

Insect Resistance Management Plans: The Farmers' Perspective

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Farmers are required to implement insect resistance management (IRM) plans for all Bt crops in order to reduce the probability that insects susceptible to Bt will develop resistance. These IRM plans require farmers to plant at least 20% of the corn acreage to a non-Bt hybrid, and in specific configurations. In order for IRM plans to be effective, farmers must correctly implement these refuge requirements both in terms of acreage and configuration. This article reports survey results which show that farmers believe refuges will be effective in managing resistance, but that they would not implement them if they were not required. The article also reports survey and focus group data on farmers' perceptions of each refuge configuration. These data show that farmers who have experience with implementing refuges report less time and effort associated with refuges, which is partly due to having learned how to implement refuges more efficiently.

Key words: Bt corn, insect resistance management, refuge.

One of the most widely adopted genetically modified crops is Bt corn, which has been modified to produce proteins from the soil bacterium *Bacillus thuringiensis* (Bt). These proteins are toxic to specific pests such as the European Corn Borer (ECB) and the corn rootworm (CRW). These Bt crops are highly effective at preventing insect damage, and as a result have been rapidly adopted since the release of ECB-resistant Bt corn in 1996 and CRW-resistant Bt corn in 2003. In 2006, Bt corn accounted for 40% of the corn acreage in the US either as a single trait or stack trait (United States Department of Agriculture National Agricultural Statistics Service [USDA NASS], 2006). The rapid adoption of Bt corn, particularly in specific regions of the US, has raised concerns about the development of insect resistance to Bt.

Insect resistance to Bt poses a major risk to the producers currently benefiting from the technology and to other producers who depend on Bt as a pesticide, such as organic producers. In order to reduce the risk of insect resistance to Bt, the Environmental Protection Agency (EPA) first issued insect resistance management (IRM) guidelines on September 29th, 2001 and then updated them on October 15th, 2001 (EPA, 2001). Registrants of Bt crops are responsible for overseeing IRM plans, and they implement these plans by having producers sign legally binding agreements. Under the IRM guidelines, producers in the primary corn growing regions are required to plant at least 20% of their corn to a refuge, i.e. non-Bt corn. Currently, there are four approved refuge configurations: the border of the field, a block within the field, splitting the planter so that there are strips through the field, or an adjacent field which is required to be across a ditch or road for CRW corn and

within half a mile for ECB corn. Producers are permitted to treat the refuge corn with a non-Bt insecticide. The effectiveness of refuges at preventing insect resistance depends in part on producers' compliance with the IRM plan regulations. Producers who are found out of compliance with the IRM plans for two years will face the penalty of no longer being allowed to purchase Bt crops (Wright & Hunt, 2004).

The purpose of this paper is to present survey and focus group results that describe farmers' thoughts on, and reactions to, current IRM plans. IRM guidelines have been mandatory since the 2002 crop year, so farmers could have up to 4 years of experience implementing them.

Literature

The literature on farmers and IRM plans has focused on whether farmers comply with the refuge requirements. Several surveys have been conducted to determine producer compliance with IRM plans (Agricultural Biotechnology Stewardship Technical Committee, 2002; Langrock, Hurley, & Ostlie, 2003; Goldberger, Merrill, & Hurley, 2005; Wang & Van der Sluis, 2005). Overall, these studies, which are individually described in detail, find that producer compliance with IRM requirements ranges from about 70-90% depending on how compliance is defined. If compliance is defined as meeting the 80:20 ratio of Bt corn to non-Bt corn at the farm level, then compliance is probably between 85 and 90%. If compliance means both meeting the 80:20 ratio *and* using the correct refuge configuration, then compliance drops to 72-76%. In terms of managing resistance, it is critical that the majority of Bt corn acres meet the IRM requirements. Overall, the research shows that larger

farms are more likely to be in compliance than smaller farms, which suggests that on an acreage basis compliance rates are much higher than these estimates, which are on a producer basis.

The ABSTC (2002) surveyed producers in the major corn-producing states to determine compliance with IRM plans in the 2002 crop year. The survey found that 86% of producers planted at least 20% of their acres to non-Bt corn and that 89% of the producers planted their Bt corn fields within a half mile of non-Bt corn fields, with 65% of the refuges being planted within the same field as the Bt crop. In addition, the ABSTC found that 88% of respondents were aware of IRM requirements and of these, 89% said they received enough information to implement a refuge.

Langrock et al. (2003) estimated the cost of compliance with IRM regulations for Minnesota corn farmers using a survey in 2002. They estimated that IRM compliance rates range between 70 and 85%, with farmers preferring IRM regulations that do not allow for insecticide treatment on the refuge crop, that specify the minimum refuge that is biologically effective, and do not require the farmer to plant the refuge in pieces throughout the Bt corn field.

Wang and Van der Sluis (2005) documented the planting practices of corn-soybean producers in South Dakota for Bt corn resistant to ECB. About 82% of the 104 respondents had planted Bt corn. Of these, 91% had planted at least some of their corn fields to both Bt and non-Bt corn. The most likely configuration was to plant the borders of the fields to non-Bt corn, followed by split planter, and finally, the within-field block. Even though a seed blend is not an approved refuge configuration, 29% of the survey respondents had mixed the seed in at least one field. About 40% of the respondents had used the adjacent-field configuration. When using the adjacent-field refuge, a sizable number did not comply with the requirement to be within half a mile of the Bt field; about 8% reported planting the non-Bt field more than half a mile away from the Bt field and 19% planted the non-Bt field more than a mile away.

Goldberger et al. (2005) used survey data from Bt corn farmers in Minnesota and Wisconsin to measure IRM plan compliance rates for the 2003 crop year. About 58% of the respondents from Minnesota and 31% of the respondents from Wisconsin had planted Bt corn, with larger farms having much higher adoption rates in both states. Goldberger et al. separately considered compliance with the refuge size requirement of 20% non-Bt corn and with the refuge configuration requirements. Producers in full compliance met both the size and the

configuration requirements, and about 76% of Minnesota producers and 72% of Wisconsin producers were in full compliance. In both states, about 85% of the respondents complied with an 80:20 ratio of Bt to non-Bt corn at the farm level, with the remaining 15% planting more than the 80% of Bt corn allowed. Refuge configuration compliance was at about 90% in Minnesota and 84% in Wisconsin. Goldberger et al. find that producer awareness of the IRM plan requirements is a strong predictor of IRM plan compliance, while producer awareness of the Compliance Assurance Program, which includes IRM education, was not significant in predicting IRM plan compliance. They also find that larger farms are more likely to comply with the *size* requirement and *both* requirements, but not *configuration* alone.

In addition to the surveys on farmer compliance, there has been one study estimating the costs to farmers of implementing the within-field refuges. Hyde, Martin, Preckel, Dobbins, and Edwards (2000) estimated the economics of three alternative refuge configurations including strips or split planter, within-field block, and a perimeter or U-shaped refuge. They examined the costs for both a 40- and 80-acre field and found that the increased labor costs range from \$0.15 to \$0.30 per acre for the within-field block and U-shaped refuge, and from \$0.038 to \$0.075 per acre for split-planter refuge. Hyde et al. showed that implementing within-field refuges does not substantially increase producers' costs.

Data

The Department of Agricultural Economics and the Department of Agricultural Statistics (DAS) at Purdue University conducted the CRW Management Survey in the spring of 2004. The sample of 4,000 producers was drawn from a list of producers maintained by DAS. We restricted the sample to Indiana farms that grow at least 200 acres of corn in order to focus on farms that produce the majority of corn in the state. Once mail survey respondents who did not grow row crops in 2003 were eliminated, there were 794 usable surveys. From the number of responses received, it was determined that a follow-up phone survey of non-respondents would be more valuable than a second follow-up mail survey in order to determine non-response bias. There were 128 phone survey respondents, and of these, 127 were usable. Therefore, there were a total of 921 usable mail and phone surveys. When returned and unusable surveys were subtracted from the initial 4,000 mail surveys sent out, the response rate was 24%. In Indiana, there are approximately 7,000 producers who grow at least

Table 1. Farm characteristics.

Farm size	Percent of farms
Less than 500 acres	17%
500-999 acres	38%
1000-1999 acres	32%
More than 2000 acres	13%
Gross farm income	
Less than \$100,000	11%
\$100,000 to \$249,999	37%
\$250,000 to \$499,999	30%
\$500,000 or more	22%

200 acres of corn (Indiana Agricultural Statistics Service [IASS], 2004). This survey sampled more than half of these producers, and the 921 respondents represent 13% of this population.

The survey had six main sections. Farmers were asked questions on the crops they planted in 2003 and intend to plant in 2004, how they manage corn rootworm, information sources they use, insect resistance management plans, markets, and farm and operator characteristics. If the reader is interested in learning more about farmer adoption of Bt corn that is resistant to corn rootworm based on these survey results, see Alexander and Mellor (2005).

After the survey, we conducted three focus groups: one in Tippecanoe County with 5 producers on March 2, 2005, one in Cass County with 8 producers on March 8, 2005, and one in Allen County with 5 producers on March 9, 2005. We chose the counties based on the corn rootworm pressure they typically receive; Tippecanoe County is in west-central Indiana and has very high corn rootworm pressure, Cass County is in north-central Indiana and has moderate to high corn rootworm pressure, and Allen County is in north-east Indiana and has low corn rootworm pressure. We discussed how farmers choose which seed corn to plant, how they manage corn rootworm and whether they plan to use CRW corn, and their opinions about the refuge configurations, including a proposed seed blend option. While these data were collected in 2004 and 2005, the findings of this paper are still relevant to farmers, seed companies, and the EPA since the IRM guidelines remain the same.

Farm Characteristics

Because of the sample restriction, the survey respondents tend to operate relatively large farms with an average farm size of 1,129 acres and the median farm has a gross farm income between \$250,000 and \$500,000 (see Table 1). The average age of the respondents is 50.7,

Table 2. Responses to statement "I believe refuges will help maintain the effectiveness of the corn rootworm technology."^a

Responses	Refuge experience in 2003	No refuge experience in 2003	Total
Frequency of mail respondents	253	490	743
Strongly disagree	5.1%	5.7%	5.5%
Somewhat disagree	7.5%	7.6%	7.5%
Undecided	13.8%	31.4%	25%
Somewhat agree	39.5%	32.0%	34%
Strongly agree	34.0%	23.3%	27%
Mean	3.59	3.89	3.69

^a Test for independence based on refuge experience: $\chi^2(4) = 30.24$, p -value < 0.0001.

with 12% of the respondents under 40 years of age. More than 90% of the respondents say that farming is their principal occupation. Thirty-nine percent of the respondents have a high school diploma, 31% have some college education or vocational training, and the remaining 28% have a bachelors or graduate degree. Overall, approximately 77% of respondents reported that they managed CRW during 2003 using a number of different methods, including soil insecticide, seed treatments, or transgenic corn. The majority of these respondents (89%) used insecticide at planting.

General Attitudes Toward Refuges

Producers in both the mail and phone surveys were asked about their attitudes toward refuges. They were asked to agree or disagree with various statements concerning refuges on a 5-point Likert scale, where 1= strongly disagree, 2= somewhat disagree, 3= undecided, 4= somewhat agree, and 5= strongly agree.

The responses to these attitudinal questions demonstrate that producers believe that IRM plans serve a needed purpose. The majority of producers (61%) agreed that refuges will help maintain the effectiveness of the CRW technology, while 25% were undecided and 13% disagreed (Table 2). The majority of producers (55%) agreed that refuges benefit all farmers, while 30% were undecided and 15% disagreed (Table 3). The majority of producers (44%) disagreed with the statement that the benefits of planting a refuge do not justify time and effort spent on them, indicating that they believe the time and effort spent on refuges is justified by the benefits (Table 4). Overall, these three attitudinal questions and producer comments in the focus groups show that the IRM education campaigns have been

Table 3. Responses to statement: “Refuges benefit all farmers.”^a

Responses	Refuge experience in 2003	No refuge experience in 2003	Total
Frequency of mail respondents	252	493	745
Strongly disagree	4.3%	6.3%	5.6%
Somewhat disagree	5.1%	10.6%	8.7%
Undecided	22.2%	33.7%	29.8%
Somewhat agree	37.7%	29.6%	32.3%
Strongly agree	30.6%	19.9%	23.5%
Mean	3.85	3.46	3.59

^a Test for independence based on refuge experience: $\chi^2(4) = 25.44$, p -value < 0.0001 .

Table 4. Responses to statement: “The benefits of planting a refuge do not justify time and effort I spend on them.”^a

Responses	Refuge experience in 2003	No refuge experience in 2003	Total
Frequency of mail respondents	252	490	742
Strongly disagree	26.6%	17.8%	20.7%
Somewhat disagree	30.6%	20.4%	23.8%
Undecided	25.0%	34.1%	31.0%
Somewhat agree	11.9%	20.8%	17.8%
Strongly agree	5.9%	6.9%	6.6%
Mean	2.40	2.79	2.65

^a Test for independence based on refuge experience: $\chi^2(4) = 25.54$, p -value < 0.0001 .

effective at explaining their benefits. One producer in Cass County said, “Well, refuges need to be done. Otherwise, you get your genetic differences and then you have no control over it.” Another producer in Allen County acknowledged that refuges are important even though he dislikes them: “I don’t like the aspect that you have to take 25% of your field and plant regular corn versus the Bt corn, but if it’s for the benefit of making sure we don’t build resistance, I don’t really have much choice....”

Despite the belief that refuges are beneficial, almost a third of producers (32%) say that they would not plant a refuge if it was not required, and another 37% are undecided (Table 5). Remarkably, almost 30% of producers said they would plant a refuge even if it was not required. Based on the focus group discussions, one reason producers will not plant a refuge unless it’s required

Table 5. Responses to statement: “I would still plant a refuge, even if it was not required.”^a

Responses	Refuge experience in 2003	No refuge experience in 2003	Total
Frequency of mail respondents	253	491	744
Strongly disagree	16.6%	16.5%	16.5%
Somewhat disagree	13.4%	16.9%	15.7%
Undecided	29.6%	42.2%	37.9%
Somewhat agree	27.3%	15.7%	19.6%
Strongly agree	13.0%	8.8%	10.2%
Mean	3.07	2.83	2.91

^a Test for independence based on refuge experience: $\chi^2(4) = 22.60$, p -value = 0.0002.

is the perception that producers who voluntarily plant a refuge are at a competitive disadvantage to producers who do *not* plant the refuge. Thus, a voluntary IRM plan will not be sufficient to ensure compliance; IRM plans must be required to ensure compliance.

Since the survey asked questions about crops planted in 2003 and 2004, we can identify those farmers who planted Bt corn in 2003 and have experience implementing refuges. It is possible that some of the farmers who did not plant Bt corn in 2003 have refuge experience in previous crop years, but unfortunately the survey did not ask questions about what the farmers planted prior to 2003. As expected, producers who have experience planting Bt crops and implementing refuges have a statistically significant more positive view toward refuges than producers who did not plant Bt crops in 2003. Furthermore, producers with experience planting Bt crops in 2003 are significantly more likely to say they will plant a refuge even if it is not required.

The majority of producers (53%) disagreed with the statement that they will not plant a CRW resistant variety because of the refuge requirement, while 24% agreed and 23% of producers are undecided (Table 6). Producers who planted either Bt corn or CRW corn in 2003 and have experience with refuges were significantly more likely than producers who do *not* have experience with refuges to say that the refuge requirement will not affect their planting intentions. However, it is clear that for a portion of producers, IRM plans are a deterrent to planting CRW corn. One Cass County producer said, “I wanted to plant the rootworm corn this year in a bad way, but my dad plants the corn and he doesn’t want to deal with the [refuge].”

Table 6. Responses to statement: "I will not plant a corn rootworm resistant variety because of the refuge requirement."^a

Responses	Refuge experience in 2003	No refuge experience in 2003	Total
Frequency of mail respondents	251	492	743
Strongly disagree	47.8%	23.4%	31.6%
Somewhat disagree	25.1%	19.3%	21.3%
Undecided	15.5%	27.0%	23.2%
Somewhat agree	9.2%	16.5%	14.0%
Strongly agree	2.4%	13.8%	9.9%
Mean	1.93	2.78	2.49

^a Test for independence based on refuge experience: $\chi^2(4)=71.61, p\text{-value}<0.0001$.

Refuge Planting Preferences

With the mail survey, producers received an information sheet describing the four EPA approved refuge configurations: within-field block, strip planting, border planting, and adjacent field (see Appendix). The order of the questions in the phone survey was slightly different from the mail survey, and the refuge questions were eliminated because of time constraints and because it was too difficult to supply the interviewees with the information sheet.

Mail survey respondents were asked how likely they are to use each of these configurations (a 5-point Likert scale where 1=not at all likely to use and 5=very likely to use), how much extra time it would take them to implement each of these refuge configurations compared to planting conventional corn (additional minutes per acre), and how much more difficult, if at all, they anticipate it would be to plant CRW corn with a refuge relative to planting conventional corn (a 5-point Likert scale where 1=same difficulty and 5=much more difficult). The results are examined separately depending on whether the producers had experience planting a refuge in 2003, and the mean response to each of these questions are provided in Table 7.¹

Comparing the refuge options, corn producers, regardless of 2003 refuge experience, were on average most likely to use the adjacent-field refuge option and least likely to use the border-planting refuge option. Producers with refuge experience in 2003 were, on average, more likely to use within-field block than split

Table 7. Comparison of refuge options.

Ranking	Mean likelihood to use ^a	Mean amount of time (min/acre)	Mean difficulty ^b
Refuge experience in 2003			
Adjacent field	3.50	3.74	1.92
Within field block	3.33	8.80	2.92
Split planting	3.24	5.55	2.40
Border planting	2.63	10.31	3.36
No refuge experience in 2003			
Adjacent field	2.82	6.21	2.55
Within field block	2.72	10.16	3.13
Split planting	2.79	6.97	2.74
Border planting	2.55	11.03	3.38

^a Respondents were asked to answer on a 5-point Likert scale where 1=not at all likely and 5=very likely.

^b Respondents were asked to answer on a 5-point Likert scale where 1=same difficulty and 5=much more difficult.

planting. In contrast, producers who did *not* have refuge experience in 2003 were more likely to use split planting than within-field block. Consistent with the mean likelihood-to-use ranking, producers with and without refuge experience, on average, found that the adjacent-field refuge takes the least amount of extra time to plant and poses the least amount of difficulty, and that the border-planting refuge option was rated as taking the most extra time to plant and the most difficult. Interestingly, despite the inconsistency in mean likelihood-to-use depending on refuge experience, all producers ranked the split planting configuration second and within-field block third in terms of least amount of extra time to plant and least amount of difficulty.

While the adjacent-field option appears the most favorable refuge option, the focus group discussions revealed that for many producers, the adjacent-field refuge is not an option due to the locations and sizes of their fields. Instead, the split-planter refuge option was one of the most popular for the focus group participants because it was the least difficult and took the least amount of extra time of the refuge configurations that they could implement on their farms. Perhaps one explanation for the higher ranking of within-field block over split planter by survey respondents who had refuge experience in 2003 is due to producer concerns about ability to manage corn rootworm and ability to segregate the refuge corn. Finally, the focus group participants and survey respondents consistently rank the border-planting option as the most difficult and taking the most extra time, with the primary advantage of the

1. The frequencies are available in Alexander (2006).

border planting being the ability to protect nearby crops from pollen drift.

When producers in the focus groups were asked which refuge configuration they use, the general answer was that it depends on the field size, the relationship of the field to other fields on the farm, the planter, and whether a neighboring field would be planted to a specialty crop. Producers said they like to have several options so that they can choose the one that best fits the circumstances. In particular, the feasibility of the refuge configurations depends on the planter: “Well, in the past with the Bt corn, we planted part of a field in Bt corn {within-field block} because it was the planter that I had {a single seed box}. In the future, I would probably look at strip planting. {He now has a planter with seed boxes on each row}.”

The focus group discussions provided detailed information on the advantages and disadvantages of each refuge configuration. These discussions clearly show that producers who have planted refuges have developed or found ways to minimize the effort associated with their implementation.

Adjacent Field

The producers in Cass County had the most in-depth discussion about the adjacent-field refuge configuration. In general, they felt this refuge configuration was not an option because they tend to have one large field per farm. When asked how large their fields are one producer said his largest field is 275 acres, another said 900 acres. As one producer put it, “We tore all the fences out and now have one big farm. You're not farming the little 20-acre field anymore.”

Split Planter

In both Tippecanoe and Cass Counties, the split-planter refuge configuration was the most popular because producers felt that it was the easiest to implement. As one producer put it, “You're talking strip till here; if you're going to fill up your eight rows, you're going to fill 'em all up and you're going to go for quite a few acres without stopping, and so that's not costing you anything. No difference than if you filled them all up with the same number all the way across.” Producers also cited the advantage of using this refuge configuration for side-by-side yield comparisons. One producer also felt that the Bt corn protects the non-Bt corn from wind. In terms of disadvantages, several producers were concerned about problems at harvest if the two hybrids perform differently: “I know the split planting is the best as far as

we've found, but it's got problems too. If your refuge and your Bt corn are significantly different, different maturity or something like that (sometimes one shells better than the other) it creates problems with setting the combine and things like that. It's not perfect.” One producer was concerned about CRW control on the refuge, but when he learned that the refuge seed could have a seed treatment, this alleviated his concern.

Within-Field Block

Several producers had implemented the within-field block refuge configuration. The two advantages cited by producers were the ability to treat the refuge and the ability to segregate the refuge corn and market it separately from the Bt corn. However, one producer said he had never heard of a farmer separately managing the refuge: “How many people end up using within-field block where any of them spray that refuge? If we'd get in a severe situation, you might, but I don't hear anybody talking about spraying their 20% refuge.”

The main disadvantage was the need to clean out seed boxes when switching between the refuge and non-refuge seed: “We used the split-planter refuge last year. Prior to that, we tried blocks within the field. Well, that got to be too much of a pain switching, cleaning boxes....” However, it was clear that producers with experience using the within-field block had figured out how to minimize the work: “We don't have to be perfect to have something like this. We have to have a minimum of 20%, so we don't stop and clean out boxes in the middle of planting. If you've got enough for 25%, then you just go ahead and put the other on top of it.”

Border Planting

Most producers felt that the border planting refuge configuration was too much work. However, at least one producer in each focus group discussion said that it is an important option that can be used to protect either their own or their neighbor's specialty crop fields from contamination due to pollen drift: “When I did this, I specifically was trying to protect a neighbor who was going non-GMO, so I planted my 32 rows on a perimeter, and then I just went to my start point and started planting. When I emptied the planter, I put the Bt variety in and started the planter there. I didn't stop and totally clean it out....” One producer said that if he buys a bulk planter, he'll use the border planting refuge with one planter dedicated for the borders and the bulk planter for the interior. Another producer thought the border planting fit his planting routine: “The reason I like border plant-

Table 8. Likelihood to choose seed-blend option instead of the four EPA approved refuge configurations.^a

Responses	Refuge experience in 2003	No refuge experience in 2003	Total
Frequency of mail respondents	249	469	718
Not at all likely	22.9%	22.2%	22.4%
Not likely	12.9%	7.7%	9.5%
Slightly likely	16.1%	13.0%	14.1%
Somewhat likely	19.3%	18.1%	18.5%
Very likely	28.9%	39.0%	35.5%
Mean	3.18	3.44	3.04

^a Test for independence based on refuge experience: $\chi^2(4)=10.51$, p -value=0.0327.

ing would be that I could plant a relatively inexpensive corn on the ends around the perimeter of my field because some of them are going to get tracked down from side dressing and there's more compaction on end rows."

Seed-Blend Option

Producers were presented with a fifth option for IRM which is called the seed-blend option. The survey respondents were told:

"There is a proposed insect resistance management plan that would allow seed companies to pre-mix the seed needed for the 20% refuge directly into the seed bag. Thus, you would not need to plant a separate area of each field to a refuge. This pre-mixed seed would cost the same as buying each hybrid separately."

More than a third of the survey respondents said that they would be very likely to choose the seed-blend option (Table 8). More importantly, producers who did *not* have refuge experience in 2003 were significantly more likely to prefer the seed-blend option over the four EPA-approved refuge configurations, with 39% saying they would be very likely to use the seed blend, compared to only 29% of producers *with* refuge experience. This finding suggests that the refuge requirement may be a deterrent for some who are not currently planting Bt crops, and that the seed-blend option would eliminate this barrier to adopting Bt crops.

In all of the focus groups, when the producers were asked how they would structure an IRM plan, at least one producer described the seed-blend option before the

moderator presented this option to the group, indicating previous awareness of this option. As one producer put it, "Actually, I like Alternative 6 that I was interviewed on a few years ago: 20% of your seed in each bag is non-rootworm corn. That way it's mixed together, so maybe in every hundred kernels you drop, 20 of them is the non-rootworm and the other 80 is rootworm, and it's scattered throughout the whole field. That way, when you plant, you dump one bag in." Several of the producers felt that the seed-blend option would work better given that seed delivery is shifting from bags of seed to bulk boxes: "We get seed in big, bulk boxes of corn now. That's what I thought we should do, just mix it all together in that box."

The primary concern cited by the producers in all of the counties with the seed-blend option was whether it would be effective at managing resistance. As one producer put it, "If you have 20% within the field, how is that 20% bug going to survive in a field where there's 80%? Eventually, they're going to get to a plant that's going to kill them, so you've eliminated the refuge."

As with some of the previous refuge configurations, the producers were concerned about their ability to manage the refuge corn and potential harvest problems due to differences between the refuge and non-refuge corn. In particular, the harvest problems could be much more severe with the seed-blend option than even the strip-planter option because the two corn hybrids are mixed together and not segregated. As one producer put it, "I've always heard if you have Variety A and Variety A with Bt, that variety seems to be a little wetter, maybe like two days." The producers were also concerned about protecting the refuge corn from rootworm damage, but this concern can be alleviated if the refuge corn is treated with Poncho 1250.

Allen County producers said that the seed-blend option would remove any concern about producer compliance with the IRM plan requirement: "From a government standpoint or from the Monsanto standpoint, they know everybody's planting 20% like they're requiring." The producers also liked the seed blend because it's easier than implementing a refuge: "I think, in summary, that the two options that seem to rise to the top for us here should meet the desires of the companies, as well as be simplistic in the farmers' compliance. Percent of sale or just put it in the bag, then there is no concern about compliance and management is greatly minimized or completely eliminated."

IRM Plan Compliance

Producers in all the focus groups believe that most farmers are complying with the IRM plan requirements to plant refugia. One producer compared IRM plan compliance with pesticide regulation compliance: "I'd say 95% is being applied right, but there's going to be some that skew that mark. You could say the same thing along the line of spraying fungicide and herbicides and all that." Producers who had planted Bt crops all highlighted their own compliance: "I complied, and I really don't know the acreages in the fields of friends or neighbors. So I really don't know the level of noncompliance, but I made an effort, and even in this 34-acre field, I complied."

When asked why a producer would choose not to comply with the refuge requirement, the two top reasons are: a) ease at planting and b) large yield differences in regions where the CRW corn performs markedly better than soil insecticides or seed treatments. As one producer put it: "Where you have a 20-bushel yield difference, they're going to say I've got a thousand acres of corn I'm planting and I don't want to plant 200 acres of corn that I know I'm going to get 20 bushels less. Now, in our part of the world, we don't see that difference every year. But if I was seeing 20 bushel yield increases every year using Bt, you'd have a tendency to want to plant 100% and use your neighbor's crop [as your refuge], but that's not legal now."

Producers in all the focus groups discussed how they would like to plant the seed in any location, as long as the total for their farm added up to 80:20. "It may not be in the exact field they want it, but I don't know that that's as critical as knowing at least 20% of our crop in Allen County has got refuge in it. So that would keep it simple. Any regulation that somebody monitors it is going to cost us as producers more money and time." Several of the producers were concerned that this would lead to an uneven distribution of refuge across a county, lessening the effectiveness of the refuge. In the end, the producers agreed that this was not a realistic proposition. One farmer who is also a seed dealer said that his customers all had the ability to comply with the IRM plans at least in terms of their seed purchases: "I intentionally stayed quiet because I was interested to hear what you fellows would say. Of course, you never get all of anybody's business, so you don't know for sure what they're doing. I am selling to no one that I can think of all Bt corn, so I would say that the ability to comply is there."

Producers in all of the counties said that they had read about spot-checks for refuge compliance and about

the penalty for being out of compliance is losing access to the technology. "I read the article I kept on my bulletin board just before I came--I knew this was going to come up. The seed companies, the dealers, and the farmers are all three equally responsible for that 20% refuge, and they can really put some fines on you. In two years, if you don't correct that, you don't get to use the product and that company may not get to use it either. They're getting serious." In addition, producers said that the threat of not being able to purchase Bt crops is a substantial deterrent to shirking on the IRM plan. In fact, one producer was taking more care in implementing an IRM plan: "We made an effort to comply when we used it last year, and I think the seed companies have put more of an emphasis on complying. If they caught you and you weren't complying, there would be some penalties for it. I also heard about a person that was hired as an intern to go around and check on farmers to see if they were complying, so I think they're making an effort to see that there is compliance."

Producers in Allen County mentioned that they would like to have a simple template to help them keep track of where they plant the refuge. They stressed that using this form would need to be voluntary. As one producer put it, "Planting's not the biggest deal. It's keeping track of where to find it afterwards [that] is the hassle."

Importance of One IRM Plan

Producers were asked the following about IRM plans for stacked traits:

"Assume that you are planning to plant CRW corn stacked with CB resistant corn. You may be required to file two plans, one for each. Alternatively, you may be able to file just one insect resistance management plan. How important, if at all, is it to you that **only one** insect resistance management plan be required?"

Producers clearly prefer only one IRM plan if they choose to plant a stacked variety with both resistance to corn borer and corn rootworm; about 75% of producers rate it as somewhat or very important to require only one IRM plan (Table 9). Producers who have experience planting refuges in 2003 were significantly more likely to stress the importance of having only one IRM plan, with 58% rating it as very important compared to only 48% of producers who do *not* have experience with refuges. In the focus group discussions, the producers said that IRM plans need to be as simple as possible, other-

Table 9. Importance of one insect resistance management plan for stacked traits.^a

Responses	Refuge experience in 2003	No refuge experience in 2003	Total
Frequency of mail respondents	240	462	702
Not at all important	2.5%	6.7%	5.3%
Not important	4.6%	3.0%	3.6%
Slightly important	11.3%	18.2%	15.8%
Somewhat important	23.3%	24.2%	23.9%
Very important	58.3%	47.8%	51.4%
Mean	4.30	4.03	4.13

^a Test for independence based on refuge experience: $\chi^2(4) = 14.62$, $p\text{-value} = 0.0056$.

wise producers either would not use the technology or they would not comply with the IRM plan requirements.

Conclusions

Based on this analysis of survey and focus group data on producers' perceptions of IRM requirements, we can draw four conclusions. First, based on producers' attitudes toward refuges, the education campaign has succeeded at explaining that refuges are important to delay insect resistance and that these benefits of IRM accrue to all farmers. Second, while the majority of producers do not base their planting decisions on IRM requirements, there is a small group of producers who choose not to plant Bt crops because they do not want to implement refuges. Third, producer compliance with the IRM requirements depends on the simplicity and flexibility of the requirements. Producers in the focus groups emphasized that it is very important to offer many options for meeting the requirements and to keep the options simple. In particular, producers felt it was essential to only require one IRM plan for stacked varieties that are resistant to both ECB and CRW. Fourth, producers view a seed-blend refuge very favorably, with producers in the focus groups saying that the seed-blend refuge should only be offered as an option as long as it is effective in managing resistance. More importantly, producers who currently do not plant Bt crops say they are very likely to use the seed-blend refuge, which may indicate that this refuge option would increase adoption of Bt corn among those producers who say IRM plans are a deterrent.

Based on these results, farmer compliance with IRM plans depends in part on whether the plans are simple to

implement, i.e., not requiring much additional work. One observation from the focus group discussions is that farmers who have experience with IRM plans have found ways to make their implementation simpler and less work. Thus, perhaps farmer groups, seed companies, or the EPA could sponsor workshops or discussions between farmers who are planting Bt crops so that they can share ideas on how to minimize the work associated with IRM plans, and thus increase compliance. From the perspective of seed companies, these discussions may have the added benefit of increasing farmer adoption of Bt crops because IRM plans are clearly a deterrent to some farmers.

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Appendix: Refuge Alternatives

If you plan to plant CRW corn, you will be required by the EPA to implement an IRM plan, which means that you will need to plant a portion of your corn to a non-CRW hybrid. The EPA mandates that a refuge (the non-CRW hybrid) be planted on **every farm**, where the refuge must be *within or adjacent to* the CRW corn field. The refuge can be treated with a soil-applied, seed-applied, or foliar-applied insecticide to control rootworm larvae and other soil pests.

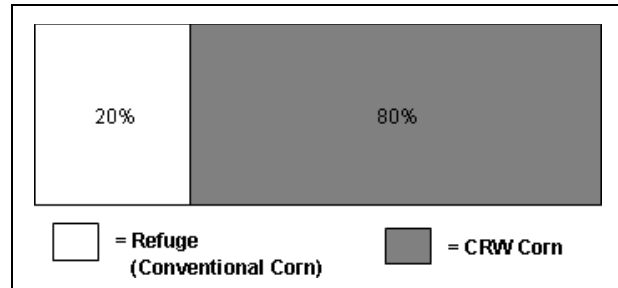
Currently, there are **four** EPA approved refuge placement alternatives. These are illustrated below. Given that you will be required to plant a refuge for your CRW corn, we would like to know your overall impression, and your most preferred alternative. For purposes of this exercise please assume the following:

- CRW corn will require a 20% refuge area
- CRW corn will be available in your preferred hybrids
- CRW corn will have a fair and reasonable price

For example, if a grower were to have 400 corn acres, he or she may plant up to 80%, or 320 acres, with CRW corn. Alternatively, if he or she were to choose to plant 100 of those acres with CRW corn, a minimum of 20 of the remaining 300 non-CRW acres need to be left considered as a refuge. The non-CRW corn refuge acres must be planted within or adjacent to the CRW corn field(s) in the following alternatives described below.

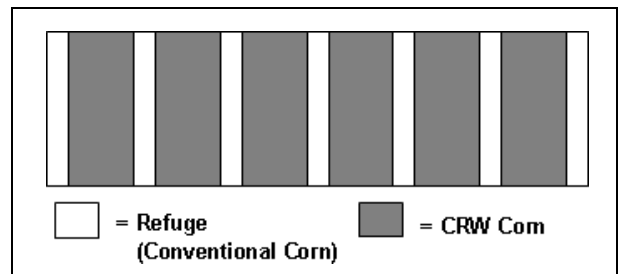
Refuge Alternative 1: Within-Field Block

Refuge planted within the same field as one or more large blocks. The refuge must be at least 20% of the CRW corn acres.



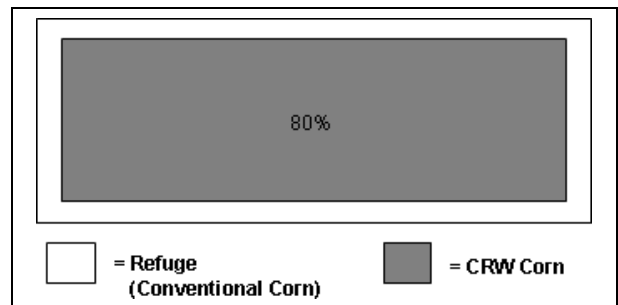
Refuge Alternative 2: Strip Planting (split planter)

Refuge planted in strips throughout the field, with a minimum of 6 rows per strip. For example, 3 boxes next to each other on a 12-row planter. The refuge must be at least 20% of the CRW corn acres.



Refuge Alternative 3: Border Planting

Refuge planted within the same field, where a minimum of 6 rows are planted around the CRW corn portion of the field. The refuge must be at least 20% of the CRW corn acres.



Refuge Alternative 4: Adjacent Field

Refuge planted in an adjacent field, separated by a road, path, ditch, etc., but not by another field. The refuge must be at least 20% of the CRW corn acres.

