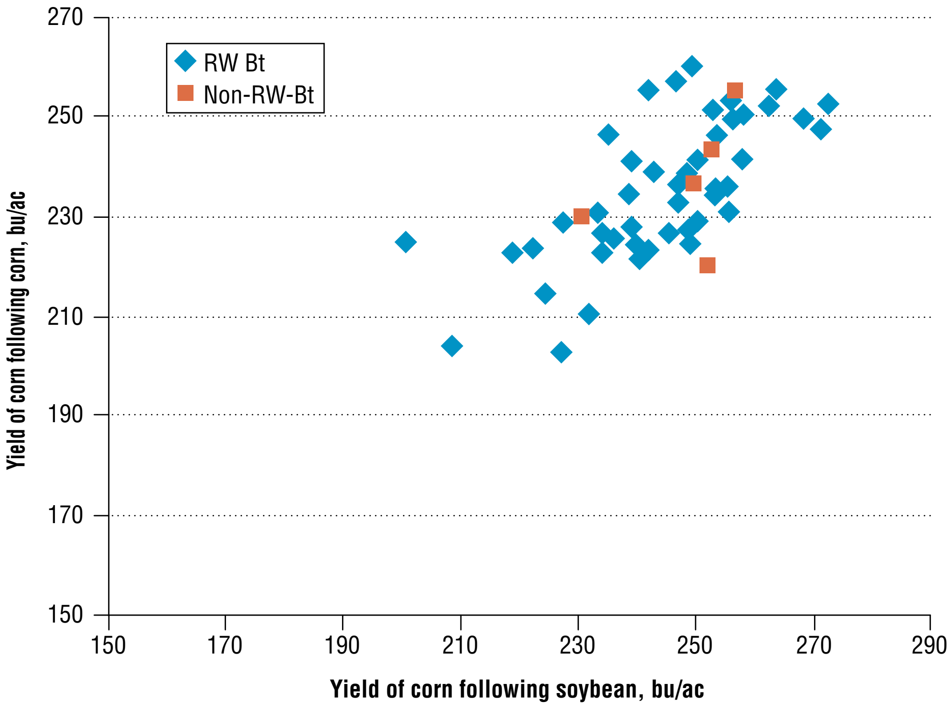


Figure 2 ■ Yields of the (same) hybrids entered into the 2007 corn following soybean and corn following corn trials at Monmouth, Illinois. Yield averages were 235 bu/acre following corn and 245 bu/acre following soybean.

make the crystalline proteins that attack the gut of insects and kill or injure larvae. Making protein costs the plant energy that might otherwise go to make yield, which could affect yield. But the amount of Bt protein produced in a corn plant is very small (on the order of 10 parts per million in young tissue; less than this in older plants) and producing such tiny amounts of protein would not be costly to the plant. Herbicide resistance GM traits typically are genes that produce slightly different (but still active) herbicide target enzymes, so that the herbicide no longer attacks this enzyme. The cost to the plant for this type of trait should be close to zero, since the plant has to make that enzyme anyway.

Several years ago, when versions of hybrids advertised as differing only in the presence of GM traits were more commonly available, we did a few studies designed to look at the effects of GM traits. Keeping in mind that these were probably not "true" isolines, we found in one study that RW Bt yielded about 4 bushels more than the conventional hybrid, and CB Bt yielded 6 bushels more than RW Bt, or about 10 bushels more than the conventional hybrid. This was without ECB pressure, and rootworm insecticides were used.

While it is usually not possible to get GM and non-GM corn isolines to compare today, we found in a recent study that two "triple-stack" hybrids did not yield consistently more than their "refuge" (glyphosate tolerant) counterpart hybrids (Figure 3). The differences among the locations were possibly due to differences in corn rootworm pressure, though we can't rule out other factors. In a second study, we found that a triple-stack hybrid compared to its "refuge" (RR) counterpart treated with soil-applied insecticide actually yielded less than the refuge hybrid at 7 of 12 sites (Figure 4.) Pressure from rootworms was light at most of these locations as well.

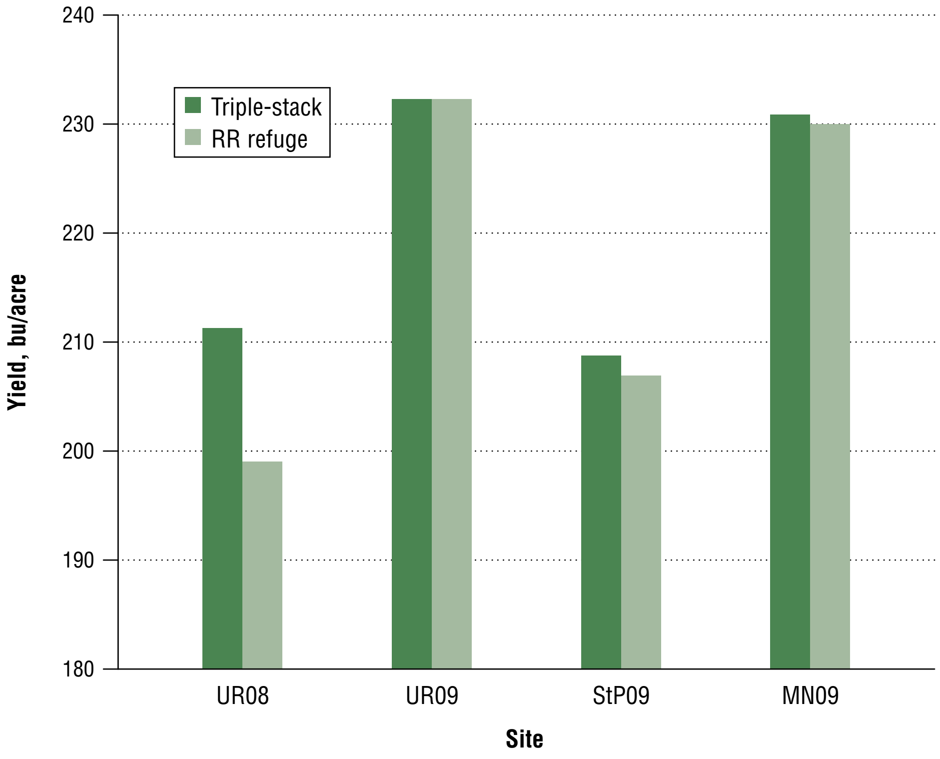


Figure 3 ■ Yields of two pairs of triple-stack and “refuge” (RR only) hybrids at four Illinois sites. The only significant difference was at the UR08 site.

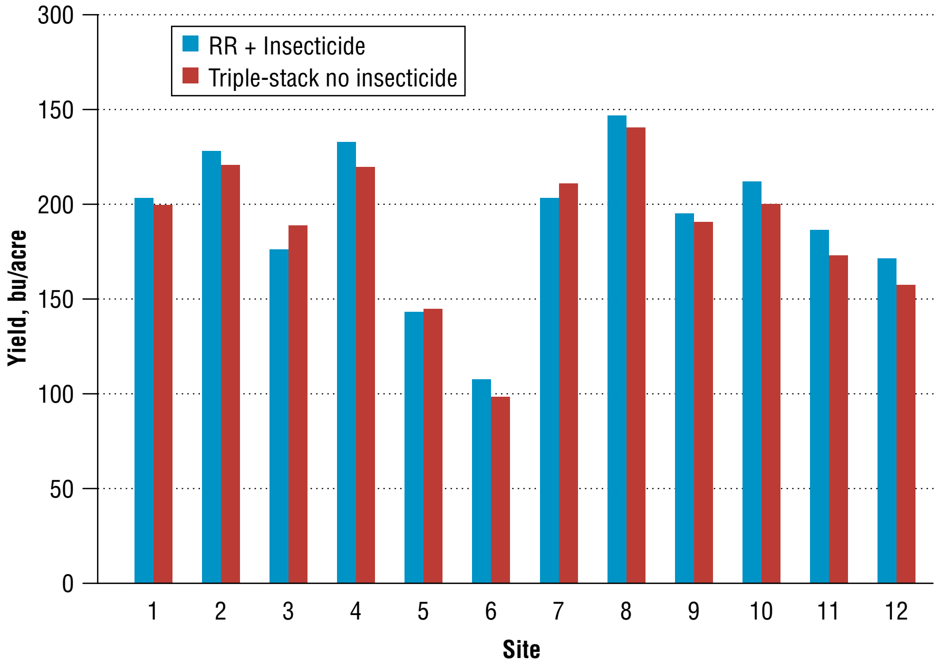


Figure 4 ■ Yields of triple-stack hybrids without soil insecticide and RR-only “isoline” hybrids with insecticide at 12 Illinois sites. Triple-stack hybrids yielded significantly more than RR hybrids at two sites (3 and 7), there was no difference at three sites (1, 5, and 9), and RR+insecticide yielded significantly more at the other seven sites.

Traits or Hybrids?

In the University of Illinois corn hybrid trials, entries are made by seed companies. In the 2009 trial in the West region (chosen as representative), only 8 of 131 entries (6 percent) were non-GM hybrids, and 119 entries (91%) were "triple-stack" or "quad-stack", with both RW and CB Bt genes and either one or two traits for herbicide tolerance (Table 1.) Only 4 entries were without RW Bt and only 2 entries were without CB Bt traits. With such an overwhelming majority of hybrids entered with multiple traits, and so few that could possibly be isolines, trying to estimate yield effects of GM traits from such data is impossible. For what it's worth, no group seemed to have a clear advantage over another group in this trial.

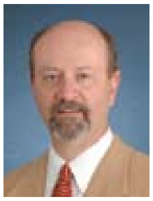
In summary, it is clear that there are many very good hybrids on the market today, and that genetic yield potential of modern hybrids has been improved substantially over recent decades. It is much less clear that the insertion of GM traits for plant-produced insecticides and for herbicide tolerance has contributed a great deal to this improvement. While we don't have non-GM hybrids available for most of today's elite corn hybrids, it is not clear that such hybrids would yield much if any less than their GM counterpart hybrids, especially under light pressure from the pests that the GM traits are designed to counter.

While we welcome the continued improvement in corn genetics that we expect to see, it is not clear that the GM traits that have been announced as being under development—drought tolerance, nitrogen use efficiency, others—will by themselves contribute to yield, though they will certainly end up in high-yielding hybrids. For now, it is important to look at hybrid performance and to choose those hybrids that provide the best return for the seed dollar invested. This does not mean ignoring the potential benefit of the GM traits when problem years occur—it may be wise to try to factor in the estimated cost and return from the use of GM hybrids against "average" pest pressure even when data from low-pressure sites shows little yield advantage to the GM hybrids.

Table 1 ■ GM traits, number of entries, and average yields by trait category in the western Illinois corn hybrid trials in 2009. Data are averages over three locations.

GM traits for Insects	GM traits for Herbicides	No. of Entries	Average yield
CB	RR	1	225
CB	RRLL	1	244
CBRW	LL	5	235
CBRW	RR	87	238
CBRW	RRLL	27	237
None	RR	2	243
None	None	8	231
	Total	131	237

Managing Insect Pests in a 5% World: A New Odyssey



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Introduction of SmartStax™ Corn Hybrids

In 2010, Monsanto Company and Dow AgroSciences through a cross licensing agreement will commercialize multi-event (MON 88017, MON 89034, DAS-59122-7, TC 1507) SmartStax™ corn hybrids that express simultaneously multiple Cry proteins (Cry3Bb1, Cry1A.105, Cry2Ab2, Cry34/35Ab1, Cry1F) targeted against both the lepidopteran complex and corn rootworms as well as provide herbicide tolerance to two herbicides (glyphosate and glufosinate). It is anticipated that enough transgenic seed will be sold to plant an estimated 3 to 4 million acres of corn in the United States. Of special interest to producers is the significant reduction in the structured refuge requirement by the U.S. Environmental Protection Agency (EPA) from 20% to 5% for above and below ground insects within the Corn Belt. The structured refuge requirement for SmartStax™ corn hybrids planted within the Cotton Belt has been reduced from 50% to 20%. This commercial launch has generated considerable excitement among producers because of the anticipated broad spectrum insect control, increased flexibility of herbicide use, reduction in the refuge requirement, and the potential for increased yields. Of concern is the persistent trend towards greater overall production costs incurred by producers.

Refuge-in-a-Bag Concept

At the time of this writing, Pioneer Hi-Bred International, Incorporated, continues to seek U.S. Environmental Protection Agency (EPA) approval for a new product referred to as Optimum® AcreMax™ 1. This product is intended to offer producers a new approach for the implementation of a refuge for corn rootworms, the so-called "refuge in a bag." According to a Pioneer Hi-Bred Technical Bulletin (08-1743, 08-2020, page 2): "Pending Environmental Protection Agency (EPA) approval, Optimum AcreMax 1 products would feature a combination of two versions of a hybrid in a single bag. Each bag would contain not more than 98% of a Pioneer® brand hybrid with Herculex XTRA (CRW/CB/LL) insect protection—a combination of the Herculex RW and Herculex I (CB/LL) traits. Each bag also would contain no less than 2% of a hybrid with the Herculex I trait that will satisfy the corn rootworm refuge requirement for the field."

On February 23-24, 2009, a FIFRA Scientific Advisory Panel was convened to evaluate the potential risks for resistance development by using a seed mix refuge of Optimum® AcreMax™1 for corn rootworm protection. As I discussed earlier this year in an article published in the *Pest Management and Crop Development Bulletin* (Issue No. 9, May 22, 2009), "contrary to the tone of some popular press articles, there remain some very significant challenges to the implementation of this concept for corn rootworm resistance management, especially at the lower range of seed mixture refuges. The full report (minutes of the meeting) are available at the following website: http://www.epa.gov/scipoly/sap/meetings/2009/february/232009finalreport.pdf. The overall report is quite lengthy and not an easy read. Provided below are direct quotes taken from the summary of panel discussions and recommendations, pages 6–8 of the report."

- "Overall, the Panel concluded that there are uncertainties with the scientific data supporting Pioneer's proposed seed blend, Optimum® AcreMax™1, and clear problems with reducing the refuge size."
- "The Panel generally agreed that data presented by Pioneer and data found in the public literature provide no compelling evidence to reduce the proportion of non-Bt plants (either as a seed blend or spatial refuge) from 20% and there was strong concern with the request for any reduction in the refuge size with a seed blend of 5% or less."
- "Data were not presented that supported a claim that potential yield losses justify a seed blend of no greater than 5%."
- "The Panel supported the recommendation to conduct additional research with various percentages of seed mixtures to determine any effects on yield."
- "Therefore, the Panel concluded that, based on the current science, it would be reasonable to commercially use 20% seed blend refuges while research suggested by the committee and other research projects are conducted to examine the performance of the seed blend strategy."
- "The Panel agreed with EPA that there is uncertainty with regard to whether the mode of action of Cry34/35Ab1 is through a toxic or repellent mechanism."
- "In summary, most Panel members believed that corn rootworm biology seems to lend itself to the seed blend concept and that while the seed blend refuge concept has merit, the Panel had concerns regarding the reduction in refuge size. However, the Panel also believed that it is vital to preserve the Bt CRW biology and was significantly concerned about the proposal to move to both a seed blend refuge and a drastic reduction in refuge at the same time."

The full report developed by the Scientific Advisory Panel is advisory to the United States Environmental Protection Agency (EPA). As of the writing of this paper, no ruling on the request by Pioneer Hi-Bred International, Incorporated has been made public.

Is the Widespread Use of Bt Hybrids Warranted?

With the commercialization of SmartStax™ corn hybrids and the potential approval to plant Optimum® AcreMax™1 corn hybrids utilizing the refuge-in-a-bag strategy, producers will have the opportunity to provide a near complete "blanket" of insect protection across their fields. This "blanket" will provide broad coverage for the lepidopteran complex and corn rootworms in cornfields throughout the Corn Belt. Since the introduction of Bt corn hybrids aimed primarily at the European corn borer in 1996, entomologists have tracked steady declines in the density of this once prominent insect pest of corn. In recent years, we have witnessed historically low numbers of European corn borer throughout the state of Illinois. In 2009, many observers noted that western corn rootworm densities seemed very low as well. Most certainly, the heavy rains that occurred during the spring and led to saturated soils may have contributed to significant larval mortality of corn rootworms soon after hatch occurred in late May and early June. However, the frequency of reports regarding the low numbers of western corn rootworms has prompted us to consider conducting some more formal surveys of western corn rootworms throughout the state in 2010. These data would be compared with western corn rootworm survey data collected in the 1970s. Will the escalating use of Bt corn hybrids eventually contribute to historically low levels of western corn rootworms, similar to what has been observed with the European corn borer? Perhaps, particularly as we see more Bt hybrids enter the market place with pyramided genes responsible for the expression of multiple Cry proteins. Is this broad spectrum of insect control warranted? Are there some similarities with the widespread planting of transgenic corn hybrids to the use of broad spectrum and highly persistent insecticides across the agricultural landscape in the 1950s and 1960s? Has insect management in corn on large-scale commercial farms "evolved" into an insurance based approach? From now on, will most producers only need to concern themselves with insect injury on 5% of their corn acres? Will they bother to even scout for insect damage on these non-transgenic corn acres? Will this limited number of non-transgenic corn acres be a sufficient market for the manufacture and distribution of soil insecticides once targeted at key insect pests? It seems worthwhile for those engaged in commercial corn production to ponder these questions as we move forward in this agricultural revolution. My thoughts on these questions will be addressed during my remarks in January.

Although Bt corn hybrids provide broad insect protection (corn rootworms and many species within the lepidopteran complex), there are several secondary insect pests that are not controlled by Cry proteins. These include soil insects such as wireworms, white grubs, and grape colaspis larvae. In order to limit injury to corn seedlings caused by these secondary insects and others, the seeds of Bt corn hybrids are treated with neonicotinoid insecticides, either Poncho® (clothianidin) or Cruiser® (thiamethoxam). Rates of these systemic insecticides are typically low (0.25 mg a.i. per seed). Heavy infestations of secondary insects have been reported to overwhelm the protection of these insecticidal seed treatments in some instances. Of concern is the widespread exposure of the secondary insect complex to the neonicotinoid insecticides now so commonly used in the corn and soybean production system of the United States.

Surveys of Secondary Insects—What Do These Data Reveal?

The potential for the development of resistance to these insecticides should be taken seriously. How often are secondary insect pests a legitimate threat to commercial corn production? Does this threat warrant such widespread use of these insecticidal seed treatments? Or, are these products now being used primarily as an insurance approach to pest management, similar to the ubiquitous use of Bt hybrids? Some insect surveys conducted in the 1950s and early 1960s by entomologists with the Illinois Natural History Survey shed some light on these questions.

From 1954 to 1963, J.H Bigger and H.B. Petty, sampled corn plants (2,760) from 452 cornfields across Illinois (the majority of fields were in the northern 2/3 of Illinois) for injury caused by one of the following groups or species of insects: wireworms, white grubs, the cornfield ant, the corn-root aphid, corn rootworms, and grape colaspis larvae. All plant samples (initially, "five-hill sample"—changed to five plants per field) were taken in untreated portions of producers' fields. Results from the 10-year investigation revealed the overall percentage of fields infested (Table 1) was relatively low for wireworms (51%), corn rootworms (29%), white grubs (22%), and grape colaspis larvae (10%). Infestations of corn rootworms were either caused by northern (dominant species) or southern corn rootworms. The western corn rootworm was not detected in Illinois until 1964, a year after the conclusion of this investigation. The overall percentage of plants infested (Table 2) was even lower for wireworms (19%), corn rootworms (18%), white grubs (7%), and grape colaspis larvae (4%). The complex of insects within a cornfield is very dependent on the cropping history of a given field. The entomologists who led this survey effort recorded the crop history for each field they sampled. The number of cornfields over the 10-year investigation with the following cropping history was as follows: corn following grass—19, corn following clover—82, corn following alfalfa—35, corn following soybeans—46, corn following small grains—26, corn following 2nd year corn—132, and corn following 3rd year corn—106. Cropping rotation practices have changed considerably since this survey was concluded in the early 1960s. Now the corn and soybean rotation dominates the agricultural landscape of Illinois and is much less likely to precipitate infestations of wireworms, white grubs, and the grape colaspis. Wireworms and white grubs are more likely to be severe problems when corn is planted into fields that have served as grassy pastures and grape colaspis grubs are more common when corn follows clover or alfalfa. These rotations are far less common today. Therefore, it seems fair to speculate that these secondary soil insects may infest fewer cornfields and plants now than they did in the 1950s and 1960s. Yet, due to the large surge in the use of Bt corn hybrids (stacked gene Bt hybrids in Illinois—59% in 2009, USDA Economic Research Service), secondary insects are exposed increasingly to neonicotinoid insecticides raising the odds that resistance may become an issue. In addition, non-target insects also are exposed in an increasing number of cornfields in which corn insect pests are most likely at sub-economic levels. The use of a Bt corn hybrid within a producer's field is most typically not based upon scouting and the use of economic thresholds. Nor do we see much integration in the use of insect management tactics within cornfields across the Corn Belt. Instead, we see Bt hybrids (treated with neonicotinoids) used as an insurance program against perceived insect threats. This clearly does not fit into the traditional IPM framework that was envisioned slightly more than 50 years ago by Vernon Stern and his California colleagues who authored a very influential paper on this topic. Their paper (Hilgardia, Volume 29, Number 2, pages 81–99), *The Integrated Control Concept*) introduced us to concepts such as economic thresholds, economic injury levels, general equilibrium position of insects, natural control, and the importance of integrating management tactics. As they addressed in their paper, failure to adhere to an integrated pest management approach could lead to a variety of problems, including the development of resistance.

Insect Management and the Bt "Syndrome"

In 2010, Corn Belt producers who are able to purchase SmartStax™ corn hybrids will be able to plant 95% of a given cornfield to one of these pyramided Bt hybrids. The 5% refuge will most likely be planted with a corn hybrid treated with a higher dose of a neonicotinoid insecticidal seed

Table 1 ■ Percentage of farmers' fields in Illinois infested with soil insects based upon surveys of 452 untreated (no insecticide) fields from 1954 to 1963, by J.H. Bigger and H.B. Petty, published in 1965 by the University of Illinois Agricultural Experiment Station, Bulletin 704.

Year	Number of Fields Sampled	Wireworms	Corn Rootworms	White Grubs	Grape Colaspis
1954	58	59	12	41	16
1955	72	69	17	28	8
1956	36	39	31	50	0
1957	35	51	31	17	6
1958	29	52	28	21	7
1959	47	49	32	17	21
1960	47	45	43	15	15
1961	60	48	37	13	7
1962	42	67	26	10	12
1963	26	31	35	8	8
10 Year Summary	452	51	29	22	10

Table 2 ■ Percentage of plants infested with soil insects based upon surveys of 452 untreated (no insecticide) Illinois fields from 1954 to 1963, by J.H. Bigger and H.B. Petty, published in 1965 by the University of Illinois Agricultural Experiment Station, Bulletin 704.

Year	Number of Plants Sampled	Wireworms	Corn Rootworms	White Grubs	Grape Colaspis
1954	355	27	14	12	5
1955	435	23	11	13	1
1956	255	11	18	20	0
1957	215	19	15	4	2
1958	190	22	16	4	3
1959	285	18	27	4	13
1960	255	18	24	5	10
1961	375	19	26	3	3
1962	260	25	14	1	3
1963	135	12	11	1	3
10 Year Summary	2,760	19	18	7	4

treatment and/or a conventional soil insecticide will be applied at planting. As the percentage of cornfields increasingly become Bt fields, we are witnessing an unprecedented transition away from the conventional IPM paradigm used for generations in commercial cornfields. Clearly there are advantages to this approach when one considers the overall reduction (pounds in the ground) of soil insecticides and the reduced exposure of producers to insecticides during calibration and planting. This is good news. In addition, perhaps we need to begin thinking of integration differently. Instead of integrating traditional management tactics, we are now, via the use of SmartStax™ corn hybrids in 2010, integrating multiple genes in corn plants that are responsible for the expression of different Cry proteins. Despite the many clear advantages of Bt corn hybrids, some cautionary notes seem prudent.

At the 2009 Corn and Soybean Classics, a significant majority of producers indicated they planted Bt hybrids in 2008 (Figure 1). Interestingly, a majority of producers also were likely to use a Bt hybrid even though anticipated damage levels were low for corn rootworms and European corn borers (Figure 2): Bloomington (76%), Champaign (86%), Malta (76%), Moline (79%), Mt. Vernon (87%), and Springfield (73%). Granted, many producers acknowledged that access to elite high-yielding germplasm necessitated their purchase of a Bt hybrid in 2008. Fortunately, a large majority of producers who planted Bt hybrids in 2008 indicated that they planted a 20% refuge according to recommended guidelines (Figure 3): Bloomington (85%), Champaign (85%), Malta (76%), Moline (76%), Mt. Vernon (83%), and Springfield (85%). Will this level of refuge compliance be maintained if the 5% structured refuge becomes the norm in the Corn Belt? Or, will many producers ignore what may be perceived as an insignificant and bothersome requirement? Will producers who do not purchase SmartStax™ hybrids continue to plant other Bt hybrids at the 20% refuge level when their counterparts (those that plant SmartStax™) are using a 5% refuge? Will the use of structured refuges become more unpopular and non-compliance a more significant issue? Answers to these questions will require some time to sort out in the market and regulatory arenas.

In the early 1980s, two entomology professors published a very insightful and controversial paper titled: *Insect Management and the Pesticide Syndrome* (Environmental Entomology, Volume 10, Number 5, pages 567–572. On pages 571 and 572 of this paper, they offered the following summary remarks:

> "In summary, it appears that farmer reluctance to change practices may be due to a false assessment of the need and benefit of insecticide usage. This assessment is currently supported by all elements associated with insect control, including agribusinesses, universities, and the USDA. Insecticides are beneficial production tools in instances where insect pressure exceeds economic damage levels. They are, however, frequently used in insurance fashion against insect-related yield losses and in many instances are not needed. Thus, an

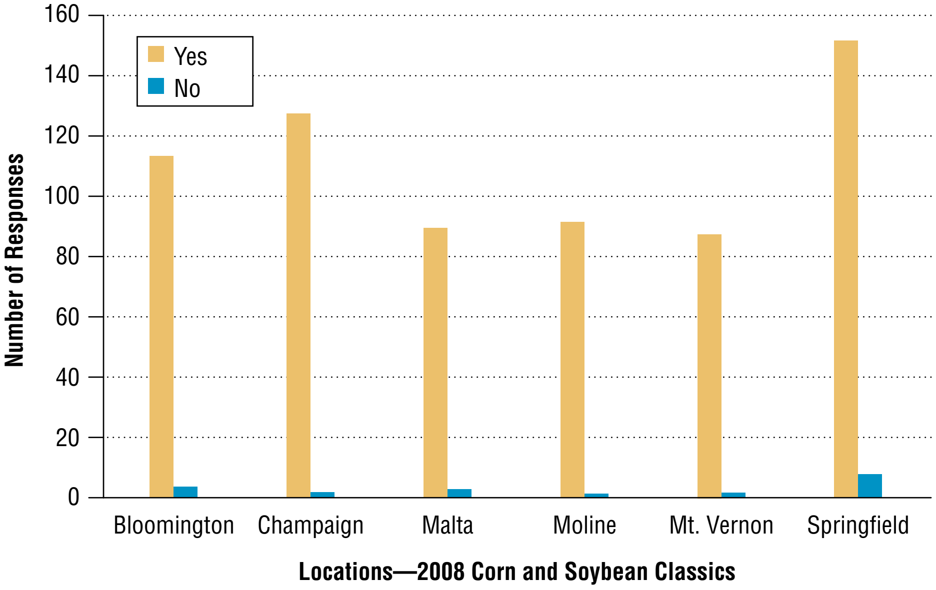

Figure 1 ■ Did you plant a Bt hybrid in 2008?

insecticide treatment syndrome has developed in U.S. agriculture. The syndrome is continually reinforced by the direct and indirect efforts of the pro-insecticide forces. Attempts to implement insect management confront directly those forces that benefit from continued use of insecticides. This confrontation and the resulting rhetoric war will subside only when the anti-insecticide groups are willing to accept that such materials play a critical and likely permanent role in pest management. In addition, the agrichemical industry, university, and related groups must accept that decisions on insecticide use must

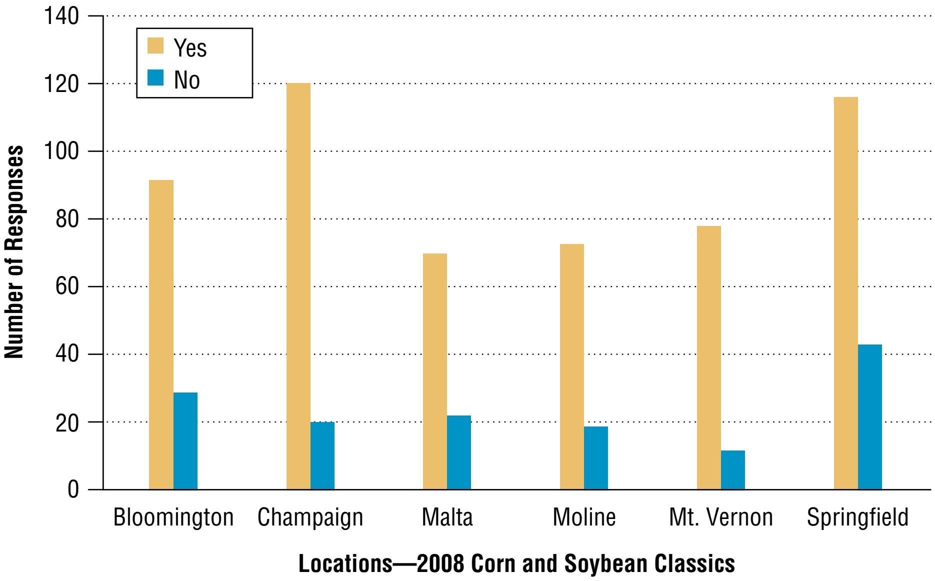

Figure 2 ■ Would you plant a Bt hybrid for CRW or ECB control knowing that anticipated damage levels were low?

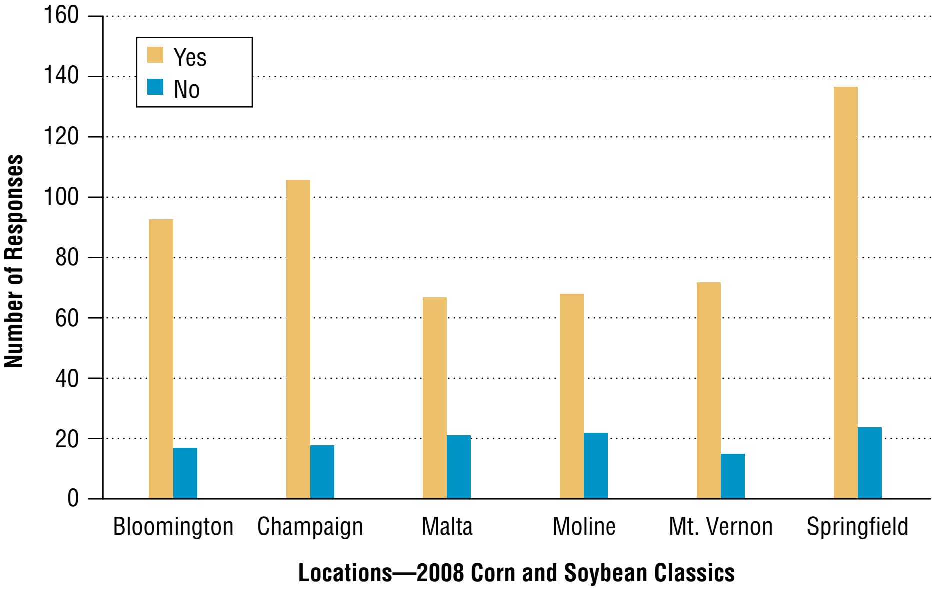

Figure 3 ■ If you planted a Bt hybrid in 2008, did you plant a 20% refuge according to the suggested guidelines?

be objective and realistic attempts to optimize pest management strategies."

In reviewing this paper, particularly the summary remarks, I was struck by the similarities with the current escalating use of Bt corn hybrids. As producers make their seed selection choices for 2010 it seems appropriate to ask the following questions: 1) Is the use of this Bt corn hybrid targeted at a likely economic infestation of insects within this field? 2) Did I scout this field the preceding year for potential future insect infestations? 3) Does the increased cost of Bt seed justify its use in a particular field? 4) Do I have access to other non-Bt elite corn germplasm? 5) If I elect to use a non-Bt corn hybrid, will I make the time to scout, inform myself of the economic thresholds for various insect pests, and apply a rescue treatment if needed? Based upon the answers to these questions, the prophylactic use of Bt hybrids may or may not make the most sense for a producer.

2009 Performance of Bt Corn Rootworm Hybrids and Soil Insecticides

In 2009, efficacy trials were established for corn rootworms at four of the University of Illinois Research and Education Centers (Table 3). All plots were planted into trap crop areas (late-planted corn, inter-planted with pumpkins in 2008). Across the experiments, fewer western corn rootworm adults were observed along with lower root injury in the untreated checks, especially at the Monmouth and Perry locations. Root damage in the DeKalb checks also was lower than in previous years. Rootworm injury at Urbana, in the checks, ranged from approximately 2.0 (two nodes of roots pruned) to 2.5. The saturated soils that occurred during larval hatch (late May through early June) most likely contributed to lower western corn rootworm densities in our experiments.

The soil insecticides Aztec 2.1G, Counter 20G, Force 2.25CS, and Lorsban 15G generally kept root injury below 0.5 (1/2 node pruned) on the node-injury scale. At the Urbana location, the soil insecticides kept root injury below 0.2, despite the greater level of pruning in the checks. Concerns are often expressed about the consistency of soil insecticides under extreme environmental conditions. These concerns were not realized in the 2009 experiments. However, the overall level of pressure at three of the experimental locations was low to moderate.

In general, the Bt treatments kept root injury below ½ node of roots pruned. However, the HxXTRA (Mycogen 2T789 + Cruiser 250) Bt treatment at Urbana had significantly more root injury (0.66) than the soil insecticides. Producers should not automatically assume that Bt corn rootworm hybrids always offer superior root protection as compared with soil insecticides. As expected, the soil insecticides when combined with YieldGard VT3 or HxXTRA hybrids resulted in node-injury ratings near 0, including the Urbana location. As a standard practice, the use of a corn rootworm soil insecticide applied at-planting with a corn rootworm Bt hybrid is not recommended. If a producer has a significant history of white grubs and/or

Table 3 ■ Preliminary node-injury ratings for corn rootworm control products in research trials near DeKalb, Monmouth, Perry, and Urbana, University of Illinois, 2009.

			Mean node-injury ratings[1,2]			
Product	**Rate per 1,000 row ft.**	**Placement[3]**	**DeKalb[4]**	**Monmouth[5]**	**Perry[6]**	**Urbana[7]**
Soil Insecticides						
Aztec 2.1G (DKC 61-22 RR2 + Poncho 250)[8]	6.7 oz	Band	0.21 d	0.21 cd	0.06 cd	0.18 cd
Counter 20G (DKC 61-22 RR2 + Poncho 250)	6.0 oz.	SB Furrow	0.13 d	0.32 c	0.25 b	0.13 cd
Force CS (DKC 61-22 RR2 + Poncho 250	0.46 fl. oz.	Band	0.23 d	0.08 cd	0.03 cd	0.18 cd
Lorsban 15G (DKC 61-22 RR2 + Poncho 250)	8.0 oz.	Band	0.38 cd	0.28 cd	0.18 bcd	0.05 d
Rootworm Bt Corn Hybrids						
HxXTRA (Mycogen 2T789 + Cruiser 250)[9]	—	—	0.05 d	0.09 cd	0.02 d	0.66 b
HxXTRA (Pioneer 34P92 + Poncho 250)	—	—	0.17 d	0.12 cd	0.05 cd	0.5 bc
YieldGard VT3 (DKC 61-19 TG + Poncho 250)	—	—	0.08 d	0.06 cd	0.02 d	0.25 cd
Soil Insecticides + Rootworm Bt Corn Hybrids						
Aztec 2.1G + YG VT3 (DKC 61-19 TG + Poncho 250)	6.7 oz.	Band	0.01 d	—	—	0.01 d
Counter 20G + YG VT3 (DKC 61-19 TG + Poncho 250)	4.5 oz.	SB Furrow	0.08 d	0.03 cd	0.03 cd	0.04 d
Force CS + HxXTRA (Pioneer 34P92 + Poncho 250)	0.346 fl. oz.	Band	0.02 d	0.01 cd	0.01 d	0.02 d
Force CS + HxXTRA (Pioneer 34P92 + Poncho 250)	0.46 fl. oz.	Band	0.01 d	0.01 cd	0.02 cd	0.01 d
Force CS + YG VT3 (DKC 61-19 TG + Poncho 250)	0.346 fl. oz.	Band	0.01 d	0.02 cd	0.01 d	0.01 d
Force CS + YG VT3 (DKC 61-19 TG + Poncho 250)	0.46 fl. oz.	Band	0.01 d	0.00 d	0.01 d	0.01 d
Lorsban 15G + HxXTRA (Mycogen 2T789 + Cruiser 250)	8.0 oz.	Furrow	0.03 d	0.04 cd	0.03 cd	0.03 d
SmartChoice 5G + YG VT3 (DKC 61-19 TG + Poncho 250)	3.5 oz.	SB Furrow	0.01 d	0.03 cd	0.03 cd	0.1 cd
Checks						
DKC 61-22 RR2 + Poncho 250	—	—	0.78 c	0.9 b	0.2 bc	2.16 a
Mycogen 2T777 RR2 + Cruiser 250	—	—	1.99 a	1.11 b	0.52 a	2.55 a
Pioneer 34P87 HxI + Poncho 250	—	—	1.41 b	2.18 a	0.34 b	2.42 a

[1] Node-injury ratings are based on the 0-to-3 root-rating scale developed by Oleson et al. (2005): 0.00—no feeding damage; 1.0—one node (circle of roots), or the equivalent of an entire node, pruned back to within approximately 1.5 inches of the stalk (or soil line if roots originate above ground nodes); 2.0—two complete nodes pruned; 3.0—three or more complete nodes pruned (greatest rating that can be given).

[2] Means followed by the same letter within a column do not differ significantly ($P = 0.05$, Duncan's New Multiple Range Test.) LSD values (P=0.05) are as follows: DeKalb = 0.40, Monmouth = 0.26, Perry = 0.15, and Urbana = 0.39.

[3] Band: insecticide applied in a 5-inch band over the planted row; furrow: insecticide directed into the seed furrow; SB furrow: insecticide applied through a SmartBox insecticide delivery system and directed into the seed furrow.

[4] DeKalb—Planted on May 24 into an area planted to a trap crop in 2008 (late-planted corn interplanted with pumpkins). Roots were evaluated on July 29.

[5] Monmouth—Planted on May 5 into an area planted to a trap crop in 2008 (late-planted corn interplanted with pumpkins). Roots were evaluated on July 20.

[6] Perry—Planted on April 23 into an area planted to a trap crop in 2008 (late-planted corn interplanted with pumpkins). Roots were evaluated on July 20. The insecticide only treatment (no rootworm Bt hybrid) Counter 20G was planted with Pioneer 34P87 HxI + Poncho 250. For the insecticide and Bt rootworm hybrid combination, both Counter 20G and SmartChoice 5G were applied with HxXTRA (Pioneer 34P92 + Poncho 250).

[7] Urbana—Planted on April 18 into an area planted to a trap crop in 2008 (late-planted corn interplanted with pumpkins). Roots were evaluated on July 22. The insecticide only treatment (no rootworm Bt hybrid) Counter 20G was planted with Pioneer 34P87 HxI + Poncho 250. For the insecticide and Bt rootworm hybrid combination, both Counter 20G and SmartChoice 5G were applied with HxXTRA (Pioneer 34P92 + Poncho 250). Lorsban 15G was applied in-furrow when used as an insecticide treatment only (no rootworm Bt hybrid used). Lorsban 15G was applied in a band with the HxXTRA (2T789) Bt hybrid.

[8] Seed treated with Poncho 250, 0.25 mg a.i. per seed.

[9] Seed treated with Cruiser 250, 0.25 mg a.i. per seed.

wireworms in a given field, the use of a soil insecticide applied in-furrow at planting should be considered.

At the time of this writing, plots were still being harvested. Based upon the overall low corn rootworm pressure in our 2009 experiments, along with the very wet season, significant yield differences across most of our treatments are not anticipated.

Concluding Remarks

The "journey" with transgenic crops remains relatively new. Yet, in this remarkably short span of time (since the mid-1990s), the manner in which producers control insect and weed infestations in commercial corn and soybeans has been revolutionized by these technological developments and their quick adoption. More advances in the biotechnological revolution are sure to follow such as RNA interference as well as the introduction of novel insecticidal proteins, very different from Cry proteins, into our crops. Yet, many of the fundamental principles of IPM and natural selection will remain constant in this increasingly 95% and 5% world.

Acknowledgements

It is my pleasure to recognize the research contributions of Ron Estes, Senior Research Specialist, Department of Crop Sciences and Nick Tinsley, Ph.D. student, regarding the corn rootworm product efficacy trials. Their implementation of these experiments and their dedication to the overall Insect Management and Product Evaluation Program is greatly appreciated.

What Does Tomorrow Hold?

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Think back a few years to when glyphosate-resistant crops were in the earliest stages of commercialization and adoption; were you optimistic that the ability to apply glyphosate in-crop for weed control would spell the end for troublesome broadleaf and grass weed species? Were you pessimistic that you would ever again need anything other than glyphosate for weed control in corn and soybean? Many folks initially shared a common perception that it was unlikely another herbicide or herbicide-resistant crop technology would be needed once glyphosate and glyphosate-resistant crops became commercially available.

Now fast-forward to the present era, in which shifts in weed spectrums and biotypes have occurred across a large portion of Illinois. Later-emerging weed species, such as annual morningglory, giant ragweed and hophornbeam copperleaf, have flourished with the concomitant decreased utilization of soil-residual herbicides. Glyphosate-resistant biotypes of horseweed (a.k.a. marestail) often frustrate farmers who attempt to chemically control them prior to planting no-till soybean. Frustration continues to build when farmers must contend with glyphosate-resistant waterhemp after soybean emergence. These examples illustrate how the once widespread optimism pertaining to the "invincibility" of glyphosate has been tempered by the realities imposed by the biological diversity inherent in Illinois cropping systems.

It appears that new weed management practices and/or technologies will be needed to help farmers manage the consequences of long-term weed control. Indeed, several new technologies have (or soon will) entered the marketplace that may provide solutions for some of today's most prevalent weed management challenges. Historically, new innovations (i.e., herbicides) were usually packaged in plastic jugs but many of tomorrow's innovations will often arrive packaged in paper bags. What glimpses into the future can we now share?

New Herbicide-Resistant Crop Technologies

As previously alluded, several new technologies introduced into the marketplace are soybean varieties and corn hybrids (packaged in paper bags) containing traits that confer resistance to primarily non-selective herbicides. The only example of this type of new technology currently commercialized is soybean resistant to glufosinate, but several other technologies are under development. What do we know about these new varieties and how might they help alleviate some of the weed management challenges farmers are encountering?

Glufosinate-resistant soybean varieties:

The 2009 growing season marked the first season glufosinate-resistant soybean varieties were commercially available. These soybean varieties are resistant to glufosinate, a non-selective herbicide sold under the trade name Ignite. Glufosinate and glyphosate share various similarities, including being non-selective, lacking soil-residual activity, providing broad-spectrum weed control, and requiring herbicide-resistant crops for in-crop applications. While these similarities (and similar sounding common names) could potentially lead some to consider these two herbicides "interchangeable", significant and important differences exist between these two herbicides such that a further comparison is warranted.

Glufosinate inhibits an enzyme known as glutamine synthetase, a plant enzyme involved in the early steps of nitrogen assimilation. This target site is completely different than glyphosate's target enzyme (EPSP synthase). Because of the dissimilarity in target sites, previous research has demonstrated that several glyphosate-resistant weed populations, including waterhemp and horseweed (marestail), can be controlled with glufosinate. Glufosinate demonstrates limited translocation following absorption into the plant, in contrast to glyphosate's extensive mobility. Glufosinate is generally considered to be a "contact" herbicide, so application parameters and environmental conditions that optimize glufosinate's performance should be given appropriate consideration. For example, bright sunshine and warm air temperatures favor improved performance of glufosinate, compared with cloudy and cool conditions. Thorough coverage of the target weed vegetation with spray solution is absolutely essential, so nozzles that produce medium-sized droplets and application volumes of at least 15 gallons per acre should be considered.

Glufosinate's spectrum of control is comparable to that of glyphosate for several weed species, but important differences exist between these herbicides. Glufosinate tends be more effective on annual broadleaf weeds than annual grasses, while glyphosate is inherently stronger against grasses than broadleaves. Overall, due to its limited translocation, glufosinate is generally not as effective as glyphosate on larger weeds. Annual weeds (both broadleaves and grasses) should not be taller than 4 to 6 inches at the time of glufosinate application. Expect glufosinate to provide only suppression of most biennial and perennial weeds, so consider tankmixing other products to improve control of these species.

Symptoms of herbicide activity tend to appear sooner after applications of glufosinate compared with glyphosate, although environmental factors can greatly influence how quickly symptoms develop. Soybean injury symptoms, consisting of small areas of chlorotic or necrotic tissue, are sometimes noticeable within approximately 5 to 7 days after glufosinate application, but usually are transitory and not evident by 14 to 21 days after application.

Hybrids and varieties resistant to glyphosate and ALS inhibitors:

Hybrids and varieties resistant to glyphosate are not unique, but the mechanism of glyphosate resistance in these soon-to-be-commercialized crops is different than the mechanism in current glyphosate-resistant crops. These new hybrids and varieties demonstrate resistance to glyphosate and ALS-inhibiting herbicides (sulfonylurea and imidazolinone) via active herbicide metabolism and an insensitive target site, respectively. Developed by Pioneer and DuPont, these crops will be termed "Optimum GAT", (the GAT acronym indicates Glyphosate ALS Tolerance), and positioned in conjunction with several new herbicide premixes. These crops are not intended to "replace" glyphosate, but rather bring options to the market that can compliment glyphosate by providing: 1) soil-residual weed control, 2) improved control of weed species not easily controlled by glyphosate alone (such as annual morningglory), and 3) enhanced control of certain glyphosate-resistant biotypes. Obviously, any weed population resistant to glyphosate or ALS inhibitors will still be resistant in fields planted to these crop varieties. However, by introducing premixes containing herbicides that are effective

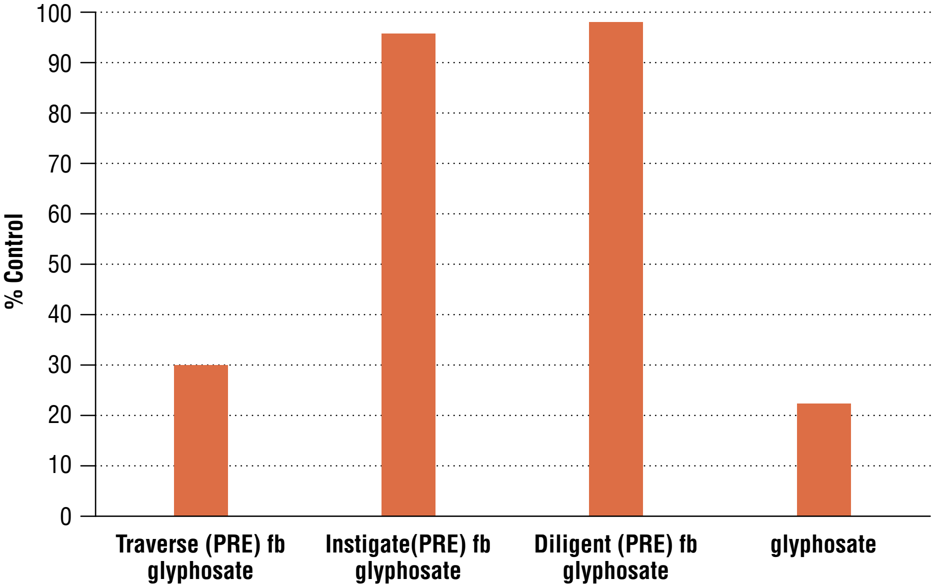

Figure 1 ■ Control of glyphosate- and ALS-resistant waterhemp with various herbicides and formulations (data collected 13 days after POST application).

against glyphosate- and ALS-resistant weed populations, overall control can be greatly improved. This can be demonstrated in Figure 1, which presents results from field research conducted to evaluate control of a glyphosate- and ALS-resistant waterhemp population with some of the new premixes that will be marketed in conjunction with these herbicide-resistant hybrids and varieties. Table 1 provides additional information about these new herbicide premixes.

Dicamba-resistant soybean varieties:

Soybean injury following exposure to dicamba has plagued Illinois soybean farmers for many years. Early (ca ~1967) recommendations from the University of Illinois suggested dicamba not be used in corn because of concerns over potentially severe soybean injury from particle (drift or volatility) movement. In past years, the characteristic leaf cupping commonly associated with exposure to dicamba has been the most frequently observed and reported type of soybean injury across most areas of Illinois.

Table 1 ■ New herbicide premixes that will be introduced in conjunction with GAT corn hybrids and soybean varieties.

Product	Components	Uses
Traverse	12.5% rimsulfuron + 12.5% chlorimuron	PRE corn/soybean
Instigate	4.7% rimsulfuron + 4.7% chlorimuron + 31.2% mesotrione	PRE corn
Trigate	6.7% rimsulfuron + 5% tribenuron + 33.3% mesotrione	POST corn
Diligent	6.31% rimsulfuron + 6.31% chlorimuron + 25.25% flumioxazin	PRE soybean
Freestyle	12.5% chlorimuron + 18.75% thifensulfuron + 18.75% tribenuron	POST corn/soybean

Earlier this decade, scientists at the University of Nebraska identified a soil bacterium that rapidly metabolizes dicamba. Using the tools and techniques of molecular biology, these scientists were able to transfer bacterial genes responsible for dicamba metabolism into several dicot plants, including soybean. Additional research with regenerated plants revealed excellent resistance to dicamba, even when dicamba was applied directly to them. Further development of this technology is now predominately being conducted in the private sector.

Many soybean farmers anticipate this technology, once commercially available, will solve many of the current problems associated with either glyphosate-resistant weeds (such as waterhemp and horseweed) or weeds that are inherently less sensitive to glyphosate (such as annual morningglory species). It might be prudent to consider that, although weed management practitioners have decades of experience using dicamba in corn and other monocot crops, very little research has been conducted examining dicamba's (intentional) use in soybean. Also, it appears that this technology may not be commercialized until the year 2014, so solutions for the weed control challenges of today still demand high priority.

For the past two seasons we have been able to evaluate soybean response and weed control following preemergence and postemergence applications of dicamba alone or in combination with glyphosate. Our experiments have been located on-farm, at a location with a confirmed glyphosate-resistant waterhemp population. Finite seed supplies and regulated status have combined to limit the amount of research possible, but some general observations have been consistent across years.

To date, we have observed very little crop response following dicamba applications. Given the inherent sensitivity of soybean to dicamba, it is quite remarkable to observe no injury following dicamba application directly onto soybean. However, movement of dicamba outside the application area (even when using small-plot research techniques) and onto nearby, non-transformed soybean highlights that much research is still needed to define stewardship practices that will be necessary for large-scale utilization of this technology.

Control of glyphosate-resistant waterhemp with dicamba has been good to excellent, depending on the dicamba application rate and timing. Dicamba applied preemergence was effective at controlling existing waterhemp, but generally did not provide much residual control. Early postemergence applications (before waterhemp exceeded about 3 inches) of dicamba tankmixed with glyphosate tended to provide better overall control compared with applications made after waterhemp exceeded 6 inches. Additional research to better define application rates and timings will occur during the next several seasons.

A New Herbicide Active Ingredient

Horseweed (*Conyza canadensis*) has become a challenging broadleaf weed in minimum and no-tillage cropping systems across much of the southern half of Illinois. Horseweed, often widely recognized by its other common name, marestail, is native to North America but historically has been a weed predominately of waste areas and fallow ground (Figure 2). With the advent of limited tillage agronomic cropping practices, and the substantial increase in their adoption during the past 20 years, horseweed has become very adapt at populating Illinois corn and soybean fields. Challenges controlling horseweed chemically prior to planting have plagued Illinois farmers for years, partly attributable to several factors, including horseweed's biology, environmental conditions unfavorable for optimal herbicide effectiveness, and the presence of herbicide-resistant horseweed biotypes. Resistance to several herbicide classes, including bipyridiliums (ex. paraquat), glycines (ex. glyphosate), ALS inhibitors (ex. cloransulam), and triazines (ex. atrazine), has been documented in US horseweed populations. Illinois has not been immune to this phenomenon, with glyphosate-resistant horseweed biotypes identified as early as 2005.

Figure 2 ■ Glyphosate-resistant horseweed can be difficult to control chemically prior to soybean planting.

A new herbicide active ingredient will be commercialized in 2009 that has proven to be very effective at controlling horseweed prior to planting. Saflufenacil can be applied prior to planting corn, small grains, grain sorghum, and soybean to control existing vegetation and provide residual control (length of residual control will depend on application rate) of annual broadleaf weed species. The active ingredient will be available in three formulated products, namely Sharpen, OpTill, and Integrity. Table 2 provides some additional information relative to each of these commercial formulations.

Table 2 ■ Information pertaining to herbicide products containing the new active ingredient saflufenacil.

Product	Crop	Rate	Burndown	Residual
Sharpen	Soybean	1 fluid ounce	MSO + AMS	Very limited
	Corn	1–3 fluid ounces	MSO + AMS	Bdlf only, rate dependent
	Small grains	1–2 fluid ounces	MSO + AMS	Very limited to limited
	Grain sorghum	1–2 fluid ounces	MSO + AMS	Very limited to limited
OpTill	Soybean	2 ounces	MSO + AMS	From imazethapyr
	Clearfield corn	2 ounces	MSO + AMS	From imazethapyr
Integrity	Corn	10 fluid ounces (coarse)	MSO + AMS	Set-up before POST
		13 fluid ounces (medium)	MSO + AMS	Set-up before POST
		16 fluid ounces (fine)	MSO + AMS	Set-up to extended

A Scabby Start with a Moldy Finish: A Look Back at the Major Field Crop Diseases of 2009

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The 2009 growing season offered many disease problems to Illinois growers. Some of the most-damaging diseases in 2009 included Fusarium head blight (scab) of wheat, Sclerotinia stem rot (white mold) of soybean, and ear rots of corn. These diseases are discussed below.

Fusarium Head Blight of Wheat

Symptoms and prevalence in 2009. Fusarium head blight (FHB; a.k.a. head scab) is a disease caused by the fungus *Fusarium graminearum*. Symptoms of FHB can be observed as "bleached" heads or heads with both green and bleached areas (Fig. 1). The disease can lower yields, test weights, and the fungus can produce mycotoxins such as deoxynivalenol (DON; vomitoxin) that can contaminate the harvested grain. The disease was prevalent in the major wheat production region of the state in 2009. A wheat field survey indicated that an overall average of nearly 50% of the wheat heads observed in the nine counties surveyed had Fusarium head blight symptoms (Fig. 2). For the FHB fungus to infect wheat heads, it requires certain weather conditions during wheat flowering through kernel development. Moderate temperatures (75 to 85°F), prolonged high humidity, and prolonged wet periods favor disease development. This temperature was prevalent when wheat was flowering in some parts of Illinois in 2009, which is one of the factors that played a role in the severity of FHB in the state.

Management. Successful management of FHB requires an integrated approach, which includes planting the most-resistant varieties, using the best cropping sequence, and applying foliar fungicides, if needed.

- **Resistant varieties.** No wheat varieties are immune to FHB, but some are more resistant than others. Most seed companies provide ratings of FHB susceptibility of their varieties. In addition, the University of Illinois

Figure 1 ■ Symptoms of Fusarium head blight on wheat heads.

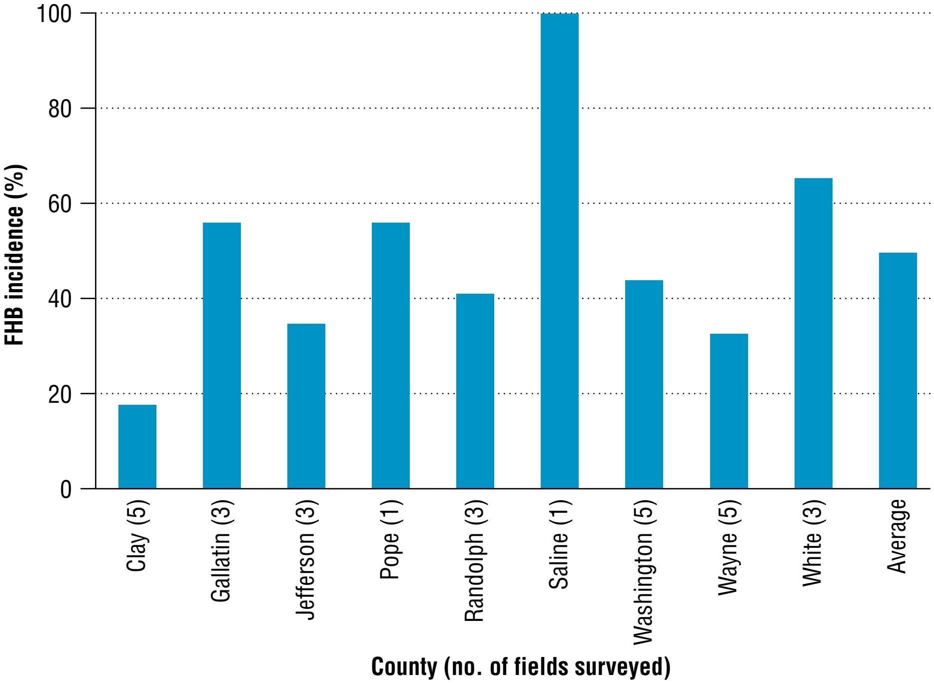

Figure 2 ■ Incidence (% wheat heads with symptoms) of Fusarium head blight in nine Illinois counties from a field survey conducted in 2009.

Small Grains Breeding Program has evaluated wheat varieties in their FHB nurseries over multiple years, and results from these evaluations are available at the University of Illinois Variety Testing Website (http://vt.cropsci.illinois.edu/).

- **Cropping sequence.** The same fungus that caused FHB also can cause Gibberella stalk and ear rot on corn. Because corn stubble can harbor the FHB pathogen, wheat following soybean is at a lower risk of developing FHB than wheat following corn.
- **Foliar fungicides.** The use of foliar fungicides is the only "in-season" option for control of FHB; however, application timing is extremely important in achieving the best efficacy. Fungicides should be applied at Feekes growth stage 10.5.1 (early anthesis). It is also important to spray with nozzles oriented to spray forward, which helps improve fungicide coverage of the head. A FHB risk assessment tool is available that will indicate FHB risk for Illinois (www.wheatscab.psu.edu); this tool can help with making fungicide decisions. Although fungicides are a good control option, losses will occur on a highly-susceptible variety sprayed with a fungicide in an environment favorable for disease. Thus, integrated management is important. Results from a field trial conducted at Urbana, IL that evaluated Prosaro fungicide over twelve different varieties that ranged from susceptible to moderately-resistant to FHB indicated that the most resistant varieties applied with fungicide had the lowest FHB severity ratings (Fig. 3).

Sclerotinia Stem Rot of Soybean

Symptoms and prevalence in 2009. Sclerotinia stem rot (SSR; a.k.a. white mold) is a disease caused by the fungus, *Sclerotinia sclerotiorum*. A fuzzy, white

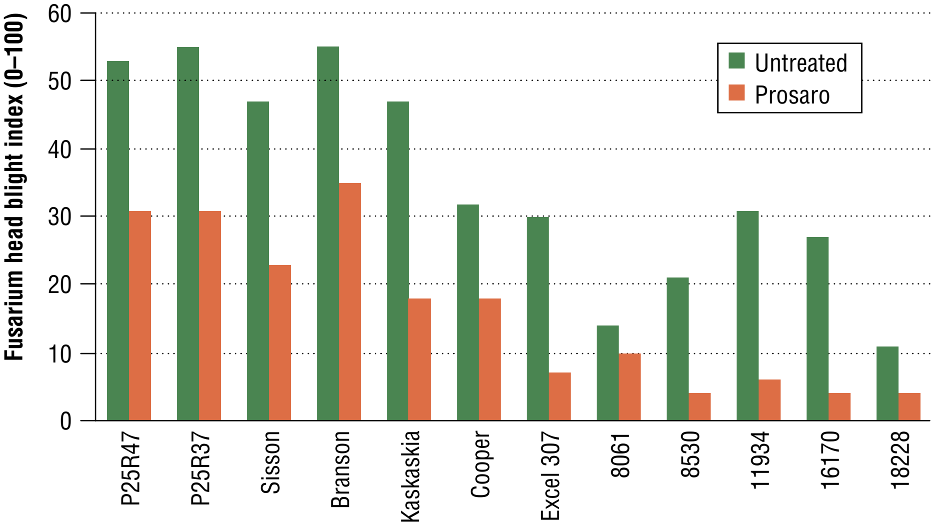

Figure 3 ■ The effect of Prosaro fungicide on Fusarium head blight across twelve different wheat varieties. This trial was conducted by Drs. Carl Bradley and Fred Kolb, University of Illinois at Urbana, IL in 2008, and was funded by the U.S. Wheat and Barley Scab Initiative.

fungal growth can be observed growing on plants affected by SSR. Symptoms include wilting leaves, stems that appear to be "bleached", and stem tissues that easily shred (Fig. 4). Small black structures known as sclerotia can be found on and inside plants that have been affected by SSR. Cool (below 85˚F) and wet weather is needed prior to and during soybean flowering for the SSR pathogen to infect and cause disease. The disease cycle of SSR is complicated, and favorable environmental conditions and soybean growth stages must intersect for the disease to occur. The fungus overwinters in the soil as

Figure 4 ■ Soybean stem affected by Sclerotinia stem rot.

sclerotia. These sclerotia can survive in the soil for many years. Under wet soil conditions, the sclerotia germinate and form small mushroom-like structures known as apothecia. Airborne spores (ascospores) are discharged from the apothecia and land on soybean plants. Ascospores that land on senescing petals of soybean flowers are the most likely to cause infection. As the soybean flower petals senesce, the ascospores begin to germinate, grow, and infect the stems. If wet and cool conditions continue, the disease continues to develop throughout the plant. Eventually, sclerotia will form on and inside the affected plants. Many of the sclerotia will be blown out of the back of the combine during harvest, adding more "inoculum" back into the field. In 2009, soybean fields in central to northern Illinois were affected by SSR. Although it is not uncommon for soybean fields to be affected by SSR in northern Illinois, SSR caused losses in a much larger area of the state in 2009 compared to typical years. The widespread observations of SSR in Illinois in 2009 can be attributed primarily to the cooler than normal temperatures and wet weather during the growing season.

Management. Management of SSR is difficult, and multiple practices must be integrated to achieve the best control.

- **Resistant varieties.** No soybean varieties are completely resistant to SSR, but some are less susceptible than others. Many seed companies have ratings available for the susceptibility of their varieties to SSR. Information about the susceptibility of some varieties can be found at the University of Illinois VIPS website (www.vipsoybeans.org).
- **Row spacing and seeding population rate.** In areas where SSR is a severe problem year-in and year-out, wider (30-inch) row spacings may reduce the disease's impact. Because wider spacing could impact the yield potential of soybean, it is recommended for SSR control only in areas where severe SSR is observed frequently. High plant populations can decrease the airflow through the canopy, which can increase the spread of SSR. For effective management, it is important to follow recommended seeding rates and avoid high seeding rates.
- **Foliar fungicides.** Currently, two foliar fungicides are registered for control of SSR in soybean (Topsin M and Domark). Correct application timing and good plant coverage are needed to achieve the best control with foliar fungicides, and under high disease pressure, foliar fungicides can be overwhelmed. In addition to foliar fungicides, Cobra herbicide has a label for SSR suppression in soybean. An SSR soybean fungicide trial that was conducted near DeKalb, IL in 2009 that tested these products will be discussed in the presentation.
- **Avoiding bin-run seed.** The SSR fungus can be seedborne, so to avoid moving the pathogen into your fields, it is important to not plant bin-run seed.
- **Biological control.** A biological control product marketed as Contans WG is available for control of SSR. This product contains the fungus *Coniothyrium minitans,* a parasite of the white mold fungus's sclerotia. Contans WG has not been evaluated in University of Illinois research trials, though research at North Dakota State University indicated it is effective at colonizing and killing sclerotia. But depending on the level of sclerotia present, disease incidence may not be affected: in fields with

a high load of sclerotia in the soil, enough sclerotia may survive to still cause a substantial level of disease. It is important to note that Contans WG should not be applied to flowering soybean plants. Rather, it should be applied to the soil in the fall after harvest or in the spring prior to planting.

Ear Rots of Corn

Diseases and prevalence in 2009. Corn ear rots were common in Illinois during the 2009 season, with Diplodia ear rot and Gibberella ear rot being the most common ear rots observed in the state. Diplodia ear rot is caused

Figure 5 ■ White fungal growth on a corn ear caused by Diplodia ear rot (A); and black specks on kernels (pycnida) produced by the Diplodia ear rot fungus (B).

Figure 6 ■ Pink to red fungal growth on a corn ear caused by Gibberella ear rot (Photo courtesy Don White, University of Illinois).

by the fungus, *Stenocarpella maydis*. Diplodia ear rot was observed across the entire state, but the most frequent reports came from central Illinois. Gibberella ear rot is caused by the fungus, *Gibberella zeae*, which is the sexual stage of *Fusarium graminearum* (the Fusarium head blight of wheat fungus). Gibberella ear rot also was reported across the entire state. Symptoms of Diplodia ear rot appear as a white mold growing on and between the kernels that generally begins at the base of the ear (Fig. 5a). Speck-sized fruiting bodies (pycnidia) will be formed by the Diplodia ear rot fungus which can be observed on the sides of kernels (Fig. 5b). Gibberella ear rot symptoms appear as a pink to red fungal growth on the kernels (Fig. 6). This growth generally occurs at the tip of the ear and can be associated with insect, bird, or hail damage. Both Diplodia and Gibberella ear rots can cause yield loss and reduced test weight, and the Gibberella ear rot fungus also can produce mycotoxins such as deoxynivalenol (DON or vomitoxin) and zearalenone. These diseases were prevalent in 2009 because of the wet weather during the growing season. Rain showers in the Fall and delayed harvest also allowed these diseases to become more severe.

Management. The first step in managing ear rots is to choose hybrids with better resistance. Generally, seed companies provide ratings of their hybrids for susceptibility to Diplodia ear rot. Avoid planting corn back into fields that had severe ear rot in 2009, as the ear rot pathogens survive in corn debris. Although the days of the moldboard plow are gone, burying corn residue affected by ear rots is one way to manage the inoculum levels that may be present the following year. However, one must balance between tilling for disease management and leaving residue to help prevent erosion.

Notes

Notes