An Economic Analysis Of Corn Rootworm Management: Areawide Pest Management Versus Soil Insecticides-A Net Present Value Approach

Christina Welch Stair, Peter Quan, and Marshall A. Martin [1]

[1] Graduate Assistant, former Graduate Assistant (currently with USDA-NASS, California), and Professor, Department of Agricultural Economics, Purdue University

Paper presented at the American Agricultural Economics Association Annual Meetings
Tampa, Florida
July 30-August 2, 2000

An Economic Analysis Of Corn Rootworm Management: Areawide Pest Management Versus Soil Insecticides-A Net Present Value Approach[1]

Christina Welch Stair, Peter Quan, and Marshall A. Martin[2]

Introduction

Western and northern corn rootworms, *Diabrotica virgifera virgifera* LeConte and *Diabrotica barberi* Smith & Lawrence, have been estimated to cause $1 billion dollars in annual costs (Metcalf, 1986). This estimate is the result of the purchase and application of soil insecticides, as well as the costs incurred from yield losses from crop damage. The costs for control of corn rootworms are the largest insect management expenditures by U.S. corn producers (Steffey, Gray, and Shaw, 1993). Yield losses arise from larval feeding on corn roots between mid-May and mid-June, which reduces water and nutrient uptake by the plant. Larval feeding also can increase the risk of soil pathogen entry into damaged root tissue, further increasing yield loss. Damage to the corn plant can occur later in the season from the adult stage of the corn rootworm, when adult beetles feed on pollen, silks, leaf tissue, and exposed kernels (Edwards, Bledsoe, and Obermeyer, 1998).

The major source of corn rootworm control is prophylactic, meaning that actions are taken before insect damage occurs in order to prevent yield losses. In some cases, crop rotation can prevent damage by disrupting the biological cycle of the corn rootworm through the elimination of a host crop. Frequently, however, the control tactic is in the form of soil insecticides utilized to protect the corn root system from corn rootworm damage and other soil inhabiting pests, such as wireworms (*Pyrophorus spp.*) and white grubs (*Phyllophaga / Lachnosterna spp.*). Soil insecticides are most commonly applied at planting, either as a band over the top of the row and in the partially open corn seed slot, or in-furrow in the corn seed slot.

[1] AAEA selected paper presented at the American Agricultural Economics Association annual meetings, Tampa, Florida, July 30 through August 2, 2000.
[2] Graduate Assistant, former Graduate Assistant (currently with USDA-NASS, California), and Professor, Department of Agricultural Economics, Purdue University.

Soil insecticides generally are regarded as an effective tool to combat corn rootworm damage. However, certain conditions can reduce the efficacy of soil insecticides, such as inadequate or excessive soil moisture, time of planting, soil microorganisms, and metabolic resistance to the soil insecticide (Edwards *et al*., 1998). These factors reduce soil insecticide efficacy from 100% to approximately an 80% level, meaning that the insecticide can control 80% of the insect population within the zone of treatment (Edwards, 1999). Additionally, concerns regarding the impact of granular soil insecticides on the environment, particularly organophosphate toxicants present in many of the widely-used soil insecticides, have led to the development of alternative methods for corn rootworm control.

One alternative method, known as Areawide Pest Management (AWPM), was devised by the Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA) (Quan, 1999). Unlike soil insecticides, which use a single tactic approach of targeting the larval stage of the insect (thereby necessitating annual treatment), AWPM utilizes integrated control tactics (adult and larvae) with the goal of eventual reduction in overall insecticide use through insect population suppression. Theoretically, the corn rootworm population could be reduced sufficiently over time to allow for a significant reduction in the amount of soil insecticides used. Adult control measures used under AWPM involve foliar insecticide use, reducing the number of eggs laid, and therefore eliminating larval problems the following season. The foliar insecticide utilized for the ongoing ARS-AWPM program is based on a semiochemical insecticidal-bait, known as Slam®. Semiochemicals are preferred over traditional foliar insecticides for environmental reasons. Slam® has a much reduced level of toxicant per pound applied per acre (around 90% less active ingredient than traditional foliar insecticides), and is specific to rootworm adults (Chandler, 2000). The integrated approach utilized in AWPM has an advantage over soil insecticides, which when used without adult control measures do not work as a population suppressor, but rather act solely as a root protectant. Potential benefits from an areawide program would be decreased insecticide applications, less applicator exposure to insecticides, and possible yield benefits over soil insecticide control measures due to the elimination of many of the factors that can reduce soil insecticide efficacy.

However, there are potential drawbacks to an areawide program. One of the major constraints to a population suppression program is beetle migration capability. It is difficult to reduce a corn rootworm population over a large area on a field-by-field basis using semiochemical baits alone, since beetles from adjacent untreated fields may reinfest a treated field, negating any suppression efforts.[3] Therefore, a crucial component to the success of adult suppression is the large size of the treated area, which should encompass several thousand acres. This makes it essential to obtain the collaboration of neighboring corn producers to achieve the ultimate goal of corn rootworm suppression.

Another constraint to the adoption of AWPM is the limited profit potential of this type of a management program. In order for growers to use AWPM, the program must be economically viable, meaning that costs incurred through utilizing AWPM should be less than or equal to the costs incurred through alternative control techniques, such as the use of soil insecticides. Theoretically, AWPM is expected to have high initial costs resulting from both adult and larval control measures, but should eventually generate a sustained period of low costs if population suppression is successful. However, the process of achieving population suppression can be difficult and costly, as repeated chemical applications could prove necessary throughout the season, increasing control costs. Additionally, there are certain costs with an AWPM program that do not occur with a soil insecticide program, such as scouting fees associated with careful monitoring of the adult corn rootworm population as well as the aerial application costs

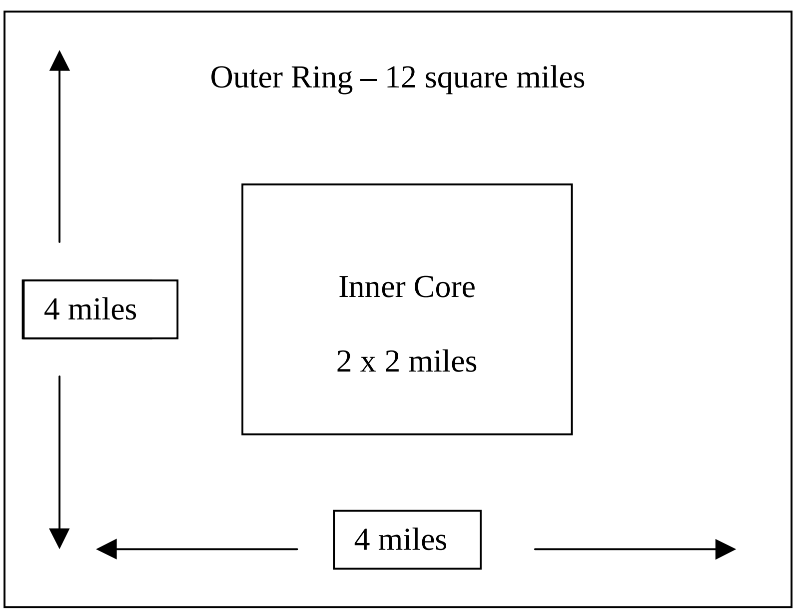
[3] Beginning in the year 2000, an alternative to Slam® will be used because of problems resulting from the use of Slam®, such as poor residual activity, clogged spray nozzles, and chemical contamination with foreign material. The replacement insecticidal-bait, Invite®, contains hawkesbury watermelon juice that acts as a rootworm feeding stimulant. The amount of toxicant used in Invite® will be equal to that used in Slam® (AWPM Connection Newsletter, April 14, 2000).

resulting from foliar sprays. Scouting is essential to an integrated control program to determine the proper timing of the aerial insecticide application as well as to determine the necessity of larval control measures (i.e., soil insecticides) in the following season. The goal of this research is to provide an economic comparison of AWPM to traditional soil insecticide use. The results offer a better understanding of the economic potential for private adoption of AWPM to control corn rootworms.

Methodology

Three sites were selected for the economic analysis of the AWPM pilot program: Indiana/Illinois, Kansas, and Iowa. Each of these 16 square mile sites contains a central 2 by 2 mile area known as the inner core, as well as a 12 square mile area that surrounds the inner core, known as the outer ring (Figure 1). The outer ring may provide a buffer to reduce the potential migration of adult beetles into the inner core fields.

Figure 1. Configuration of AWPM Experimental Sites



Both the inner core and outer ring fields are aerially sprayed when beetle population levels reach designated threshold levels. Beetle populations are determined by weekly scouting. The Indiana/Illinois site is slightly different from the other two sites because soybean fields, as well as cornfields, are scouted and sprayed due to the presence of the western corn rootworm beetle variant which oviposits in soybean fields and thus may damage first-year corn. This variant beetle has made control of corn rootworms more costly to growers in the Eastern Corn Belt. Currently, growers must apply a soil insecticide to protect first-year corn as well as continuous corn. Areas that do not contain the variant form of the beetle require no soil insecticide treatment in first-year corn, unless volunteer corn is a problem in a crop like soybeans.

Insect thresholds used to trigger spray applications are different depending upon the site. Since each site has a unique environment as well as a unique relationship between beetle population and plant injury, modifying scouting techniques and threshold levels to match the individual site should enhance the probability of success for AWPM at each site (Bledsoe, 2000). The thresholds at the Indiana/Illinois site in 1997 and 1999 were 0.5 beetles per plant per day in first-year corn, 0.7 beetles per plant per day in continuous corn, and 2 beetles per sticky card per day in soybeans. Thresholds were slightly different in the outer ring in 1998, when trigger thresholds were raised to 2 beetles per plant per day for both first-year corn and continuous corn (Gerber, 2000). The thresholds at the Kansas site in 1997 and 1998 were 35 beetles per yellow sticky trap per week. These thresholds were lowered in 1999 to 25 beetles per yellow sticky trap per week (Whitworth, 2000). The thresholds at the Iowa site in 1997, 1998, and 1999 were 6 beetles per yellow sticky trap per day (Berry, 2000).

In the first stage of the economic analysis, growers in each of the three sites responded to a two-part questionnaire in 1997 and 1998. These questionnaires were used to obtain information regarding input use, yields, cultural practices, and variable and fixed costs incurred by the growers. To determine the economic profitability of an AWPM program, a comparison was made between the corn rootworm control costs for AWPM, which used scouting and aerial application techniques, and the control costs for nearby fields which managed corn rootworm damage with soil insecticides. A cost comparison also was made between the inner core and outer ring to determine if the inner core achieved any benefit due to its location. As previously mentioned, the outer ring should act as a "buffer" for the inner core, protecting the inner core from migrating beetles.[4]

Since AWPM benefits are expected to be achieved through insect suppression over time, an 8-year time-frame was selected to calculate the expected profitability of both the AWPM and soil insecticide approaches. Eight years is a reasonable planning horizon for a corn producer, and allows for four cycles of a corn/soybean rotation for the first-year corn treatment program in the Indiana/Illinois site. To capture the time-value of money, the Net Present Value (NPV) method was used to estimate future revenue and expense streams in current dollars. The corn rootworm control method with the highest NPV is the most profitable control method for corn producers.

NPV Methodology

The NPV equation is as follows:

$$NPV = \frac{TR_n - (TC_n \times (1 + i)^{n-1})}{(1 + d)^n}$$

Where:

TR_n = Total Revenue for year n

TC_n = Total Cost for year n

d = Discount Rate

i = Inflation Rate

In this analysis, the NPV was calculated for years one through eight. This equation was used for each AWPM site to calculate the NPV per acre for both the inner core and outer ring.

[4] For a complete report on the 1997 and 1998 survey data and statistical analysis of the variable and fixed production costs see: Stair, Quan, and Martin, 2000.

The NPV per acre also was calculated for the soil insecticide method. For all three sites, the discount rate (d) was 12.4%, which represents the weighted cost of capital for the farmers in each site (Quan and Martin, 1999). Input price inflation was assumed to be 3% per year throughout years four through eight. Actual costs were used for 1997, 1998, and 1999. The total revenue was calculated by multiplying the average price of corn by the corn yield per acre for a given year. (In the Indiana site, one acre is comprised of half soybeans and half corn, so TR = (soybean price) x (soybean yield) x 0.5 + (corn price) x (corn yield) x 0.5). The total cost is comprised of the costs associated with rootworm control, which for the inner core and outer ring were the costs of aerial application per acre plus the per acre chemical costs. Initially, scouting costs were assumed to be zero. If the NPV of AWPM was estimated to be greater than the NPV of the soil insecticide method, then the scouting costs that could be afforded by the farmer were calculated. (The reasoning behind this approach is that if subsidizing farmers for an AWPM program was deemed necessary by the economic analysis, the payment of scouting fees could be a method of distributing a subsidy). If any soil insecticides were used for AWPM acreage, (as was necessary in Year 1 for all sites, and also was necessary in subsequent years for the Indiana/Illinois site) the soil insecticide costs per acre were applied to the percentage of the acreage which used soil insecticides, based on the grower survey data. Total costs for the traditional approach, the soil insecticide method, were simply the soil insecticide cost per acre. (Some growers who used the traditional soil insecticide method used scouting for other insects, such as European corn borer, spider mites, etc. However, for the traditional soil insecticide method, scouting costs were not allocated to corn rootworm control, as soil insecticides were used annually regardless). All other corn production costs (seed, fertilizer, harvesting, etc.) were assumed to be the same for both the AWPM and soil insecticide approaches to corn rootworm control.

If the NPV of the inner core or outer ring for the AWPM approach is estimated to be higher than the NPV of the soil insecticide method, then AWPM is more profitable, ignoring scouting costs. Therefore, if indeed the NPV for AWPM is greater than the NPV for the soil insecticide method, then a scouting cost is estimated that a grower could afford to pay and be equally well-off as with the soil insecticide method.

If the opposite is true, and the NPV of the inner core or outer ring for the AWPM approach is less than the NPV of the soil insecticide approach, then AWPM is not as profitable, even ignoring the scouting costs associated with AWPM. In this case, a "yield protection effect" is calculated. This is the number of additional bushels per acre that the AWPM approach would require to make this method at least as profitable as the soil insecticide method. This hypothetical yield benefit is possible since several factors can reduce soil insecticide efficacy, such as cool spring soil temperatures, early planting relative to larval emergence, and excessive or inadequate rainfall. Also, while the corn roots are protected in the zone where insecticide is placed, roots that extend or grow beyond this treated zone are unprotected. Additionally, soil insecticides do not offer the corn plant any protection from adult rootworm beetles that feed on corn silks during pollination, sometimes causing decreased yields. AWPM has the advantage of offering protection from this silk clipping.

Scenario Methodology

Since actual adult beetle infestation levels are only available for 1997, 1998, and 1999, the infestation levels for the remaining five years (2000 – 2004) must be estimated. Four different scenarios are examined in the NPV analysis. Scenario 1 assumes that years 4-8 will have infestation levels similar to those encountered in 1997. Scenario 2 assumes that years 4-8 will have infestation levels similar to 1998. Scenario 3 assumes that years 4-8 will have infestation levels similar to 1999. Finally, Scenario 4 is a "best-case" scenario. Scenario 4 assumes that enough insect suppression occurred in years 1-3 so that no additional treatments are needed for the AWPM sites in years 4-8.

Indiana/Illinois Results

The Indiana/Illinois site was somewhat different from the other AWPM sites in that this site had to combat the variant form of the western corn rootworm. This variant not only causes damage to continuous corn, but also causes economic damage to first-year corn because of ovipositing in soybeans. Based on this occurrence, it was necessary to scout and spray soybean acreage as well as corn acreage, creating substantially higher costs for the AWPM program. The percentage of AWPM acreage that required treatment had a major impact on control costs (Table 2). Recall that the insect thresholds used to trigger spray treatments in 1997 and 1999 were 0.5 beetles per plant per day in first-year corn, 0.7 beetles per plant per day in continuous corn, and 2 beetles per sticky card per day in soybeans. In 1998, thresholds for the outer ring were raised to 2 beetles per plant per day due to the high spray costs incurred in the AWPM program in 1997. (Gerber, 2000).

Table 2. Indiana/Illinois AWPM site: Percentage of acreage requiring spray applications

1997 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	100%	100%
Corn-two treatments	66%	58%
Corn-three treatments	5%	4%
Soybeans-one treatment	98%	97%
Soybeans-two treatments	77%	45%
Soybeans-three treatments	13%	17%

1998 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	66%	19%
Corn-two treatments	6%	0%
Corn-three treatments	0%	0%
Soybeans-one treatment	9%	77%
Soybeans-two treatments	0%	8%
Soybeans-three treatments	0%	0%

1999 Spray Treatments (% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	62%	77%
Corn-two treatments	25%	21%
Corn-three treatments	5%	5%
Soybeans-one treatment	89%	94%
Soybeans-two treatments	43%	67%
Soybeans-three treatments	7%	28%
Soybeans-four treatments	0%	2%

The data indicate that infestation levels were higher in 1997 then in 1999. Infestation levels were relatively lower in 1998. The higher infestation levels in 1997 and 1999 resulted in higher control costs. Since larvae are particularly susceptible to high levels of soil moisture, excessive rainfall in June of 1998 (Indiana Agricultural Statistics, 1998) reduced infestation levels due to greater corn rootworm mortality. The population rebound in 1999 suggests that sustained population suppression had not been achieved in the first three years of the AWPM program.

The key yield, price, and cost parameters involved in the Indiana/Illinois NPV calculations are listed below (Table 3).

Table 3. Indiana/Illinois Parameters for one acre

	1997	1998	1999
Corn Yield	143	154	150
Corn Price	$2.53	$2.05	$1.99
Bean Yield	42	44	43.5
Bean Price	$6.59	$5.35	$4.64
Soil Insecticide Cost	$13.27	$14.06	$14.48
Slam® Cost[a]	$7.50	$7.69	$7.84
Aerial Cost	$5.00	$5.00	$5.10

[a] Slam® was the foliar insecticidal-bait used in the AWPM pilot program. This cost was based on a rate of 3/8 lb Slam® per acre @ $20.00, $20.50, and $20.90 per lb in 1997, 1998, and 1999, respectively.

For the remaining five years of the analysis, a corn yield trend of 1.5 bushels/acre/year was used, which was based on a 20-year Indiana trend in yield data. The Indiana soybean yield trend is 0.5 bushels/acre/year, also based on a 20-year trend in yield data. Yields reported for 1997 and 1998 were from the grower questionnaires, and the yield for 1999 was obtained from the Indiana Agricultural Statistics yield data for the site region. The projected corn price was $2.51/ bushel and the projected soybean price was $6.22, which again are based upon 20-year averages. Note, these prices were greater than the actual market prices in 1998 and 1999, but very similar to 1997 market prices. No loan deficiency payments or AMTA payments were included.[5] Farmers would be eligible for these payments irrespective of the method used to control corn rootworms. The soil insecticide, Slam®, and aerial application costs were inflated 3% per year for years 2000-2004.

For the soil insecticide approach, soil insecticides were assumed to be used on 100% of the corn acreage each year for all eight years. For the AWPM approach, soil insecticides were assumed to be used on 100% of the acreage in 1997 only. However, according to the project supervisor for the Indiana/Illinois site, soil insecticides were still necessary on many cornfields in 1998 and 1999 due to high beetle pressure (Gerber, 2000). In 1998, soil insecticides were used on 95.5% and 89.3% of the corn acreage in the inner core and outer ring, respectively. In 1999, 82.4% of the inner core cornfields and 75.4% of the outer ring cornfields were treated with soil insecticides.

To estimate the amount of soil insecticides to be used in the year 2000, it was necessary to calculate the 1999 acreage that required aerial retreatment for adult beetle control within 10 days of previous treatment. According to Larry Bledsoe, entomologist, Purdue University, if a field required retreatment with Slam® within 10 days of a previous treatment, the beetles that

---

[5] AMTA is an acronym for Agricultural Market Transition Act, a component of the 1996 Farm Bill. AMTA provides for 7 years of direct payments, unrelated to production, to farmers who had certified program acreage during 1991-1995 (ERS, 1996). Loan deficiency payments, also part of the 1996 Farm Bill, establish a base price for corn and soybeans.

survived the first treatment would have had sufficient time to lay eggs. These eggs would then hatch the following season, and a soil insecticide would be warranted to prevent damage from rootworm larvae (Quan, 1999). Following this logic, in 1999, 34.7% of the soybean acres in the inner core were retreated within 10 days, and 44.8% of the soybean acres in the outer ring were retreated within 10 days. Since these soybean acres will be rotated to corn in the year 2000, it was assumed that these retreatment percentages would be the percentages of the corn acreage that would require a soil insecticide in the year 2000. Finally, the projected percentage of soil insecticide required in 2001-2004 depended on which scenario was calculated (Table 4). For example, Scenario 1 assumed that the infestation levels in years 4-8 were similar to levels in 1997. Therefore, the acres requiring retreatment within 10 days would be similar to 1997, indicating that the percentage of acres requiring soil insecticide would be similar to that of 1998.

Table 4. Indiana/Illinois AWPM Site: Percentage of Corn Acres Using a Soil Insecticide (1997-1999 actual, 2000-2004 projected)

	Scenario 1 [a]		Scenario 2 [b]		Scenario 3 [c]		Scenario 4 [d]	
Year	Inner Core	Outer Ring	Inner Core	Outer Ring	Inner Core	Outer Ring	Inner Core	Outer Ring
1997	100%	100%	100%	100%	100%	100%	100%	100%
1998	95.5%	89.3%	95.5%	89.3%	95.5%	89.3%	95.5%	89.3%
1999	82.4%	75.4%	82.4%	75.4%	82.4%	75.4%	82.4%	75.4%
2000	34.7%	44.8%	34.7%	44.8%	34.7%	44.8%	0%	0%
2001	95.5%	89.3%	82.4%	75.4%	34.7%	44.8%	0%	0%
2002	95.5%	89.3%	82.4%	75.4%	34.7%	44.8%	0%	0%
2003	95.5%	89.3%	82.4%	75.4%	34.7%	44.8%	0%	0%
2004	95.5%	89.3%	82.4%	75.4%	34.7%	44.8%	0%	0%

[a] Assumes years 4-8 have infestation levels similar to 1997
[b] Assumes years 4-8 have infestation levels similar to 1998
[c] Assumes years 4-8 have infestation levels similar to 1999
[d] Assumes years 4-8 require no treatment

The NPV results for Indiana/Illinois provide an indication of the potential economic viability of AWPM in this region (Table 5).

Table 5. Indiana/Illinois NPV Results of Four Scenarios

SCENARIO 1: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1997 [a]		
	NPV ($/acre)	Yield Protection Effect (bu/acre/yr)
Inner Core	$1,386.02	30
Outer Ring	$1,392.42	28
Soil Insecticide	$1,479.14	

SCENARIO 2: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1998 [b]		
	NPV ($/acre)	Yield Protection Effect (bu/acre/yr)
Inner Core	$1,437.14	13
Outer Ring	$1,432.65	15
Soil Insecticide	$1,479.14	

SCENARIO 3: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1999 [c]		
	NPV ($/acre)	Yield Protection Effect (bu/acre/yr)
Inner Core	$1,417.83	20
Outer Ring	$1,403.91	24
Soil Insecticide	$1,479.14	

SCENARIO 4: YEARS 4-8 HAVE NO TREATMENT [d]		
	NPV ($/acre)	Yield Protection Effect (bu/acre/yr)
Inner Core	$1,465.49	4
Outer Ring	$1,464.44	5
Soil Insecticide	$1,479.14	

[a] High infestation assumption
[b] Low infestation assumption
[c] Moderate-to-High infestation assumption
[d] Best case infestation assumption

The AWPM approach was not economically viable in the Indiana/Illinois site unless AWPM provided a yield benefit relative to the soil insecticide approach. The primary reason for this outcome was that both corn and soybean acreage were sprayed with Slam® to control corn rootworms. Each of the four scenarios above indicated that the NPV for AWPM was less than the NPV for the soil insecticide method. It appears that for AWPM to be at least as profitable as the soil insecticide approach, a yield protection effect ranging from 4 to 30 bushels per acre per year would be needed (Table 5). These yield increases do not include scouting fees, since these estimates assumed zero scouting costs.

In order to observe the effect of certain parameter changes on the economic profitability of AWPM, additional NPV models were analyzed. Since the majority of the Indiana/Illinois site follows a corn/soybean rotation, it is the eggs laid in soybean acreage that will hatch in the corn acreage the following year, presenting a threat for root damage from larval feeding. Therefore, theoretically, if only soybean acreage were sprayed to prevent egg-laying, rather than the corn and soybean acreage, the subsequent corn acreage should be protected from larval feeding at a reduced cost. When only soybean acreage was sprayed in years 4-8, a yield protection effect ranging from 4 bushels per acre per year (Scenario 4) to 20 bushels per acre per year (Scenario 1) would still be required to make AWPM as profitable as the soil insecticide method. If only the soybean acreage was sprayed in all eight years, a scouting fee of $0.75 per acre per year could be afforded in Scenario 4; however, all other scenarios required a yield protection effect ranging from 4 to 14.5 bushels per acre per year. While the treatment of only soybean acreage does seem to reduce costs of AWPM, this technique might not adequately lower the beetle population in the site. Increased beetle migration could occur from the unsprayed corn acreage to the soybean acreage, increasing the frequency of spray treatments of the soybean acreage, further increasing costs.

Another situation was analyzed to determine if AWPM would be economically profitable in the event that Slam® (or a similar product) could be purchased at half-price. If Slam® could be purchased at half-price in years 4-8 of the program, a yield protection effect ranging from 4 bushels per acre per year (Scenario 4) to 23.5 bushels per acre per year (Scenario 1) would still be required. If Slam® could have been purchased at half-price throughout all eight years of the AWPM program, again, a yield protection effect would still be required, ranging from 1 bushel per acre per year (Scenario 4) to 20 bushels per acre per year (Scenario 1).

Kansas Results

Unlike the Indiana/Illinois site, the Kansas site did not require any treatment of first-year corn. Therefore, costs associated with rootworm control were significantly less than the costs in Indiana/Illinois. Also, spraying frequencies for Kansas were lower than for Indiana/Illinois (Table 6). Recall that the insect thresholds used to trigger spray treatment in 1997 and 1998 were 35 beetles per sticky trap per week, and in 1999 were lowered to 25 beetles per sticky trap per week (Whitworth, 2000).

Table 6. Kansas AWPM site: Percentage of acreage requiring spray applications

1997 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	60%	55%
Corn-two treatments	12%	8%
Corn-three treatments	0%	4%

1998 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	58%	26%
Corn-two treatments	39%	16%
Corn-three treatments	19%	0.5%

1999 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	53%	57%
Corn-two treatments	6%	0%
Corn-three treatments	6%	0%

At the Kansas site, corn yields were higher, and Slam® plus aerial application costs were lower than at the Indiana/Illinois site (Table 7).

Table 7. Kansas Parameters for one acre

	1997	1998	1999
Corn Yield	167	160	165.6
Corn Price	$2.65	$1.95	$1.97
Soil Insecticide Cost	$14.28	$14.71	$15.15
Slam® Cost[a] + Aerial application	$10.23	$10.23	$10.23

[a] Slam® cost was based on a rate of 3/8 lb per acre

The 1997 and 1998 yields were obtained from questionnaires returned by growers in the Kansas site. The 1999 yields were obtained from the Kansas Agricultural Statistics yield estimate for the region. To project corn yields for years 4-8, a yield trend of 2.1 bushels/acre/year was used, based on a 20-year regression analysis of historical Kansas data. The corn price used for the later years of the analysis was $2.51/bushel, which also was obtained from 20 years of historical price data. This corn price was similar to 1997, but greater than actual 1998 and 1999 market prices. Soil insecticide, Slam®, and aerial application costs were inflated 3% per year for years 4-8.

To conduct the Kansas NPV analysis, the same four scenarios were analyzed. For the soil insecticide method, it was assumed that 83% of the corn acreage used a soil insecticide for all eight years. This percentage was obtained from the economic surveys conducted in 1997 and 1998, which indicated the amount of soil insecticide typically used by growers in the Kansas site. For the AWPM approach, it was assumed that 83% of the corn acreage used a soil insecticide in 1997, but no soil insecticide was used in the remainder of the analysis. The results of the Kansas NPV scenarios suggest the AWPM approach could compete favorably with the soil insecticide approach. Kansas growers could pay a moderate scouting cost, and be at least as well off economically with the AWPM approach (Table 8).

Table 8. Kansas NPV Results of Four Scenarios

SCENARIO 1: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1997 [a]		
	NPV ($/acre)	Scouting Cost ($/acre)
Inner Core	$1,900.61	$2.20
Outer Ring	$1,909.16	$4.00
Soil Insecticide	$1,888.47	

SCENARIO 2: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1998 [b]		
	NPV ($/acre)	Scouting Cost ($/acre)
Inner Core	$1,888.22	$0.00
Outer Ring	$1,915.81	$5.00
Soil Insecticide	$1,888.47	

SCENARIO 3: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1999 [c]		
	NPV ($/acre)	Scouting Cost ($/acre)
Inner Core	$1,902.82	$2.80
Outer Ring	$1,911.69	$4.50
Soil Insecticide	$1,888.47	

SCENARIO 4: YEARS 4-8 HAVE NO TREATMENT [d]		
	NPV ($/acre)	Scouting Cost ($/acre)
Inner Core	$1,920.72	$6.20
Outer Ring	$1,927.70	$7.50
Soil Insecticide	$1,888.47	

[a] Low-Moderate infestation assumption
[b] High infestation assumption
[c] Moderate infestation assumption
[d] Best case infestation assumption

In each of the four scenarios, AWPM was shown to be at least as profitable as the soil insecticide method depending on the actual scouting fee paid by Kansas growers. Growers could afford moderate scouting fees in most years ranging from $2.00 to $5.00 per acre (Table 8).

Using these data, AWPM seems to be an economically reasonable alternative to the soil insecticide method in North Central Kansas. However, there was one unexpected result: the outer core indicated a greater benefit than the inner core. This is contrary to the original hypothesis which speculated that the inner core should experience lower infestation levels due to the "buffer effect" offered by the outer ring fields to protect the inner core from migrating beetles. This buffer effect did not occur in 1997, 1998, nor 1999 in Kansas. A reason for this may be that beetles are more mobile than originally thought, or the outer ring buffer is not large enough to prevent migration into the inner core (Wilde, 2000).

Since Slam® and aerial application costs used for the Kansas analysis were lower than for the other sites, a cost analysis using slightly higher Slam® and aerial application costs was calculated to see if these lower costs resulted in the more favorable outcome for the AWPM approach. The results of this analysis still indicate that Kansas farmers could afford to pay moderate scouting fees ranging from $1.60 per acre per year (inner core, Scenario 1) to $7.10 per acre per year (Scenario 4). The exception was the inner core in Scenario 2, where a yield protection effect of 1 bushel per acre per year would be needed for growers utilizing the AWPM approach to be equally well-off with growers using the traditional soil insecticide approach, ignoring scouting costs.

Additionally, similar to the Indiana/Illinois NPV analysis, the profitability of AWPM with Slam® purchased at half-price was analyzed. If Slam® could be purchased at half-price for years 4-8, a scouting fee could be afforded for all scenarios, ranging from $1.50 per acre per year (inner core, Scenario 2) to $7.50 per acre per year (Scenario 4). If Slam® could have been purchased at half-price for all eight years of the program, the scouting fees that could be afforded ranged from $2.20 per acre per year (inner core, Scenario 2) to $8.00 per acre per year (Scenario 4).

Iowa Results

The Iowa site was similar to the Kansas site because the treatment of first-year corn for corn rootworm was unnecessary. The AWPM acreage requiring spray applications in Iowa was only slightly less than in Indiana/Illinois (Table 9). Recall that the insect thresholds used to trigger spray treatments in 1997, 1998, and 1999 were 6 beetles per sticky trap per day (Berry, 2000).

Table 9. Iowa AWPM site: Percentage of acreage requiring spray applications

1997 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	98%	91%
Corn-two treatments	68%	43%
Corn-three treatments	0%	0%

1998 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	41%	47%
Corn-two treatments	0%	2%
Corn-three treatments	0%	0%

1999 Spray Treatments		
(% of total corn/soybean acres)	Inner Core	Outer Ring
Corn-one treatment	71%	73%
Corn-two treatments	16%	21%
Corn-three treatments	0%	1%

The data show that the acreage requiring spray treatments in the Iowa site was substantially reduced in 1998. However, the cause of the lower infestation levels in 1998 could have been weather-related, similar to the Indiana/Illinois site. Excessively wet conditions in June of 1998 (Iowa Agricultural Statistics, 1998) could have contributed to greater corn rootworm larval mortality rates. The number of spray applications increased in 1999, as the rootworm population rebounded from its decline in 1998, but were still below 1997 levels.

Aerial application costs and Slam® application rates were slightly higher in Iowa than for the other two sites (Table 10).

Table 10. Iowa Parameters for one acre

	1997	1998	1999
Corn Yield	152	159	158
Corn Price	$2.33	$1.86	$1.87
Soil Insecticide Cost	$12.53	$13.48	$13.88
Slam® Cost[a]	$11.01	$11.01	$11.01
Aerial application	$6.25	$6.25	$6.25

[a] Slam® cost was based on ½ lb per acre rate @ $22.02 per lb

The 1997 and 1998 yields were obtained from the questionnaires returned by growers in the Iowa site. The 1999 yields were obtained from the Iowa Agricultural Statistics yield estimates for the region. A regression analysis of 20-year historical Iowa data was used to project corn yields for years 4-8, resulting in a yield trend of 1.2 bushels/acre/year. The corn price used for the later years of the analysis was the 20-year average of historical price data, or $2.37 per bushel. As with the other two sites, this corn price was similar to 1997, but higher than the market prices observed in 1998 and 1999. Costs for soil insecticides, Slam®, and aerial application were inflated 3% per year in years 4-8.

For the soil insecticide control method, soil insecticides were assumed to be used on 91% of the acreage for all eight years of the analysis. For the AWPM method, the inner core and outer ring fields were treated with soil insecticides on 91% of the acreage only in 1997. This percentage was obtained from the economic surveys completed by the Iowa growers in 1997 and 1998.

Results of the Iowa NPV analysis generally do not economically favor the AWPM approach compared to the soil insecticide method (Table 11).

Table 11. Iowa NPV Results of Four Scenarios

SCENARIO 1: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1997 [a]		
	NPV ($/acre)	Yield Protection Effect (bu/acre/yr)
Inner Core	$1,588.58	11
Outer Ring	$1,606.30	8.2
Soil Insecticide	$1,655.01	

SCENARIO 2: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1998 [b]		
	NPV ($/acre)	Yield Protection Effect (bu/acre/yr)
Inner Core	$1,647.31	1.4
Outer Ring	$1,646.08	1.6
Soil Insecticide	$1,655.01	

SCENARIO 3: YEARS 4-8 HAVE SAME INFESTATION LEVELS AS 1999 [c]		
	NPV ($/acre)	Yield Protection Effect (bu/acre/yr)
Inner Core	$1,626.21	4.9
Outer Ring	$1,624.84	5.1
Soil Insecticide	$1,655.01	

SCENARIO 4: YEARS 4-8 HAVE NO TREATMENT [d]		
	NPV ($/acre)	Scouting Cost ($/acre)
Inner Core	$1,666.64	$2.00
Outer Ring	$1,669.34	$2.80
Soil Insecticide	$1,655.01	

[a] High infestation assumption
[b] Low infestation assumption
[c] Moderate-to-High infestation assumption
[d] Best case infestation assumption

The empirical results indicate that the AWPM method for controlling rootworm was not as profitable as the soil insecticide method unless there was an actual yield benefit from using AWPM. The exception was the very optimistic Scenario 4, where it was assumed that years 4-8 would have required no Slam® treatment. In this case, AWPM was as profitable as the soil insecticide method, and farmers could have afforded to pay between $2 and $3 per acre in scouting fees.

The profitability of AWPM with Slam® purchased at half-price was also analyzed for Iowa. If Slam® could be purchased at half-price for years 4-8, the only scenario that allowed for a scouting fee was Scenario 4, where no treatment was required for years 4-8. The remaining three scenarios indicated that a yield protection effect would still be required, ranging from 0.25 bushels per acre per year (Scenario 2) to 7 bushels per acre per year (Scenario 1). If Slam® could have been purchased at half-price for all eight years of the program, a scouting fee ranging from $1.85 per acre per year (Scenario 2) to $5.00 per acre per year (Scenario 4) could be afforded.

Conclusions

One of the overall objectives of the areawide pest management (AWPM) pilot program is to determine if a reduction in the amount of soil insecticides used to control the corn rootworm is possible by lowering the beetle population equilibrium level with multiple tactics. This economic analysis was conducted to determine if AWPM is as profitable as the traditional single tactic soil insecticide approach. Through comparisons of the Net Present Values between the AWPM and soil insecticide methods, the most profitable control approach was determined based on an 8-year time frame with four possible infestation scenarios.

The economic analysis for the Indiana/Illinois site suggested that the soil insecticide approach was the most profitable control measure in all four scenarios. In order for the AWPM approach to be at least equal to the soil insecticide approach, a yield protection effect for AWPM between 4 to 30 bushels per acre per year would be necessary, depending upon the infestation scenario analyzed. In addition to this yield protection effect, a scouting subsidy would be required. The presence of the western corn rootworm variant, which causes damage to first-year corn, significantly raises control costs for AWPM in the Indiana/Illinois site due to the necessity of treating both corn and soybean acreage.

The economic analysis for the Kansas site was more favorable towards AWPM, indicating that AWPM could be a viable alternative to the soil insecticide method in each of the four scenarios. Kansas growers could afford to pay scouting fees from zero to $7.50 per acre, depending on the scenario. Population suppression and the lack of the variant form of corn rootworm contribute to the potential profitability of AWPM in Kansas.

The economic analysis for the Iowa site indicated that the soil insecticide method was more profitable than the AWPM approach in three of the four scenarios. In the three scenarios where the soil insecticide approach was the most profitable, a yield protection effect ranging from 1.4 to 11 bushels per acre per year, in addition to subsidized scouting fees, would be necessary to make AWPM as profitable. In the very optimistic fourth scenario, where no Slam® treatment was needed in years 4-8, AWPM was more profitable than the soil insecticide method, and Iowa growers could afford to pay a scouting fee of $2 to $3 per acre.

These results indicate that AWPM has the potential of being an economically viable alternative to the soil insecticide approach in selected situations, as was observed at the Kansas site. However, the lack of population suppression at the Indiana/Illinois and Iowa sites greatly decreased the profitability of AWPM at these sites. The migratory capability of the corn rootworm beetle hampers such suppression efforts, and is a key issue to be analyzed by entomologists. The hypothesized “buffer effect” that should protect the inner core from beetle migration was not observed from the current data, suggesting that perhaps a much larger buffer area is necessary to prevent beetle migration into the inner core. Private adoption of an AWPM program will not be economically attractive to corn producers unless increased profitability for the AWPM method can be demonstrated in future years as the USDA-ARS and land grant universities continue research at these key regional sites.

REFERENCES

Berry, Ed. April 18, 2000. Areawide IPM Specialist, Iowa State University, Department of Entomology. E-mail communication.

Bledsoe, Larry. May 10, 2000. Professor in the Department of Entomology, Purdue University. E-mail communication.

Chandler, Laurence. April 12, 2000. USDA-ARS, Director of Corn Rootworm Areawide Pest Management Program. E-mail communication.

Edwards, C.R., L.W. Bledsoe, and J.L. Obermeyer. 1998. Managing corn rootworms. Report E-49. Field Crops. Purdue University Cooperative Extension Service, Department of Entomology, West Lafayette, IN.

Edwards, C. Richard. 1999, 2000. Professor in the Department of Entomology, Purdue University. Personal communication.

Gerber, Corey K. 2000. Areawide IPM Specialist, Department of Entomology, Purdue University. Personal communication.

Indiana Agricultural Statistics. June 15, 22, 1998. Indiana Weekly Weather and Crops. Online Posting, April 11, 2000. http://www.aes.purdue.edu/agstat/cropweat

Iowa Agricultural Statistics, State Climatologist, Iowa Dept. of Agriculture and Land Stewardship. 1998. Iowa Precipitation, 1998. Iowa Precipitation Surplus, Inches.

Metcalf, R.L. 1986. Foreword. P. vii-xv, *In*: J.L. Krysan and T.A. Miller [eds.], Methods for the study of pest *Diabrotica.* Springer, New York.

Quan, Peter, and Marshall A. Martin. 1999. Corn rootworm control: economic evaluation of an areawide pest management approach. Master's thesis, Purdue University Department of Agricultural Economics.

Steffey, K.L., M.E. Gray, and J.T. Shaw. 1993. Corn hybrid response to corn rootworm injury. 68-72.

Whitworth, Jeff. 2000. Areawide IPM Specialist, Kansas State University, Department of Entomology. E-mail communication.

Wilde, Gerald. May 3, 2000. Professor in the Department of Entomology, Kansas State University. E-mail communication.