An Optimal Corn Rootworm Scouting Program for Improved Profitability of Areawide Pest Management in the Eastern Corn Belt

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Background

Corn rootworm (*Diabrotica* spp.), is a major economic pest in corn. Crop losses and associated control costs attributed to this pest cost US farmers an estimated $1 billion annually (Metcalf, 1986). Rootworm larvae feed on and tunnel inside roots, which can lead to root pruning and yield reduction. While larvae are often the most injurious, adult beetles also feed on silks, leaves, and pollen.

Compounding the magnitude of the economic damage from this insect is its ability to adapt to a variety of management practices. Corn rootworms have a history of developing resistance to several insecticides. In addition, two species, western corn rootworm (WCR) and northern corn rootworm (NCR) have adapted to crop rotation practices in the Northern and Eastern Corn Belt. It is believed NCR have developed extended diapause, which allows the eggs to remain dormant for two or more winters, until the field is rotated back to corn (Levine, et al., 1992). In Illinois and Indiana, WCR beetles have been observed laying eggs in soybeans. Historically, corn rootworm beetles only laid eggs in corn. Since larvae will starve without corn roots, a corn- soybean crop rotation was an effective cultural control. However, eggs laid by the variant WCR in soybeans will hatch into larvae in corn fields the next year, causing damage to first-year corn not protected by a soil insecticide. As a result of these adaptations, previously effective crop rotation practices no longer control corn rootworm in some areas. The evolution of the WCR variant, in particular, has significantly increased grower's reliance on soil insecticides in east central Illinois and northeastern Indiana. A recent survey found that over three-fourths of the farmers in this region now apply a soil insecticide to first-year corn (Harbor, 2002). Heavy use of soil insecticide may lead to insect resistance. This concern, combined with the uncertain future availability of common soil

insecticides, led the USDA to develop the Areawide Pest Management Program (AWPM) as an alternative approach to corn rootworm control.

AWPM relies on a soil insecticide bait, aerially broadcast over a large geographic area with active adult beetles. The goal is to suppress the adult beetle population and prevent egg laying. In theory, the populations would be suppressed below economically damaging levels over time, gradually requiring less insecticide. High costs at the beginning of an AWPM program, incurred to achieve adequate population suppression, could be offset by a period of lower control costs in the future. In addition, far less active ingredient would be applied to the soil, since the insecticidal bait mixture used in AWPM has one-tenth the toxicant of traditional soil insecticides.

AWPM programs were developed on 16 square mile sites in Kansas, Iowa, and on the Illinois/Indiana border (Figure 1). Areawide corn rootworm control was implemented annually on these sites from 1997-2001. Each year, corn rootworm levels were closely monitored. Fields within the site were scouted weekly throughout the growing season to determine when adult insect levels reached a predetermined economic threshold. At this threshold, aerial applications of an insecticide were made to control adult beetles. Soil insecticides were only recommended on first-year corn if the spraying program in the previous year did not adequately suppress the adult beetle population. While the data suggest AWPM can provide the same level of corn rootworm control as traditional soil insecticides alone, profit maximizing farmers will not adopt AWPM unless it is equally or more profitable than currently available alternatives.
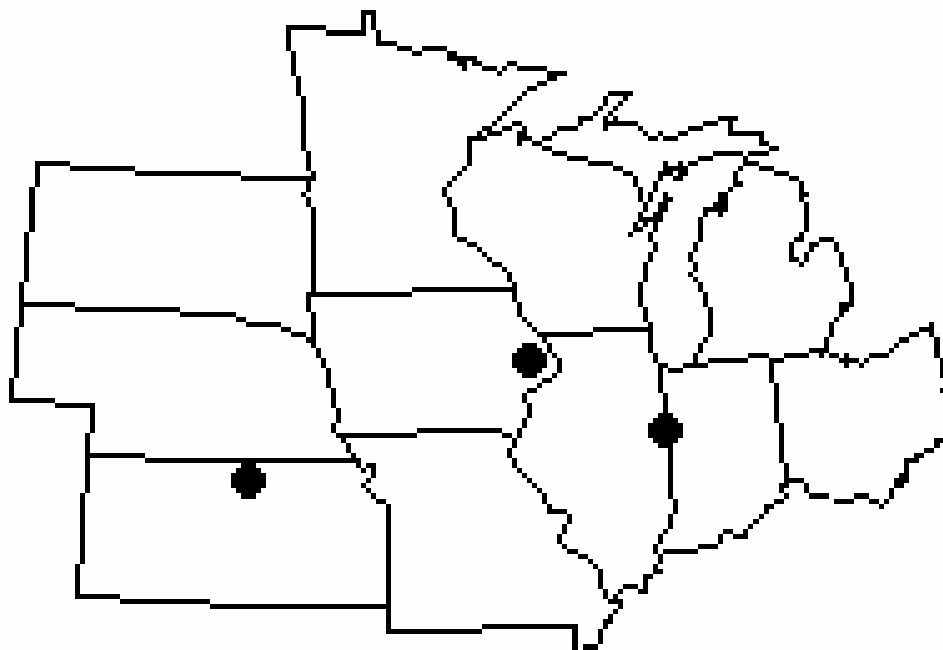
Figure 1. Location of AWPM Experimental Sites: Kansas, Iowa, and Illinois/Indiana

Previous work by Quan (1999) and Stair (2000) examined the Net Present Value (NPV) of AWPM in comparison to soil insecticides on a per acre basis. Their analysis was updated with the most recent data from 2000 and 2001. AWPM is not cost competitive with a soil insecticide alone at the Illinois/Indiana site. The NPV analysis indicates that in order for AWPM to be cost competitive, the areawide approach would have to provide increased corn yields of approximately 7-14 bushels of corn per acre each year (West, 2003).

There continues to be substantial pressure from WCR at this site, despite intense scouting and spraying efforts to suppress adult beetles. As a result, the costs of AWPM to prevent economic damage to crops are still higher than with soil insecticides alone. In order for AWPM to be a cost-effective strategy for rootworm control at this location, costs must be reduced. This paper examines several factors that may be affecting the profitability of

AWPM at the Illinois/Indiana site in order to determine under what conditions AWPM might be more profitable in an area where the WCR variant is present.

Factors Affecting Profitability

There are several factors that may be affecting the profitability of AWPM at the Illinois/Indiana site. Soil insecticide use on first-year corn fields within the AWPM managed acres remained fairly high throughout the program. These acres were in effect incurring a "double cost" for two control strategies. However, Purdue University entomologists recommended soil insecticide on corn following soybeans within the AWPM program only if WCR beetle levels reached five beetles/trap/day. Examination of the WCR populations throughout the growing season for each year has shown that farmers applied soil insecticide more often than recommended (West, 2003). Most likely, farmers in this area applied a soil insecticide on their first-year corn fields due to tradition, as "insurance" to manage risk of potential yield loss, or due to reluctance to rely solely on AWPM for insect suppression. Although crop scouts regularly monitored the fields and reported their findings to growers, the ultimate choice of whether to apply a soil insecticide was left to each grower. Consequently, the continued widespread use of soil insecticides reduced the profitability of the arewide program at this site.

The presence of the WCR variant, which unlike in the other sites, required scouting and spraying of both corn and soybean fields. This added cost, together with a low economic threshold in soybeans, also affected the profitability of AWPM. The true economic threshold at which soybean fields should be treated with an aerial application of insecticide was unknown at the beginning of the AWPM program in 1997, so a relatively low threshold (two beetles/trap/day) was chosen for the best crop protection. Over the course of the AWPM

program in the Illinois/Indiana site, it was observed that using a two beetles/trap/day threshold in soybeans to trigger aerial applications often resulted in a very large amount of spraying, especially in years with high adult insect populations. This contributed to the higher cost of the AWPM program.

AWPM requires intensive management, as the site must be scouted weekly throughout the season to ascertain the rootworm population levels and the optimal timing of aerial application. If scouting and/or spraying costs could be reduced, AWPM could become a more attractive alternative for farmers. However, a reduction in scouting and/or aerial treatments may result in yield losses if some fields that reach the economic threshold are not treated and corn rootworm damage occurs. This paper analyses several potential strategies for reducing scouting and/or spraying costs, including a reduction in scouting frequency and a reduction in the number of fields scouted.

Procedure

Corn rootworm data from all soybean and corn fields within the Illinois/Indiana site were obtained from the project manager for the period 1997-2001. These data were superimposed by field onto color-coded site maps to determine if any patterns emerged. There are six maps for each year; one for each of the scouting weeks. For the years 1997-1999, every corn and soybean field within the site was scouted. Fields received aerial insecticide applications on a field-by-field basis as they reached the WCR threshold for the given crop. Recall that the threshold for soybean fields was two beetles/trap/day for 1997-2001. The threshold for corn fields in 1997-1999 was 0.5 beetles per corn plant in first-year corn and 0.7 beetles per plant in continuous corn. In 2000 and 2001, a different spraying approach was used. The site was divided into nineteen, 640-acre sections. In an attempt to

achieve better insect suppression, if one soybean field within a section reached the two

beetles/trap/day threshold, all corn and soybean fields within that section received the aerial

treatment. Thus, in 2000 and 2001, it was not necessary to scout every corn field as well as

every soybean field. About 35% of the corn fields within the AWPM site were scouted to

monitor the WCR populations in 2000 and 2001 (Gerber, 2002). The aerial spraying decision

was based on the soybean WCR populations alone in these two years.

Results

Change in Soybean Economic Threshold

The maps showing the WCR populations by field were examined to determine which

soybean fields would be sprayed in 1997-1999 under a two, three, four, or five

beetles/trap/day threshold and field-by-field spraying (Figure 2). For 1997-1999, only the

soybean threshold was adjusted. For 2000 and 2001, the field-by-field data indicated which

sections would be sprayed each week under the various soybean thresholds and sectional

spraying (Figure 3).

The acreage that would be sprayed under the various insect thresholds for each year

was calculated and used to estimate total spraying costs. The costs associated with a full, six-

week scouting schedule and an economic threshold set at three, four, and five beetles/trap/day

were compared to those using a two beetles/trap/day threshold. Potential savings from

spraying at a higher economic threshold were calculated (Table 1).

Due to the different spraying methods used in 1997-1999 and 2000-2001, average

savings estimates were calculated for 1997-1999, 2000-2001, and 1997-2001. This allows

comparisons of potential savings under different spraying regimes. For example, raising the

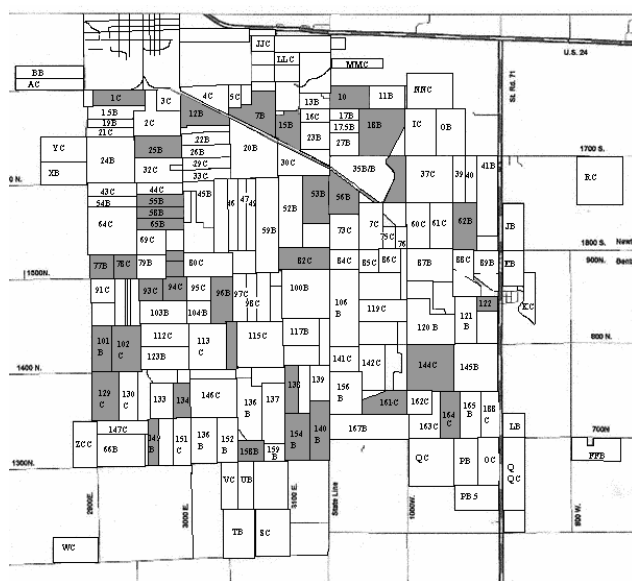economic threshold from two to five beetles/trap/day could provide $11.02 per acre in savings

Figure 2. Sample Map Illinois/Indiana Site: Aerial Treatment by Field Under Three beetles/trap/day Threshold for Soybeans[a] in 1999, Week Two

[a] Shaded fields represent corn and soybean fields with WCR populations at or exceeding the threshold. In 1999, the threshold for corn was 0.5 beetles/plant/day (first-year corn) and 0.7 beetles/plant/day (continuous corn).
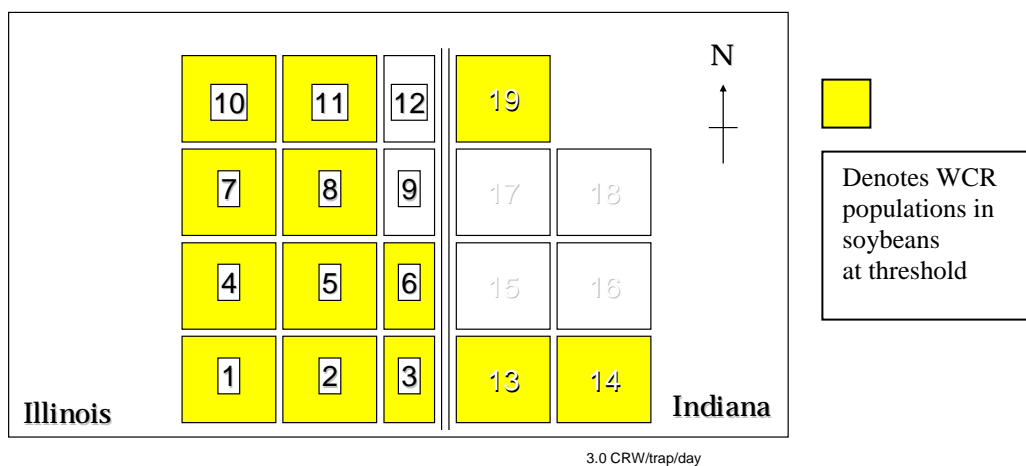

3.0 CRW/trap/day

Figure 3. Illinois/Indiana Site: Sections to be Sprayed Under Three beetles/trap/day Threshold in Soybeans, Week Three, 2000

over the five year period, 1997-2001. However, raising the threshold from two to five

beetles/trap/day could provide $17.69 per acre in savings under the sectional spraying method

used in 2000 and 2001 (Table 1). Savings are generally higher with a sectional spraying

method than with a field-by-field method because by reducing scouting/spraying, entire

sections, rather then individual fields, may not be treated.

Table 1. Savings From Raising the Economic Threshold in Soybeans

	Average Savings 1997-1999	Average Savings/Acre 1997-1999	Average Savings 2000-2001	Average Savings/Acre 2000-2001	Average Savings 1997-2001	Average Savings/Acre 1997-2001
Two to Three[a]	$30,339	$3.26	$79,219	$8.53	$49,900	$5.38
Two to Four[b]	$52,052	$5.61	$117,648	$12.68	$78,290	$8.44
Two to Five[c]	$61,014	$6.57	$164,161	$17.69	$102,273	$11.02
Three to Four[d]	$21,713	$2.33	$38,429	$4.14	$28,400	$2.60
Four to Five[e]	$8,962	$0.97	$46,514	$5.07	$23,983	$2.58

[a] Increase in the economic threshold from two beetles/trap/day to three beetles/trap/day
[b] Increase in the economic threshold from two beetles/trap/day to four beetles/trap/day
[c] Increase in the economic threshold from two beetles/trap/day to five beetles/trap/day
[d] Increase in the economic threshold from three beetles/trap/day to four beetles/trap/day
[e] Increase in the economic threshold from four beetles/trap/day to five beetles/trap/day

Reducing the Number of Weeks Scouted

Another possible method of reducing scouting or spraying costs for AWPM would be

to reduce the amount of scouting. Currently, the protocol requires that all soybean fields and

some of the corn fields be scouted once a week for six weeks during the growing season.

Scouting may be reduced by scouting fewer weeks and/or fewer fields. AWPM requires

intensive scouting measures to assure optimal timing of the aerial insecticide application.

However, if these rigorous scouting practices could be reduced such that the optimal timing of

aerial sprays and the level of WCR control are not diminished, AWPM might become more profitable.

The color-coded maps, showing fluctuations in the WCR population for each year, were examined to determine if it would be possible to scout fewer fields and still reach the same spraying frequency. This way, WCR control would not be compromised. For example, it was determined upon examination of the populations in 2001, that most sections required aerial insecticide applications according to the two beetles/trap/day threshold in weeks three, four, and five (Figure 4.).

If scouting and spraying were only conducted in weeks three, four, and five under a modified AWPM protocol in 2001, a majority of the acres that required spraying in 2001 would still have been treated. However, scouting costs would have been reduced by half. Savings also would come from eliminating the aerial spraying that would have been conducted in weeks one, two, and six.

A similar analysis of the adult beetle population fluctuations over the six weeks for the years 1997-2000 was conducted. The savings that could be incurred by scouting/spraying for three weeks instead of six was calculated. A reduction in scouting from six to three weeks results in average savings of $12.28 per acre at the two beetles/trap/day threshold and $6.76 per acre at the five beetle level, averaged over 1997-2001. Under the sectional spraying method of 2000-2001, only three weeks of scouting produces savings of $14.38 per acre at two beetles/trap/day, and $5.87 per acre at five beetles/trap/day (Table 2).
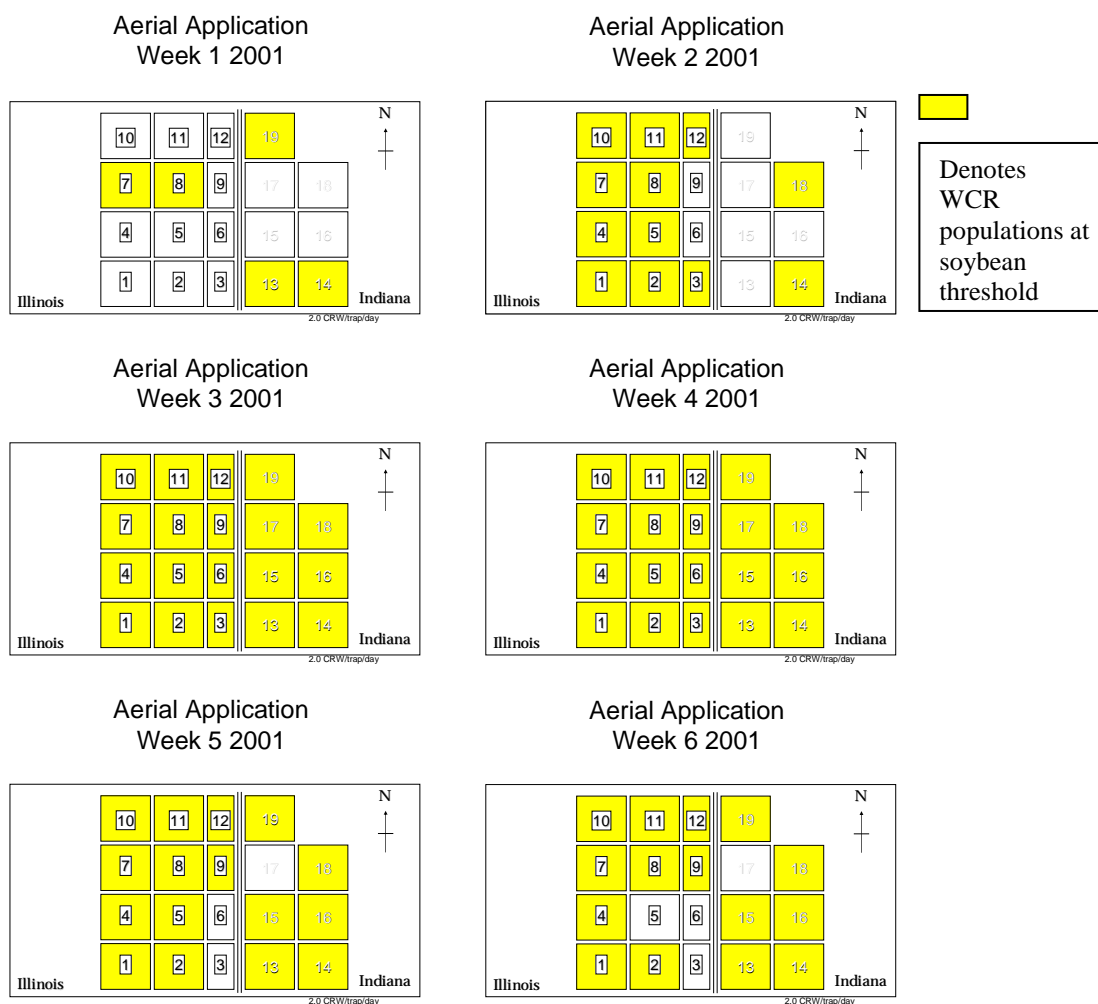
Figure 4. Illinois/Indiana Sectional Maps Showing what Sections Would Have Been Treated Under Two beetles/trap/day Threshold (2001).

Table 2. Cost Savings: Reducing Scouting to Three Weeks 1997-2001
Savings from Reduced Scouting and Spraying Only

	Average Savings 1997-1999	Average Savings/Acre 1997-1999	Average Savings 2000-2001	Average Savings/Acre 2000-2001	Average Savings 1997-2001	Average Savings/Acre 1997-2001
Two[a]	$100,883	$10.87	$133,495	$14.38	$113,928	$12.28
Three[b]	$85,752	$9.24	$86,321	$9.30	$85,157	$9.18
Four[c]	$73,020	$7.87	$70,375	$7.58	$71,962	$7.75
Five[d]	$68,272	$7.36	$54,462	$5.87	$62,748	$6.76

[a] Savings associated with a two beetles/trap/day economic threshold
[b] Savings associated with a three beetles/trap/day economic threshold
[c] Savings associated with a four beetles/trap/day economic threshold
[d] Savings associated with a five beetles/trap/day economic threshold

In addition to only scouting three weeks, a strategy to further reduce costs would be to simultaneously raise the economic threshold. Thus, savings would be gained from less aerial spraying associated with the higher insect threshold, less aerial spraying needed for a three week treatment, and lower scouting costs. Examining the average costs from 1997-2001, an increase in the threshold from two to three beetles/trap/day and scouting for three weeks would reduce costs by $14.55 per acre. Increasing the threshold from two to five beetles/trap/day and scouting for three weeks would result in cost savings of $17.78 per acre. The same changes in scouting under the sectional spraying method used in 2000-2001 would produce $17.61 and $23.56 in savings per acre, respectively. (Table 3).

Table 3. Savings from Threshold Changes and Three Weeks Reduced Scouting/Spraying

	Average Savings 1997-1999	Average Savings/Acre 1997-1999	Average Savings 2000-2001	Average Savings/Acre 2000-2001	Average Savings 1997-2001	Average Savings/Acre 1997-2001
Two to Three[a]	$116,091	$12.51	$163,483	$17.61	$135,048	$14.55
Two to Four[b]	$125,072	$13.48	$188,023	$20.26	$150,252	$16.19
Two to Five[c]	$129,286	$13.93	$218,623	$23.56	$165,021	$17.78

[a] Increase in the economic threshold from two beetles/trap/day to three beetles/trap/day
[b] Increase in the economic threshold from two beetles/trap/day to four beetles/trap/day
[c] Increase in the economic threshold from two beetles/trap/day to five beetles/trap/day

Substantial savings could be gained from scouting and spraying only three weeks, rather than six. However, without scouting soybean fields in these weeks, it would be impossible to determine what kind of crop damage might occur in corn planted the following year. Soil insecticide use is currently recommended for a soybean field going into corn the following year if the WCR numbers reach five beetles/trap/day at any time during the six-week scouting period. If a soybean field were to reach this level in week one, two, or six (and not during weeks three, four, or five), the recommendation for a soil insecticide would not be

made, and serious losses could occur in the corn crop the next season. This assumes farmers were not overusing soil insecticides. The WCR population does not always peak in weeks three, four, or five in every year. It may peak in weeks one or two, as it did in 1999. If the insect population were to peak towards the beginning of the scouting period, or the end, there is a large potential for a loss in corn the following year. For these reasons, eliminating scouting during part of the growing season may not be a wise choice. However, this scouting reduction is worth examining, since potential savings of $6.76 to $17.78 per acre exist, depending on the threshold (Tables 2 and 3).

Reducing the Number of Fields Scouted

An alternative method for reducing scouting and related costs in AWPM is to reduce the number of fields scouted each week. Scouting and spraying, if appropriate, would be conducted on the remaining fields for six weeks. Tradeoffs between the reduced cost of less scouting/spraying and potential increases in the insect population or yield damage exist as with a three-week scouting regime. However, only the number of fields scouted each week would be reduced. Selected fields would continue to be monitored throughout the entire six-week scouting season.

To estimate what the cost savings would be from such a scouting regime, half of the corn and soybean fields for 1997, 1998, 1999, and half of the soybean fields for 2000 and 2001 were randomly selected to be scouted. Every other soybean field from a numerical list was chosen for each year. The same procedure was used to select corn fields that would have been scouted in 1997, 1998, and 1999. For example, soybean field numbers 1, 3, 5, etc., were selected to be scouted in 2000. In this hypothetical scouting scenario, the same fields would be scouted each week for a particular year. The fields that were chosen to be scouted were

not the same year to year, since most of the fields are in a corn-soybean rotation. Nor were the fields the same for 1997, 1999, and 2001, or 1998 and 2000, those years with similar cropping patterns. The corn rootworm data and the fields designated to be scouted were used to determine which fields or sections would still be scouted and sprayed.

The costs were calculated for this scouting regime and compared to the situation where all fields (including corn fields for 1997-1999) were scouted. Savings arise from reducing the number of fields scouted, and from the consequent reduction in spraying (Table 4). Fields or sections that would have been sprayed under a given economic threshold may not be sprayed, if the field (or a field within a specific section) that reached threshold was not scouted. Over the five years in the study, the average savings from reducing the number of fields scouted was $7.43 per acre at a two beetle threshold and $5.58 at a five beetle threshold. In 2000-2001, these savings would have been $6.67 at a two beetle threshold and $5.18 at a five beetle threshold.

Table 4. Savings from 50% Reduction in the Number of Fields Scouted

	Average Savings 1997-1999	Average Savings/Acre 1997-1999	Average Savings 2000-2001	Average Savings/Acre 2000-2001	Average Savings 1997-2001	Average Savings/Acre 1997-2001
Two[a]	$73,720	$7.94	$61,894	$6.67	$68,989	$7.43
Three[b]	$69,299	$7.47	$43,843	$4.72	$59,116	$6.37
Four[c]	$58,290	$6.28	$45,143	$4.86	$53,031	$5.71
Five[d]	$54,257	$5.85	$48,031	$5.18	$51,767	$5.58

[a] Savings associated with a two beetles/trap/day economic threshold
[b] Savings associated with a three beetles/trap/day economic threshold
[c] Savings associated with a four beetles/trap/day economic threshold
[d] Savings associated with a five beetles/trap/day economic threshold

As when limiting the scouting period to three weeks, savings are also possible if fewer fields are scouted each week, while concurrently raising the economic threshold. Savings could result from less aerial spraying needed at the higher insect threshold, less aerial spraying of fields or sections that reached threshold, and lower scouting costs. For example,

an increase in the threshold from two to five beetles/trap/day combined with a 50% reduction in the number of fields scouted could result in cost savings of $16.60 per acre over 1997-2001 (Table 5). Potential savings are even greater under a sectional spraying method, like the one used in 2000 and 2001. Under a sectional spraying method, raising the economic threshold from two to five beetles/trap/day and scouting fewer fields could produce $22.86 in per acre savings.

Table 5. Savings from Threshold Change and 50% Reduction in the Number of Fields Scouted

	Average Savings 1997-1999	Average Savings/Acre 1997-1999	Average Savings 2000-2001	Average Savings/Acre 2000-2001	Average Savings 1997-2001	Average Savings/Acre 1997-2001
Two to Three[a]	$99,637	$10.74	$123,062	$13.26	$109,007	$11.75
Two to Four[b]	$110,342	$11.89	$162,791	$17.54	$131,322	$14.15
Two to Five[c]	$115,271	$12.42	$212,193	$22.86	$154,040	$16.60

[a] Increase in the economic threshold from two beetles/trap/day to three beetles/trap/day
[b] Increase in the economic threshold from two beetles/trap/day to four beetles/trap/day
[c] Increase in the economic threshold from two beetles/trap/day to five beetles/trap/day

Risk From Reduced Scouting and Spraying

If scouting is only conducted on 50% of the fields at the site, some fields that reach the designated threshold might go untreated. This poses a risk of yield loss to the farmers who manage those fields. The probability of not spraying a section when a field reaches the economic threshold is a partial measurement of the risk incurred from a reduction in scouting and spraying. To determine the probability of not spraying a section that needed treatment, the number of acres that would have been "missed" (acres reaching threshold that were not scouted or were within sections that were not treated) was calculated, and compared to the number of acres that would have been treated when every field was scouted (Figures 5 and

6). The number of acres that would have been "missed" was also calculated as a percentage

of the acres that would have been sprayed under a six-week scouting regimen (Figure 7).
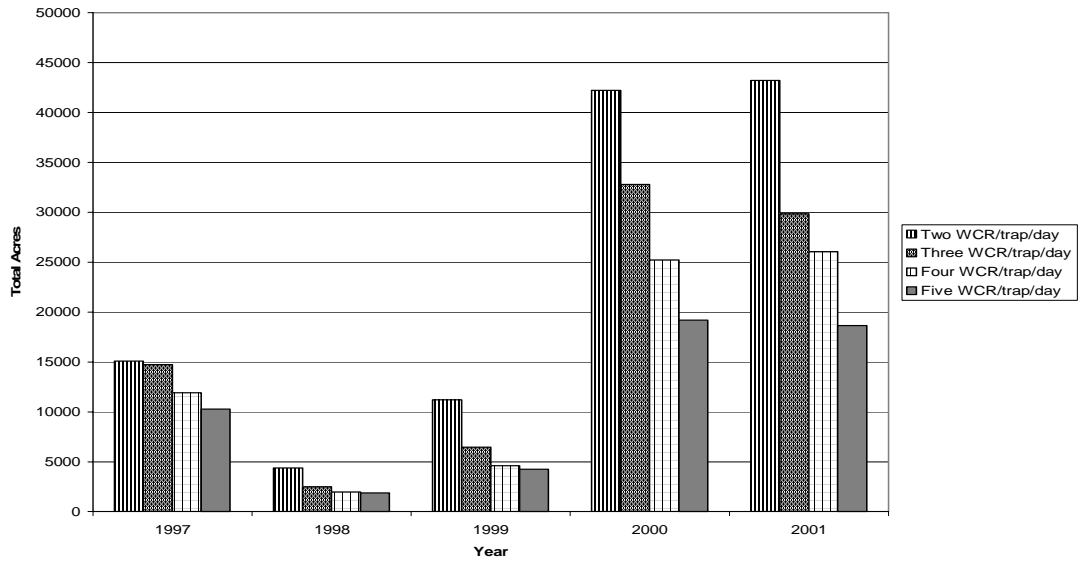

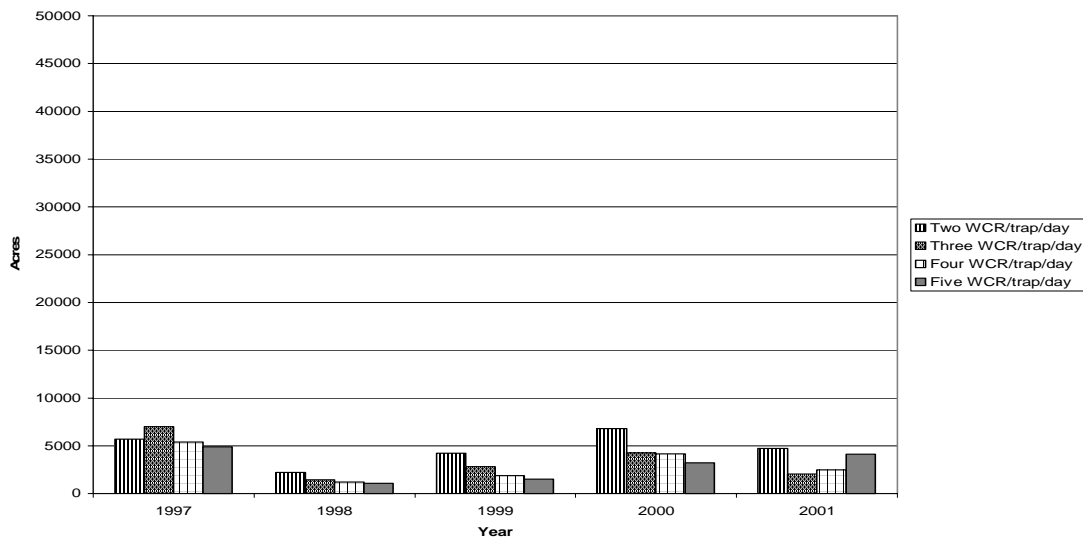Figure 5. Acres Sprayed Under Various Soybean Thresholds and Six Weeks of Scouting

Figure 6. Acres Reaching Threshold: "Missed" With 50% Fewer Fields
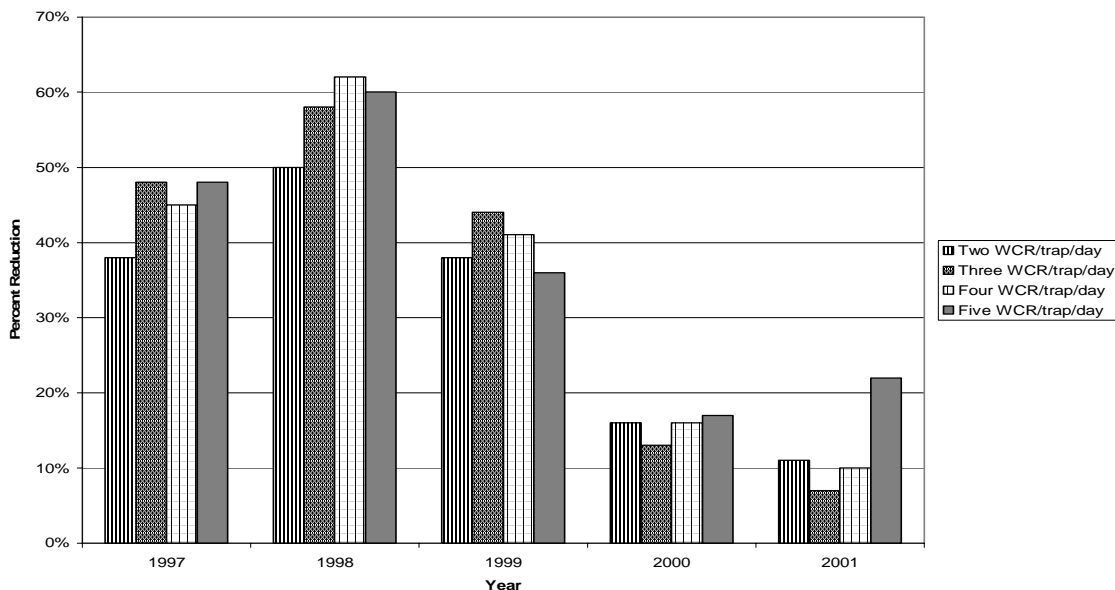Scouted

Figure 7. Percentage Reduction in Acres Sprayed with 50% Reduction in Number of Fields Scouted

Use of a sectional spraying method in 2000 and 2001 resulted in a much larger number of acres requiring aerial treatment than the field-by-field method followed in 1997, 1998, and 1999 (Figure 5). For example, in 1997, at two beetles/trap/day, about 15,000 acres would have been treated. At the same threshold in 2000, under a sectional spraying method, about 43,000 acres would have required treatment.

A larger percentage of the total acres requiring treatment each year would have been "missed" in 1997, 1998, and 1999 than in 2000 and 2001. For 1997-1999, 37-62% of the acreage that reached threshold would have been "missed." Contrast this to 7-22% for 2000 and 2001 (Figure 7). This is largely a consequence of shifting from a field-by-field spraying approach in 1997-1999 to a sectional approach in 2000 and 2001. If spraying is conducted based on WCR counts for each field, fields that reached the threshold, but are not scouted, would not receive aerial treatments. If a sectional spraying method is used, fields that reached threshold, but are not scouted, still might receive aerial treatments if they are located in a

section that is sprayed. Consequently, measuring the risk purely on the percentage of acres

that would not be treated, but reached the economic threshold, when 50% of the fields were

scouted, can be misleading. For example, in 1998, the percentage reduction in acres sprayed

may be higher than in 1999. However, because a smaller number of acres would have been

missed in 1998, the overall risk would be less. In 1997-1999, 1,100-7,000 acres would not

have been sprayed, depending on the threshold. In 2000 and 2001, 2,000-6,800 acres would

have been missed (Figure 6).

An AWPM program that incorporates a reduction in the number of fields scouted,

and/or an increase in the economic threshold may be a reasonable approach to reduce costs.

However, in the past, AWPM has employed more stringent management of WCR. Hence,

any effort to relax the control technique may expose crops to higher WCR pressure that could

result in yield loss.

In a management program designed to reduce scouting, there are several possible

levels of scouting that could be used (75% of the fields, 50% of the fields, etc.). Each level of

reduced scouting is associated with a different level of risk. It is assumed that as the number

of fields scouted is reduced, the probability that fields that reach the threshold might go

untreated will increase, as will the risk of yield loss. In this case, the risk arises from fields

that may need to be treated under a certain threshold, that do not receive treatment because

they are not scouted, or located in a section that is not sprayed. Corn planted in fields

following soybeans that were not appropriately scouted/sprayed, may be damaged by high

levels of WCR. Sections in which there are only one or two fields that reach threshold are

less likely to be sprayed under a reduced scouting regime that scouts a limited set of fields.

The total level of risk (at a given economic threshold) that may be assumed from

alterations in the previous AWPM practices can be characterized from two sources: the

probability that fields that need treatment go untreated, and the potential yield loss resulting from a certain WCR population size that goes unchecked. The economic threshold chosen will have an important effect on the measurement of risk. A relatively low economic threshold in soybeans would result in a high spraying frequency. Any reduction in scouting/spraying would result in more "missed" acreage. Also, if this threshold is proven to be low (for example, two beetles/trap/day), greater potential for economic damage exists for fields that go untreated, as the threshold would be reached more often and earlier in the season.

The data suggests that even accounting for yield losses expected for the WCR levels at the Illinois/Indiana AWPM site on the maximum amount of estimated "missed" corn acreage, reducing the number of fields scouted may still be a viable way to improve the economic viability of AWPM for corn rootworms (West, 2003). However, any yield losses incurred on corn acreage as a result of those reductions would diminish the impact of the savings. These potential losses vary according to many agronomic and environmental factors. Therefore, their potential magnitude is difficult to predict. In addition, reduction in scouting/spraying may impede successful insect suppression in the AWPM site. Less effective insect suppression would also diminish the favorable economic impact of potential savings.

While it is difficult to predict the potential yield losses resulting from a targeted scouting/spraying protocol that reduces the number of fields scouted/sprayed, some studies have examined the quantitative relationship between corn rootworm populations and corn yields (Turpin et al., 1972, Chiang et al., 1980, Branson et al., 1980). Most relate root damage measured on the root rating scale developed by Hills and Peters (1971) to yield loss. The scale ranges from one to six, from least to most severe damage. Turpin et al., (1972) estimated a root rating of 2.5 on this scale as the economic injury level (EIL) in corn. At this

level of root damage, the loss in yield justified the cost of control (soil insecticide). The EIL

for rootworm in corn has been continually modified and re-evaluated since Turpin's study.

Currently, many researchers accept a root damage rating of three as an accurate EIL for WCR

in corn. Branson, et al. (1980), with artificial infestations of WCR, estimated yield loss by

relating it to the root damage rating by using regression techniques (Table 6). In this study, a

four percent yield reduction in corn was associated with a root rating of two.

Table 6. Results from Branson, et al. (1980)

Root Rating (One to Six scale)	Yield Reduction	Yield Reduction on 150 bu./acre
2	4%	6 bushel
3	7%	10.5 bushel
4	10%	15 bushel
5	14%	21 bushel
6	18%	27 bushel

While there have been many efforts to improve and refine the EIL for rootworm in

corn, economic thresholds for WCR in soybeans have just recently been examined, and

continue to be developed. These thresholds attempt to use beetle counts in soybeans to

predict the level of infestation, and subsequent root damage, in corn the following year.

These studies have highlighted the following relationship (Ratcliffe, Gray, et al, 2002).

Table 7. Relationship Between Adult WCR in Soybeans and Corn Root Injury
the Next Year

WCR beetles/trap/day in Soybean	Root Rating in Corn Next Year (1-6 Scale)
0-4	1 or 2
5	3
10	4
11+	5 or 6

From these studies, it is possible to estimate potential yield losses based on typical corn rootworm levels at the Illinois/Indiana AWPM site. Levels generally run between zero and four beetles/trap/day in soybeans. This could result in root ratings of one or two, according to the Ratcliffe study (2002). Branson (1980) showed that these root ratings could lead to a four percent yield reduction (Table 6), or six bushels per acre for a 150 bushel/acre field. Losses may be higher or lower depending on rainfall, hybrid vigor, stress, and first-year or continuous corn cycles.

To measure the risk of yield loss that might be incurred from reducing the number of fields scouted and sprayed under AWPM, consider the following scenario.

(1) Assume expected corn yield is 150 bushels per acre; soil insecticide cost is $15.00 per acre; and average corn price is $2.00 per bushel.

(2) Under AWPM, fields/sections are receiving aerial treatment when WCR soybean counts reach two beetles/trap/day. This analysis has shown implementation of a reduced scouting regime, where 50% of the soybean fields are scouted, and spraying was reduced, could save an average of $7.43 per acre over the entire site for the five years examined (Table 4). In this example, the economic threshold remains two beetles/trap/day, while the number of fields scouted is reduced.

(3) Assume by scouting only 50% of the soybean fields (and 50% of the corn fields in 1997, 1998, and 1999), 60% of the fields are "missed," meaning they do not receive any WCR control when needed. Soybean fields are not scouted/sprayed and those corn fields the following year go without soil insecticide, even if needed. This is a liberal estimate, as the analysis has shown that in the majority of the scenarios where 50% fewer fields were scouted, less than 60% of the acreage that reached the threshold was "missed." (Figure 7).

(4) The Illinois/Indiana AWPM site is roughly half soybeans and half corn. It is assumed that 100% of soybeans will be rotated into corn the following year. If 60% of the soybean acres are not treated when they reach threshold, in effect, 30% of the total site would be left untreated.

(5) Savings from the reduction in scouting and spraying are $7.43 per acre, or approximately $68,989 on the average of 9,281 acres in the site each year. Thirty percent of the entire AWPM site, or 2,784 acres of corn, would go without soil insecticide each year under reduced scouting and spraying. Therefore, the AWPM program could afford to lose $24.78 per acre ($68,989/2,784 acres), or approximately 12 bushels of corn per acre, on the corn acres that were not treated.

Since the actual yield loss may be closer to six bushels per acre according to Branson's root rating/yield loss relationship, using a targeted scouting regimen could still reduce AWPM costs.

Conclusions

Scouting fewer fields at an economic threshold in soybeans greater than two beetles/trap/day can result in $11.75 - $16.60 in per acre savings (Table 5). While even higher savings can be gained from reducing the scouting/spraying period from six to three weeks, large potential for crop loss exists in corn the following year if the population were to peak during a week that was not scouted. For this reason, a three-week scouting/spraying season is not recommended as a desirable way to reduce AWPM costs.

Net Present Value analysis over an eight-year time horizon (1997-2004) suggests AWPM is not as profitable as traditional soil insecticides alone in regions of the Eastern Corn Belt where the WCR variant is present. Recall that NPV analysis indicates that in order for

AWPM to be cost competitive, the areawide program would have to provide increased corn yields of approximately 7-14 bushels of corn per acre each year (West, 2003). At an average market price of two dollars per bushel, the "profitability gap" between AWPM and soil insecticide is about $14-28$ per acre, depending on the level of corn rootworm pressure. This paper has shown that $11.75-$16.60 in savings gained by scouting fewer fields at a higher economic threshold in soybeans could partially bridge this profitability gap. While any yield losses incurred on corn acreage that was not treated as a result of reduced scouting/spraying would diminish the impact of these savings, this adjustment in scouting and spraying practices in the Area Wide Pest Management Program could make it an economically viable alternative to soil insecticides and transgenic corn in the Eastern Corn Belt.

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