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THE ECONOMICS OF WITHIN-FIELD BT CORN REFUGES

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Farmers who plant *Bacillus thuringiensis* (Bt) corn are obligated to plant a 20% non-Bt corn refuge as part of an Insect Resistance Management program. This paper analyzes the economics of alternative refuge configurations. Ignoring potential genetically modified organism (GMO) separation requirements, planting strips is the least cost method of meeting the 20% refuge requirement.

Key words: Bt corn; European corn borer (ECB); *Ostrinia nubilalis* (Hübner); refuge; Insect Resistance Management (IRM); budget analysis.

The commercial introduction of Bt corn has provided United States (U.S.) corn farmers with a powerful tool to control European corn borer (*Ostrinia nubilalis* Hübner) (ECB) infestations. Annually, ECB is responsible for one to two billion dollars in damages in the United States (Russnogle, 1997). These losses are comprised of lost yields as well as control costs. Traditionally, farmers have used cultural practices (Pilcher & Rice, 1998) and insecticides to manage ECB. However, the most optimistic estimates of control are only about 80% with insecticide applications. Some Bt corn hybrids, on the other hand, provide nearly 100% protection throughout the growing season.

Given the relatively high level of protection against ECB damage, farmers must weigh the expected benefits of the new technology against the premium charged for the seed. Previous research (Hyde *et al*., 1999a), based on typical Indiana ECB infestation and yield levels, showed that adoption is profitable where the probability of infestation is at least four in ten years or where yields are higher than the Indiana average of 135 bushels per acre (United States Department of Agriculture, National Agricultural Statistics Service (USDA/NASS), 1986-1997). In such situations, Bt corn adoption rates may be relatively high.

Some people are concerned that ECB may develop resistance to Bt toxins in regions where Bt corn is planted over large areas of the environment. Thus, a "high dose/refuge" Insect Resistance Management (IRM) strategy has been advocated by university scientists, seed industry representatives, and U.S. regulatory officials. This IRM strategy has two key components. First,

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the Bt toxin must be expressed at a "high dose" concentration in plant tissues. That is, it must kill all but the most resistant ECB. Second, a refuge area must be planted to non-Bt corn such that a proportion of the ECB will be unexposed to the Bt toxins. It is expected that the resistant ECB emerging from the Bt areas will mate with ECB from the refuge, which will be predominantly susceptible to the Bt toxins. The goal is to maintain resistance at a low level in the overall ECB population. This strategy is based on the idea that resistance is a heritable genetic trait (Onstad & Gould, 1998).

The refuge size has been a matter of considerable debate. University scientists, including the North Central Regional Research Committee NC-205, have recommended planting a 20-30% refuge that is not to be sprayed with an insecticide for ECB. If the farmer wants to spray, then a 40% or larger refuge would be appropriate (Ostlie *et al*., 1997). Most of the seed industry, as well as the National Corn Growers Association, forged a unified position that promoted a 20% refuge regardless of whether it is sprayed or not. Their argument is that farmers do not know at the time of seed purchase whether they will need to spray or not. The Environmental Protection Agency (EPA) approved this 20% refuge proposal in January 2000.

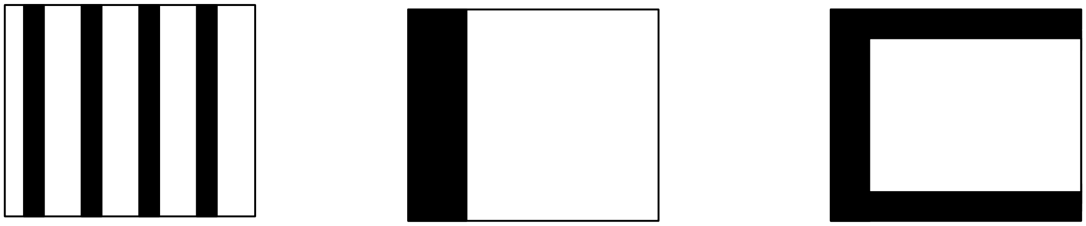
Under the approved proposal, refuges must be planted within a half-mile of Bt corn, while the recommended distance is a quarter-mile. The North-Central Regional Research Committee (NC-205) recommends that the refuge be planted within the same half section, that is, 320 acres (Ostlie, Hutchison, & Hellmich, 1997). Under both proposals, refuges can be planted in adjacent fields if within the specified distance. However, the focus of this paper is on refuges planted within the Bt cornfield.

Research on refuges has predominantly focused on estimating the proportion of refuge that should be planted as a fraction of the Bt corn acreage (Hurley, Babcock, & Hellmich., 1997; 1998). That research used a dynamic model to estimate the length of time until widespread resistance occurs given alternative refuge percentage. However, the refuge can be planted in several different configurations. The objective of this research is to compare the economic costs of planting alternative 20% refuge configurations within the Bt corn field as part of an IRM program.

Method

A partial budget analysis was used to analyze the costs of planting three different refuge configurations (figure 1). Two issues that arise from planting within-field non-Bt corn refuges were investigated. First, increases in the time needed to plant alternative refuges leads directly to increases in labor costs. Second, the increase in planting time stretches the entire planting period, causing some fields to be planted later than they would be otherwise. Fields planted later in the season tend to yield less than fields planted in a timely manner (Doster *et al*., 1995). Therefore, planting more fields later in the season may lead to an indirect cost in the form of lost yields.

Figure 1: Three Refuge Configurations.



Strips **Block** **U**

It is important to recognize that the assumptions made in this analysis considerably restrict the farmer's actions. For instance, the farmer is assumed to fill hoppers before entering each new field. This, and other assumptions, do not allow the farmer to behave as efficiently as he or she otherwise would. Therefore, the estimates of additional costs to meet the refuge requirements are biased upwards.

Results

Labor Cost Differences

This analysis was performed for two different fields, a 40-acre square field and an 80-acre rectangular one. These are assumed to be representative of many fields on Corn Belt farms[1].

- *40-acre field.*

  The labor costs associated with planting refuge are compared directly to the labor costs associated with planting the entire field to non-Bt corn, thus planting no refuge in the field. When compared to this base, it was found that planting a refuge of six-row strips resulted in lower labor costs than either the block or the U-shaped refuge. It costs about $0.30 more per acre to plant the block or U, whereas it costs only $0.075 per acre more to plant strips.

  Cost differences arise from how the refuge is planted. The 40-acre field can be planted non-stop when only non-Bt corn is planted. With the refuge, however, the farmer must take extra time to empty and fill seed hoppers to change from Bt to non-Bt seed or vice versa. When planting strips, only three hoppers on the assumed 12-row planter must be changed. On the other hand, all hoppers must be changed when planting the block or the U. The extra time spent changing seed in the hoppers is the source of the labor cost differences.

- *80-acre field.*

  The total field costs associated with planting an 80-acre field are the same as the 40-acre field. This occurs because the number of extra hopper changes is the same as in the smaller field. On a per-acre basis, however, the cost is half that of the smaller field. The strips configuration costs $0.038 more per acre while the block and U cost $0.15 more per acre. While strips are the most economical, this result must be tempered by practical issues associated with potentially separating the corn at harvest and spraying for ECB in the refuge. These are discussed in the conclusions of this paper.

Yield Loss Due to Delayed Planting

To analyze the potential effects of delayed planting, a representative farm with 1,000 corn acres was analyzed. It was assumed that 520 acres were comprised of 40-acre fields, while 480 acres were made up of 80-acre fields, that is, about half of the total acreage in each type of field. The delays are based on "good" field days during the planting season as used in linear programming based farm planning models (Doster *et al*., 1995). Thus, the expected effects of weather are accounted for in the analysis.

When compared to strips, about one bushel per acre is lost on average in the block and U configurations. This happens because the increased planting time pushes 133.9 acres to a planting date after May 10. Test plot data show that corn planted between May 10 and May 16 will yield about 5% less than earlier planted corn (Doster *et al*., 1995). The per-acre economic impact of this yield loss is simply the price of a bushel of corn since one bushel is lost per acre when averaged across the entire farm.

Table 1: Summary Of Results.

	Strips	**Block Or U**
Increased Labor Costs (dollars ($))	0.038 - 0.075	0.15 - 0.30
Yield Losses Due to Delayed Planting[a] (bushels)	NA	1

Note: All results are on a per-acre basis. [a] Block or U is compared to Strips here. It is not relevant to compare Strips to non-Bt corn.

Conclusions

The results presented here suggest that differences in the cost of planting alternative non-Bt corn refuge configurations are small, even under the restrictive assumptions made. Furthermore, planting a strip configuration was shown to be the lowest cost method of meeting the refuge requirement. The block and the U not only cost more in terms of direct labor costs, but also in yield losses due to late planting. However, even $0.30 per acre, the largest cost difference we estimate, is only 0.16% - 0.27% of total variable costs per acre ($112 - $177) (Doster *et al*., 2000).

Although the focus of this article is on within-field refuges, some practical considerations may prohibit their use in favor of refuges in adjacent fields. Farmers may need to separate their GMO grain from their non-GMO grain for at least three reasons. First, reluctance of some U.S. grain importers, most notably the European Union and Japan, to import genetically modified corn has led some U.S. processors (Archer Daniels Midland, National Starch, and A.E. Staley, for example) to demand that the corn be separated. Not only must Bt and non-Bt corn be harvested separately, but to avoid cross-pollination, the non-Bt corn must be planted a certain distance from Bt corn. A.E. Staley has specified a 60-foot separation. This means that most, if not all, of the within-field refuge could not be certified as non-GMO. Furthermore, this has led to modest (5 to 10 / bushel) premiums for some non-GMO corn. It appears most likely that farmers would choose to plant refuge in adjacent fields in these circumstances so that they can maintain some level of flexibility in their marketing plan.

Second, feedback from farmers and university researchers indicates that Bt corn may dry more slowly than non-Bt corn. If the difference is significant enough to warrant different harvest dates, the farmer may want to consider planting refuge in adjacent fields to allow for increased harvest efficiency relative to leaving the refuge section of a Bt cornfield for later harvest.

Finally, spraying may not be practical for within-field configurations. Areas with historically heavy insect damage may find it impractical to spray strips in a field. Thus, those farmers who may decide to spray the non-Bt portion of the field for ECB should consider a block configuration when planting within-field refuges or plant a refuge in a neighboring field.

The total cost of planting a within-field refuge is small given the restrictive assumptions made in this analysis. This is good news for farmers planting Bt corn. Increased efficiency will lower costs from those reported here. Thus, farmers who can economically control ECB by planting Bt corn will not face significantly higher total production costs by satisfying the EPA mandated 20% refuge requirement.

Endnotes

[1] For a detailed list of assumptions used in this analysis see Hyde *et al*. (1999b).

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