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The Economic Impact of Corn Rootworm Resistant Traits: *Implications of Proposed Higher Refuge Requirements in the U.S.*

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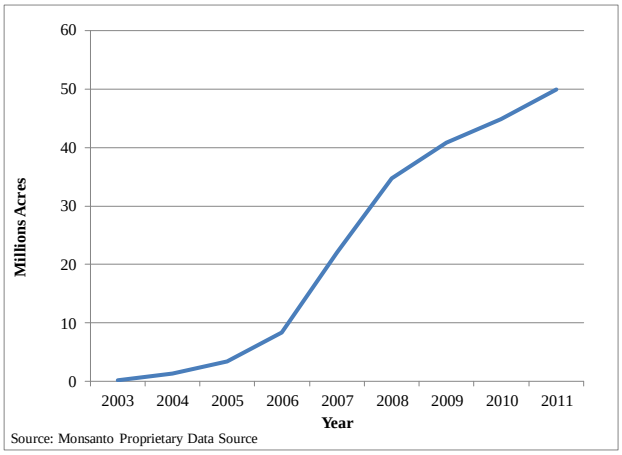
Introduction

In 2002, corn rootworm was estimated to have caused yield losses and control costs that exceeded $1 billion [1]. That was before the advent of corn rootworm-resistant biotech traits. Up to that time, a one-year corn rotation had been effective in limiting corn rootworm damages. However, the development of two opportunistic rootworm variants—the soybean variant and the extended diapause variant—resulted in decreasing yield and increasing control costs even with crop rotation. Subsequently, beginning in 2003 farmers began planting genetically engineered corn rootworm-resistant varieties. Figure 1 plots the striking increase in acreage planted to corn with the rootworm-resistant trait since then.

The US Environmental Protection Agency (EPA) requires that a non-traited corn refuge be planted near biotech corn. This requirement was instituted to mitigate insect resistance (as has occurred with many other insecticides). Originally, the EPA set the required refuge acreage at 20% for Corn Belt states and 50% for the Cotton Belt states. Lately, some small pockets of resistance to a single corn rootworm trait have been found, spurring some to recommend a significant increase in the required refuge for rootworm-traited corn. There is no question that increasing the required refuge substantially will delay resistance build-up. The purpose of this article is to illuminate the potential costs of this policy so that a proper evaluation of it can be made by scientists and policymakers involved in the decision making.

Figure 1. U.S. Planted Corn Acres with Corn Rootworm Traits, 2003-2011



More recently, so-called RIB hybrids (Genuity®, SmartStax®, RIB Complete™, or Agrisure® 3122 hybrids) have been introduced. The name

"RIB" stands for Refuge in a Bag. Each bag contains a precise blend of 95% Genuity®, SmartStax®, or Agrisure® 3122 hybrids — and 5% non-*Bt* seeds, thus enabling producers to reduce their refuge from 20% to a 5% unstructured refuge. The 2013 pricing difference between RIB and structured refuge products is an additional $2.78 per acre for SmartStax® and $1.85 per acre for VT® Double PRO® for Monsanto Brands. The added convenience and benefit of having the higher yielding and risk reducing RIB hybrids on 15% more of a farm's acres—without a structured refuge and without a substantial increase in the seed cost—leads to an increase in the economic benefits of RIB while inherently ensuring refuge requirements are met.

The 2012 75-year-high record corn planting has been subjected to a "worst in a lifetime" drought for many farmers [2]. The effect on expected corn yields was reflected in October 2012 when the USDA's [3] projected 2012/2013 US corn yield was revised down to 122 bushels per acre. The RIB technology has likely prevented a bad situation from being much worse. In 2012, 88% of the US corn crop was planted with genetically modified corn [4]. If current projections are accurate the 2012 US crop will have the lowest yield since 1995. In 2003, only 40% of the US corn crop was planted using genetically modified corn [5]. While it is difficult to disentangle the impact of the various innovations over time, it is apparent that the proliferation of corn rootworm-traited hybrids has lessened the adverse impact from this disastrous drought.

This year provides a natural experiment that illustrates the likely yield decrease that would result from a higher refuge requirement combined with an inelastic demand. Between June and October 2012, USDA corn yield projections declined by 26%, from 166 bushels per acre to 122 bushels per acre. This fueled a 42% increase in corn prices over the same period (from $5.20 per bushel to $7.40 per bushel). In other words, for every 1% decline in expected yield, the expected corn price increased by 1.6%. The same increase in price, and hence a comparable impact on yields, would result from changing the refuge requirement back to 20% (in the Corn Belt) and 50% (in the Cotton Belt) for corn containing corn rootworm protection traits, assuming adherence to these refuge requirements.

Economic Analyses of Corn Rootworm-Traited Corn Seeds

The first economic study of corn rootworm resistant corn was an ex-ante, counterfactual analysis of the benefits from adoption of the YieldGard® Rootworm-traited corn had it been available in crop year 2000 [6]. The study found that the total net benefits to farmers would have been $231 million in 2000. The pecuniary benefits accruing to non-farmers (technology developers and seed companies), would have been $171 million, representing 2.36% of the total value of the corn crop. Non-pecuniary benefits of $3.80 per acre (see the section below on non-pecuniary characteristics) would have contributed another $58 million in farmer benefits. Overall, $460 million of total benefits would have accrued had the corn rootworm trait been available in 2000.

Another study by Rice [7] estimated total annual farm-level benefits assuming 10 million acres of corn were planted with hybrids containing the corn rootworm protection trait. Included were intangible benefits to farmers (reduced exposure to insecticides, ease of handling, and better pest control); $231 million from yield gains, improved harvesting efficiency, increased yield protection; a decrease of about 5.5 million pounds active ingredient of insecticide per 10 million acres; 5.5 million gallons of water and 70,000 gallons in fuel not used in application; 1 million fewer insecticide containers; increased planting efficiency; and improved safety of wildlife and other non-target organisms.

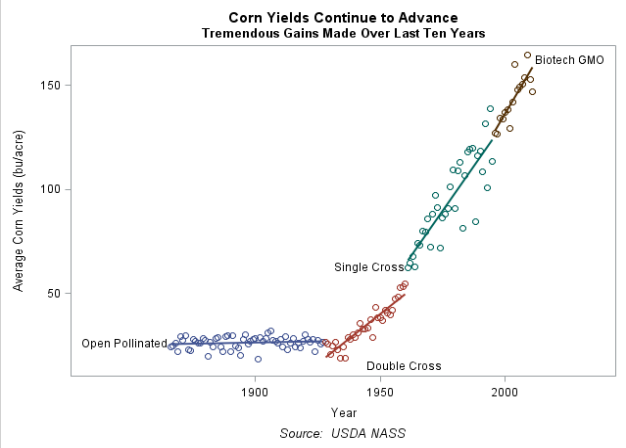
Effect of Corn Rootworm Traits on Corn Yield

Figure 2 shows the steady increase in the US corn yield trend. Little advancement was made in corn yields until about the mid-1920s when hybrid corn was introduced. Further advances occurred in the mid-1960s when double crossing was developed, and with the passage of the 1970 Plant Variety Protection Act, which allowed plant cultivars to enjoy patent protection. These two events facilitated tremendous yield gains.

When biotech corn was introduced in the mid-1990s corn yields soared even higher. Tannura et al. [10] hypothesized that good weather in recent years largely explains this increased growth rate. However, Vados et al. [11] found that, after accounting for the good weather during the period 1981 to 2008 and steady germplasm improvement, there is a significant, positive effect of the corn rootworm-protected traits on corn yield of about 7%. Given an average corn yield of 160 bushels per acre at the beginning of the period, this would result in an 11-bushel increase in corn yield simply due to the adoption of the corn rootworm protection traits. At current corn prices of about $7.40 per acre, this would increase revenue from corn by $81.40 per acre. Given the rapid adoption of the corn rootworm traits since 2003 and the increase in total corn acres of 17.3 million acres (from 2003 to 2012), the advent of corn rootworm resistant corn has arguably contributed substantially to the prosperity and record-level net farm income US corn farmers have recently experienced.

Ma et al. [8] found Bt corn rootworm hybrids yielded from 11% to 66% more than untreated, untraited hybrids that were a near genetic match. If one assumes a 160-bushel expected corn yield, the yield increase found in the study ranges from 17.6 to 105.6 bushels per acre. Of course, the yield advantage depends on corn rootworm infestations in a particular year and location. Generally, a yield advantage due to the corn rootworm trait was found to be present at least one of every three years. Taking the midpoint of the yield benefits found by Ma et al., and dividing it by three, the expected yield increase in any single year is about 29.33 bushels per acre. At the December 2012 corn futures price of about $7.40 per bushel [9], the total revenue gain would be $217 per acre.

Figure 2. Corn Yield Across Technology Eras



Combinations of insect protection traits have led to even larger yield benefits. Goodwin et al. [12] conducted a study of over 10,000 side-by-side comparisons of conventional hybrids with no insect protection traits against hybrids having one trait for controlling corn borer-like insects and one trait for controlling corn rootworm. They found that these triple-stack hybrids had an average 11.32 bushel per acre yield advantage over the non-traited or just herbicide tolerant hybrids. This is similar to the advantage found in the Ma et al. study. When more than one trait is added to individually control for corn borer and corn rootworm, this yield advantage increases by an additional 6-8 bushels per acre over the single-traited corn rootworm resistant hybrids [13].

Profit vs. Utility

As noted above, farmers consider additional factors beyond financial profits in their decision to adopt a new technology. These factors

reflect intangible characteristics associated with the technology that may not be as readily priced, but confer value nonetheless. That is, economists say the farmers maximize their own utility, rather than just maximizing profits, by taking into account the value of some intangible characteristics of the new biotechnologies.

Non-Pecuniary Impacts

Farmers realize gains from non-pecuniary characteristics of the corn rootworm-traited corn hybrids that are not directly traded in markets and are, therefore, not directly priced. The values of these characteristics include additional safety for farm workers and operators, important environmental benefits; additional convenience, simplicity and flexibility of growing these hybrids; and reduction in yield risk. This reduced risk alone has been estimated to be worth about $0.80 per acre per year to corn producers for the single corn rootworm-traited corn [6] — and about $6.50 per acre per year for the multi-corn rootworm-traited corn hybrids such as SmartStax® corn [14].

Risk Reduction

In the last decade, farmers and agronomists began to notice some interesting characteristics of the insect-protected biotech corn. Corn rootworm-traited hybrids tended to have larger and deeper root balls and tended to exhibit significant yield advantages relative to their conventional counterparts during periods of environmental stress. This was especially apparent in 2005 in Illinois, when a significant drought event occurred. Those hybrids with corn rootworm traits fared significantly better than those without the traits in terms of plant health, decreased lodging, and ultimately yield.

In light of an expanding crop insurance program, some began to question whether this might have important implications for the pricing of crop insurance. The implications were important not just to farmers who were paying for coverage. Taxpayers were shouldering an increasing burden in subsidizing the program.

In April of 2007, the Monsanto Company approached the Risk Management Agency (RMA) with a proposal to evaluate yield risk differences and their implications for the pricing of crop insurance coverage. Monsanto proposed an endorsement to the existing crop insurance programs that would provide a premium discount to farmers planting certain biotech hybrids that were proven to have lower yield risk. The proposal was approved in September 2007 and in 2008 corn farmers in Illinois, Indiana, Iowa, and Minnesota were able to elect the “Biotech Yield Endorsement” and receive a premium discount for approved biotech corn. Discounts of approximately 18% were realized in the first year with 5.8 million acres in the four pilot states insured and resulted in savings of $29.4 million to corn farmers and $33.3 million to taxpayers through premium subsidy savings. The typical premium for conventional corn on those policies that took the endorsement was $59.01 per acre. On those same policies, the acreage qualifying for the endorsement had an average premium of $48.36, representing a savings of $10.65 per acre.

In 2009, the RMA added biotech hybrids from Pioneer. In the second year, participation doubled to almost 12 million acres. The total savings to farmers and taxpayers as a result rose to $131 million. Over the four-year period between 2008 and 2011, the program generated over $532 million in savings to growers and taxpayers. In 2011, RMA pointed out that biotech corn had become so ubiquitous as to minimize the need for differentiating between conventional and biotech corn and so the endorsement was discontinued.

The statistical methods used by RMA to establish crop insurance premium discounts for biotech corn hybrids can be employed to evaluate the effects of increasing the required refuge from 20% to 50%. The RMA analysis confirmed a statistically significant relationship between the biotech yield advantage and growing conditions, such that periods of significant stress (e.g., drought) exhibited larger

differences between the biotech and conventional corn yields. The regression model implied that corn yields would have been lower by 5.4 bushels per acre in 1998 and up to 14.1 bushels per acre in 1988. If we value the differences using the 2011 acreage of 89 million corn acres and the current price of $7.40 per bushel, the lost value resulting from a higher refuge ranges from $3.5 billion in 1998 to $9.3 billion in 1988. Although these calculations extrapolate results for the Corn Belt to corn acres nationally, they demonstrate the significant economic costs associated with foregone revenues resulting from the imposition of a higher refuge requirement that reduces biotech acreage by 30 percent.

Environmental Impacts

The evidence has shown that the biotech seeds also have environmental benefits. Corn rootworm-traited hybrids trade a relatively toxic suite of soil-applied insecticides for in-plant insect protection that is unambiguously better for the environment.

Environmental Benefits

In two farmer surveys, one conducted in 2002 [6] and one in 2009 [13], growers were asked to place a value on the environmental benefits of the corn rootworm-traited corn hybrids. The first survey asked about the single-traited corn rootworm resistant hybrids. Farmers responded that they placed an average value of about $0.21 per acre per year on the environmental benefits. When asked in 2010 about the environmental benefits of the multi-traited corn rootworm resistant hybrids, growers placed an average value of over $2.00 per acre per year on the same set of environmental benefits. It is evident that both the continued use of the traits and the addition of multi-traited corn rootworm resistant hybrids have had an important impact on the value to farmers of the environmental benefits afforded by the corn rootworm traits.

Refugia and Resistance

When the multi-traited corn seed (multiple modes of action for above-ground pests, for corn rootworm, and for herbicide tolerance, respectively) was commercialized, EPA approved a new kind of refuge that was a mixture of 95% SmartStax® and 5% non-traited seed in every bag of corn seed. In a survey conducted in 2011, growers in the Plains States, Corn Belt, and Northeastern U.S. estimated additional farm level value of the 5% RIB over the 5% structured refuge to average $18.30 per acre [14].

An additional benefit of RIB merits attention. Anecdotal evidence and survey results imply that about 1/3 of farmers have not strictly adhered to refuge requirements. This could exacerbate resistance in the single-corn rootworm-traited corn. RIB eliminates this possibility and assures compliance without incurring the costs of monitoring.

Corn Rootworm Traits' Impacts on Non-corn Farmers

Several studies have estimated the decline in the world price of corn resulting from the widespread adoption of the Bt corn traits to range from 1.94% [15] to 2.5% [16]. But for the adoption of the corn rootworm-traited hybrids, corn prices would be about 2 to 2.5% higher now. This lower corn price has benefitted all users of corn, including livestock producers, producers of corn sweeteners or corn-sweetened products, and corn ethanol producers. At current expected corn prices, this price decline amounts to about $0.185 per bushel per year and with an estimated 12.3 billion bushels produced in 2011 [3] an annual, overall reduction in total expenditures of about $2.3 billion.

Conclusions and Policy Implications

Even though we cannot impute a precise number to the total net benefits of the corn rootworm traits, it is clear that the corn-rootworm-traited hybrids have provided an immense benefit to corn farmers, non-corn farmers, the environment, and consumers in the

U.S. and worldwide. Any attempt to further regulate the use of these traits must weigh these lost benefits against the relatively small potential benefits from increasing refuge size. While it is difficult to disentangle the precise impact of the various innovations that have transpired for US corn hybrids over the period 2003 to 2012, it is reasonable to conclude that the stacked hybrids that include the corn rootworm trait have played a significant role in lessening the adverse impact of the disastrous drought experienced in 2012.

Rather than "throwing the baby out with the bath water," we recommend consideration of the tremendous cost to the industry, farmers, and consumers that would accrue if use of this trait were to be reduced via changes in refuge requirements. Instead, a combination of rotation, best management practices, and adoption of multi-traited corn hybrids makes more sense.

In addition, it is not clear that corn farmers will comply with a larger refuge requirement after enjoying the benefits of the lower refuge requirements and, now, the RIB option. To enforce this requirement would require substantial, and probably prohibitive, monitoring costs. Even if the higher refuge requirements are incorporated into a RIB strategy, significant undue costs may be realized in areas where resistance is not a problem. These costs also would have to be incorporated into the decision calculus to require a higher refuge. All things considered, it is clear that a significantly higher refuge requirement for corn rootworm-traited corn is almost certainly not the best way to solve the problem of an isolated area where resistance build-up has been observed.

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