

PURDUE AGRICULTURAL ECONOMICS REPORT

MAY 2004

United States and European Consumer Demand for Genetically Modified Food in an Experimental Market

Jayson L. Lusk

Few issues in United States (U.S.) agriculture have become as contentious as biotechnology in food production. For agricultural producers, biotechnology has the potential to lower production costs by reducing input usage. Biotechnology also has advantages of potential food and environmental quality improvements. Despite the promise of biotechnology, a number of real and perceived risks exist. For agricultural producers, one of the greatest risks of continuing to grow genetically modified crops is that of potential consumer backlash, both domestically and abroad. For example, the European Union (EU) restricts imports of U.S. commodities that have been genetically modified by imposing a moratorium on approving new genetically modified crops and through mandatory labeling laws. EU countries require labeling of genetically modified foods, and a number of large EU retailers have agreed to stop selling all genetically modified foods, effectively banning genetically modified foods for most EU consumers. The European stance on biotechnology, among other factors, has had a significant effect on US-EU agricultural trade. According to US Department of Agriculture data, US exports of corn to the EU have fallen 99% since 1995 and

exports of soybean meal to the EU fell 66% over the same time period.

Understanding Demand for GMO Foods

U.S. agricultural producers need to develop an understanding of consumer demand for genetically modified foods to assess the viability of current production practices and to forecast future marketing opportunities. The conventional wisdom is that U.S. consumers are generally accepting (or perhaps unknowledgeable) of genetically modified foods. However, there is clearly some segment of the population that is adamantly opposed to use of biotechnology in food production and are willing to pay premiums for foods without genetically modified ingredients. How large is this consumer segment? What kinds of premiums will this segment pay for genetically modified foods? Is this consumer segment likely to grow or decline in the future? These questions are, at present, largely unknown.

Naturally, U.S. agricultural producers are also interested in international consumers' perceptions of genetically modified foods, as exports account for a large portion of U.S. commodity sales. Understanding international consumer demand for genetically modified foods is complex.

Take for example the EU. The EU often cites consumer food safety concern as a basis for restricting imports of genetically modified foods. However, it is possible that the cited food safety concerns are simply a way for the EU to protect domestic agricultural producers from international competition. So, are EU consumers really all that different that those in the US and if so why?

Researching Consumer Demand

Recent research undertaken by Purdue University and the University of Reading, England has begun to address these questions. In the summer and fall of 2002, a number

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of research sessions were held with primary household shoppers in Long Beach, CA (47 participants), Jacksonville, FL (39 participants), Lubbock, TX (80 participants), Reading, England, (108 participants) and Grenoble, France (98 participants). In these research sessions, consumers were asked a number of questions to determine their knowledge and attitudes about the use of genetic modification in food production. Then, consumers bid in an auction. Using an auction to determine how consumers value genetically modified food is advantageous because the approach creates an active market that involves the exchange of real food and real money to determine the price-premium placed on a food containing no genetically modified ingredients versus a food containing genetically modified ingredients. A substantial amount of academic research has shown that individuals' responses to hypothetical survey questions are poor predictors of actual behavior. By using a non-hypothetical auction with real food and real money, this study avoids the bias inherent in hypothetical surveys.

The non-hypothetical market was designed to determine the premium consumers placed on a non-genetically modified cookie by eliciting consumers' "willingness-to-accept" compensation to exchange a non-genetically modified cookie for a genetically modified cookie (figure 1). In this auction, consumers were given a cookie that contained no genetically modified ingredients. Then, consumers bid to exchange their non-genetically modified cookie for an otherwise identical cookie that did not contain genetically modified ingredients. The lowest five bidders won the auction and were paid the fifth lowest bid amount to exchange their non-genetically modified cookie for genetically modified cookies. All participants were required to eat the cookie they possessed at the end of the research session; auction winners ate genetically modified cookies and auction losers ate non-genetically modified cookies. The structure of the auction is such that individuals have an incentive to bid the *minimum* amount of money it was worth to them to exchange their non-genetically modified cookie for a cookie containing genetically modified ingredients (i.e., their "willingness-to-accept"). It is worth noting that this auction operated in manner exactly opposite of that with which most readers are likely familiar. In a traditional "willingness-to-pay" auction, individuals bid to purchase an item they desire where the highest bidder(s) win the auction and pay

one of the highest bid amounts for the item. This study used a "willingness-to-accept" auction where individuals bid to accept a good they did not want where the lowest bidders(s) won and were paid one of the lowest bid amounts to take the item.

Research Results

For ease of exposition, data from the three U.S. locations were pooled together (figure 1). Clearly, U.S. consumers were much more willing to consume the genetically modified cookie than were the EU consumers. Over 65% of U.S. consumers demanded an amount between \$0.00 and \$0.24 to exchange their non-genetically modified cookie for the genetically modified cookie, whereas, only 37% of English and 27% of French consumers fell in the same category. In contrast, most French consumers (52%) demanded more than \$2.00 to eat a genetically modified cookie, whereas, only 16% for English and 9% of U.S. consumers demanded more than \$2.00 to exchange their non-genetically modified cookie for the genetically modified one.

Two important conclusions can be drawn. First, *on average* EU consumers are much more concerned about consuming this particular genetically modified food than are U.S. consumers. But averages don't tell the whole story. The second important conclusion is that there is significant heterogeneity within each country, with significant segments of the English and French

Purdue Agricultural Economics Report is a quarterly report published by the Department of Agricultural Economics, Purdue University.

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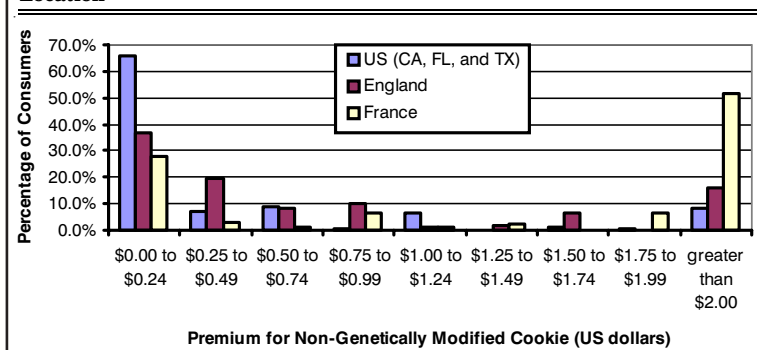
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Figure 1. Distribution of Premiums for Non-Genetically Modified Cookie by Location



populations having both relatively low and high concern for this genetically modified food.

Although this study only relates to consumer demand for one particular type of genetically modified food (a cookie), survey questions reveal similar relationships between the U.S. and EU consumers when they are asked about general acceptance and concern for genetically modified foods. EU consumers were more concerned about, and less accepting of, genetically modified foods on average than were U.S. consumers. Having established that there are, in fact, differences in U.S. and EU consumers, the interesting question becomes why these differences exist. To address this issue a number of survey questions were asked. In general, cross-country differences might arise because of differences in knowledge; trust; general attitudes toward the environment, food, and technology; and perceptions of the benefits and risk of biotechnology.

- ▶ In terms of subjective knowledge (i.e., the self-reported level of knowledge on a scale of 1 = very unknowledgeable to 9 = very knowledgeable), consumers in all three countries believed they were relatively unknowledgeable about issues related to genetically modified foods; however, the French consumers had a much higher level of subjective knowledge than U.S. and English consumers. However, in terms of objective knowledge about genetically modified foods, which was determined by asked a number of textbook true/false questions; there was little difference across countries. So, while French consumers *believed* they were more knowledgeable about genetically modified foods, they are no better at correctly answering true/false questions about genetically modified foods than were U.S. and English consumers. Overall, responses to the true/false questions indicate that objective knowledge levels in all three countries are moderate to low.

- ▶ The French and English consumers were much more concerned about the environment in general and viewed genetically modified foods as a greater risk to the environment than U.S. consumers.
- ▶ English, and especially French, consumers were much less optimistic about the ability of technology in general, to improve society and civilization than were U.S. consumers.
- ▶ French and English consumers were much less trusting of information about genetically modified foods from their federal food regulatory agencies (i.e., the FDA, USDA, and their international equivalents) than were U.S. consumers. In addition, U.S. consumers were more trusting of agribusinesses than were the EU consumers. In contrast, the EU consumers were more trusting of information about use of genetic modification in food production from activist groups such as Greenpeace than were U.S. consumers.
- ▶ In general, there was no relationship between consumers' demographic characteristics such as income, education, race, and religion and acceptance of genetically modified foods. Age had a slight influence on acceptance, with older consumers being more accepting of genetic modification in food production than younger consumers.
- ▶ Within the U.S., California consumers were more concerned about the use of genetic modification in food production than were consumers in Texas and Florida. In fact, consumers in California, on average, demanded up to twice as much money to consume a genetically modified cookie than consumers in Texas and Florida.

Implications, Opportunities and Concerns

These results have a number of implications for U.S. agricultural producers. First, results suggest

that roughly 10% of U.S. consumers are adamantly opposed to use of biotechnology in food production and this number is much higher in England (16%) and France (52%). Thus, it appears there are viable niche marketing opportunities in the U.S. to promote and sell "GMO free" foods. Some of this market is currently being met by firms that typically bundle "GMO free" and organic attributes, but there may be room for more players in this arena. These results also imply that US exporters will likely encounter strong resistance to future efforts at liberalizing the EU's policies on genetically modified foods. Although products such as Round-up Ready soybeans are approved for sale in the EU (albeit with a mandatory label), little is actually sold. One of the major impediments to entering the European markets with genetically modified foods are the European food retailers who have decided to effectively ban genetically modified foods from their shelves. One might question why European food retailers ban genetically modified products even though most European countries have labeling laws for genetically modified food such that consumers can pick-and-choose as they please. One answer may be the retailers' fear of reaction from consumer and environmental activist groups, which tend to be larger in Europe than in the U.S. Helping European retailers devise strategies to contend with activist protests could help open the door for US exports. Ongoing research on consumer behavior is aimed at determining the extent to which consumer aversion to genetically modified foods will change in the future due to education, communication strategies implemented by the biotechnology industry, the popular press, and future scientific discoveries.



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Increasing the Value of Manure with a Variable Rate Fertilization Program

Dayton Lambert, J. Lowenberg-DeBoer and Gary Malzer

Some custom manure handling services are starting to offer site-specific application. From an engineering standpoint site-specific manure application equipment is very similar to that used for variable rate application (VRA) of liquid fertilizer, but from a management point of view, variable rate manure is quite different from VRA of fertilizer. The key difference is that manure is highly variable in nutrient content. This variability can be reduced, but not eliminated, by agitation and calibration. Partly as a result of this variability, it has proven more difficult to estimate site-specific crop response to manure than to fertilizer. Also because site-specific manure application is quite new, not all producers have access to this service. The goal of this article is to summarize the results of a recent study of the economics of site-specific manure application. The results of this study will be of particular interest to farmers, manure custom application providers and agencies dealing with regulation of livestock waste.

VRA fertilizer has become quite common since it was first introduced in the late 1980s. Variable rate manure (VRM) has only recently been introduced. Over half of all fertilizer retailers in the U.S. offer some kind of computer controlled VRA. Most Corn Belt farmers have access to this service. The most recent USDA estimates indicate that about 11% of all corn received some VRA fertilizer in 2000. There are at least six companies that currently manufacture variable rate manure application equipment.

Experimental Design

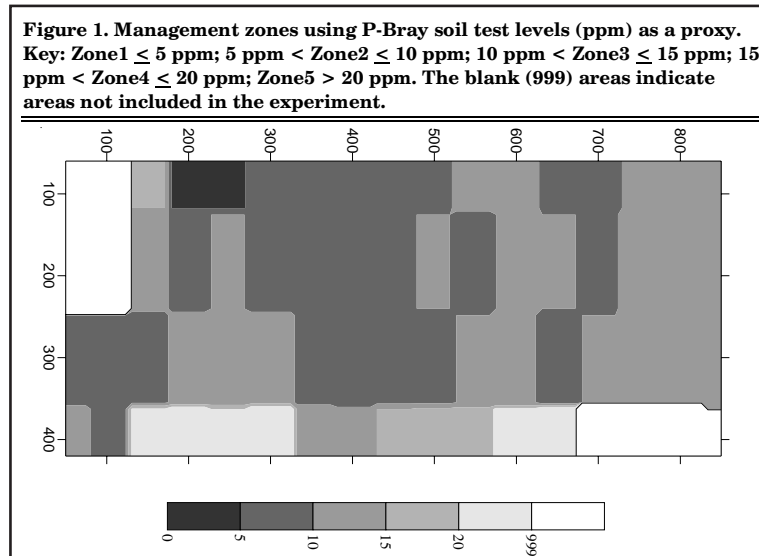
The variable rate manure experiment was conducted in cooperation with the University of Minnesota and Christensen Farms, near Sleepy Eye, Minnesota. Corn grown during the 1999 season was followed by soybean in 2000. Four rates of liquid swine manure, including a check strip (0, 2000, 4000, 6000, and 8000 gal/acre) were applied over a 10.7 acre field in constant rate strips. Manure was only applied



before the corn-growing season. One manure sample was taken from every load at the beginning of the application. This sample was analyzed for nitrogen (N), phosphorous (P), and potassium (K) content. No manure was applied prior to planting soybean. Manure was applied via surface broadcast and immediate incorporation with double discs attached to the applicator. Yield data was collected in 50 foot segments for corn and soybean crops. Grain yield was measured from the center row of each treatment strip using a Massey Ferguson plot combine equipped with a ground distance monitor and computerized Harvest Master weigh-all (Harvest Master, Logon Utah). Every 50 feet, the combine was stopped and the harvest grain weighed.

Site-specific crop response to manure was estimated for management zones based on phosphorous soil test levels (Figure 1). This zonation makes sense because: (1) the candidate management zones are supported by University of Minnesota extension recommendations; (2) P is a convenient proxy since it correlates strongly with zinc (Zn), pH, and % organic matter (%OM) soil tests; and (3) P is a manageable input that has been well-studied in extension and agronomic literature.

In the economic analysis, whole field management and variable rate manure strategies are combined with one of three soil fertility management strategies: (1) do nothing (a whole-field strategy), (2) use soil test information to raise potassium (K), phosphorus (P), or lime levels to whole-field average levels recommended by extension, and (3) to use soil test information to vary P, K, or lime site-specifically. In total, there are six scenarios. Whole field management strategies are evaluated at extension recommendation rates (3500 gal/acre) and the field specific optimal manure rate (4719 gal/acre).



Estimating net Present Value

Because manure application, fertilizer spreading and harvest occur in the data over a two year period, the analysis relies on net present value (NPV) to allow for the time value of money. In general NPV discounts costs and returns by a factor that depends on the cost of capital (also known as the discount rate) and the time at which the cost or revenue occurs. Specifically the discount factor is $(1+r)^{-t}$, where r is the cost of and t is the number of years since the first manure or fertilizer was applied. In this case the NPV is discounted revenue from corn, minus manure application costs, plus discounted revenue from soybeans, minus information costs, the variable rate application fee and fertilizer cost. The discount rate used in this report is 7.5%.

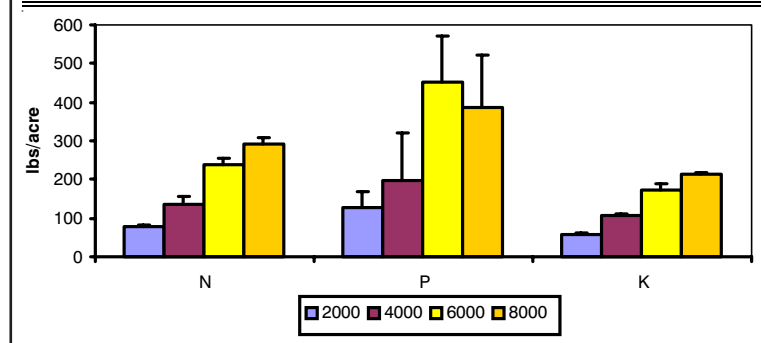
The average cost of a single-product VRA in the Midwest was about \$5.64/acre in 2000, and a soil test fee (including lab analysis) averaged \$6.11/acre. The price/lb of P_2O_5 and K_2O were \$0.28 and \$0.15. The price/lb of lime was \$0.007. These costs apply only when a producer chooses to adjust P, K, or pH to target levels. Corn and soybean prices used in the analysis were \$2 and \$6/bu, respectively. For more details on cost, see Lambert et al., 2003.

Results

Statistical analysis of the manure nutrient contents revealed that although the gallons applied manure per treatment are known, the manure N, P, and K content varies (Figure 2). Error bars in Figure 2 show the range of nutrient application for a given application rate. N and K were very consistent sample to sample, but P content varied widely. In particular the 6000 gallon manure application sometimes applied more P than the 8000 gallon treatment.

Using the site-specific crop responses to manure estimated from the on-farm trial data, the maximum NPV of \$607/acre is achieved with the variable rate manure strategy, combined with a variable rate fertilizer strategy (Figure 3). The next highest NPV (\$605/acre) was achieved by the strategy which

Figure 2. Average nutrient application and variability of nitrogen, phosphorous, and potassium in manure treatments (2000, 4000, 6000, and 8000 gallons/acre).



applies manure at a field specific optimal rate (WFM*), combined with a variable rate fertilizer program, followed by the strategy which applies a uniform rate of manure at the extension recommendation rate of 3500 gal/acre combined with variable rate fertilizer (\$597/acre).

Profit maximizing manure rates by zone vary from about 2500 gal/acre to 8000 gal/acre (Figure 4). Optimal manure rates are usually lower when some fertilizer is applied to complement the nutrients in manure. The average profit maximizing manure rate for the variable rate manure and fertilizer strategy is 5600 gal/acre. The average economically optimal rate for the variable rate

manure strategy using soil test information and following the extension guidelines for variable rate fertilizer is 4800 gal/acre. The extension recommendation of 3500 gal/acre is lower than the average VRM application and may have environmental benefits.

Conclusions

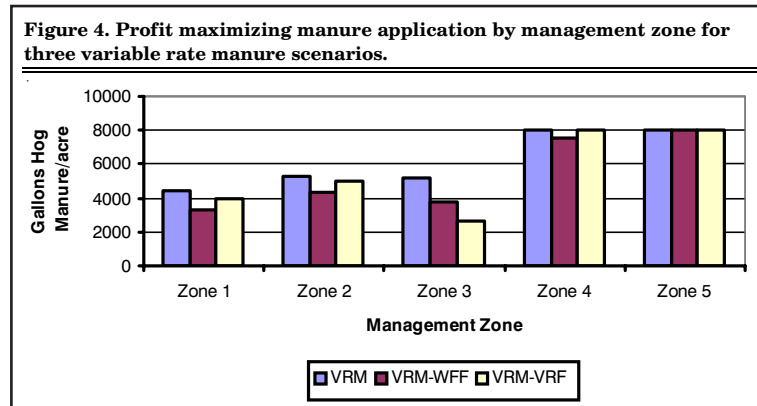
Given the variability of the nutrient content of manure, it is difficult to argue that the VRM-VRF strategy is a better strategy than the WFM strategy combined with variable rate fertilizer program. The WFM-VRF strategy results in an NPV that is only about two dollars/acre lower than the VRM-VRF approach.

Figure 3. Net present values (NPV) for manure management strategies. Key: VRM = Variable rate manure only; VRM-WFF = VRM combined with a whole-field P, K, and lime fertilization program; VRM-VRF = VRM combined with a variable rate fertilizer (VRF) program; WFM = whole-field manure management strategy only, evaluated at an extension recommendation rate of 3500 gal/acre; WFM-WFF = WFM combined with a whole-field P, K, and lime fertilization program; WFM-VRF = WFM combined with a P, K, and lime VRF program; WFM-VRF* = WFM-VRF evaluated at the field specific, optimal manure rate (4719 gal/acre).



Statistically, they are not significantly different. With good agitation and careful calibration, a uniform application of manure is a reasonable goal. With current technology,

accurate VRA of manure quantity is possible, but it is difficult to control the actual soil nutrients applied. VRF can be used to more economically and accurately manage soil variability.



For more information:

Lambert, Dayton, Gary L. Malzer, and Jess Lowenberg-DeBoer. 2003. "A Systems Approach Incorporating Soil Test Information into Site-specific Manure Management Recommendations". Staff Paper #03-13, Purdue University Department of Agricultural Economics, West Lafayette, IN, 47906, <http://agecon.lib.umn.edu/cgi-bin/view.pl>.



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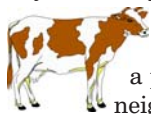
Indiana Farm Management Tour

Elkhart and LaGrange Counties June 30 and July 1, 2004

Wednesday June 30, 2004

1) Crystal Valley Dairy Farm — Elkhart County — Interview at 1:00 p.m. Mini-tours at 1:35 p.m. on farmland preservation zones, combining two farms into one, and milking parlor/dairy facilities.

Crystal Valley Dairy Farm was formed in 1998 by the Udder Guys Co., LLC, a partnership between neighboring dairymen Mike



Yoder and Mike Lee and their families. Both recognized that partnering together would more easily allow modernization of their existing facilities. Many of their decisions are directed toward keeping their farm viable in a rapidly growing community. The tour will feature their experience in merging two existing family farms into a partnership and in the development of farmland preservation zones.

2) Yoder Popcorn — LaGrange County — The tour will stop here at

3:00 p.m. before moving on to visit the Hoop Land Farms operation.

Richard, Sharon, and Rusty Yoder purchased Yoder Popcorn in 1999 to diversify their family business.



Yoder Popcorn now sells its popcorn through specialty stores, via the Internet, and from their own retail store, which they opened in July of 2003.

3) Hoop Land Farms — LaGrange County — Interview at 4:00 p.m. Mini-tours on irrigation and variable rate planter/GPS technology at 4:20 p.m.



On what by today's terms is considered a small farm, three generations are making it work and work well. The Yoder farm has been in the family since 1901 and five generations later is still going strong. The Yoders have kept the family farm strong and viable

through innovation and diversification. They were one of the first farms in LaGrange County to install irrigation in 1973. Today, they farm 1,345 acres on which, besides corn and soybeans, they grow popcorn and alfalfa.

4) Evening program at 5:30 p.m. "Amish Farming Practices," Clearspring Produce Auction Building, 2050 S 300 W, LaGrange, IN.

Amish Haystack Dinner

A presentation on "Amish Farming Practices" will be preceded by an Amish Haystack dinner. A donation of at least \$5 to the Amish who provide the meal is expected. Donations will be used to benefit the Amish community.

Participants must pre-register for dinner by June 18 by calling 1-888-EXT-INFO or the Elkhart County (219-533-0554) or LaGrange County (260-499-6334) Purdue Extension office.

Thursday July 1, 2004

5) Lord's Seed LaGrange County Interview at 8:00 a.m. Mini-tours starting at 8:45 a.m. on pickle production; fertility, field mapping, and weather data technology; seed corn production and processing; irrigation; and the farm office complex.

Lord's Seed is a diversified family farm business focused on providing services to the seed industry. Crops produced include seed corn, identity preserved corn and soybeans, and pickles. The family also operates a grain company and manages a seed corn processing plant for Great Lakes Hybrids. Irrigation, field mapping, variable rate application, and spray monitors are just a few of the technologies employed on this farm. The business has grown rapidly, which has led to organizational, communication, financing, and management succession challenges. Learn what they are doing to meet these challenges.

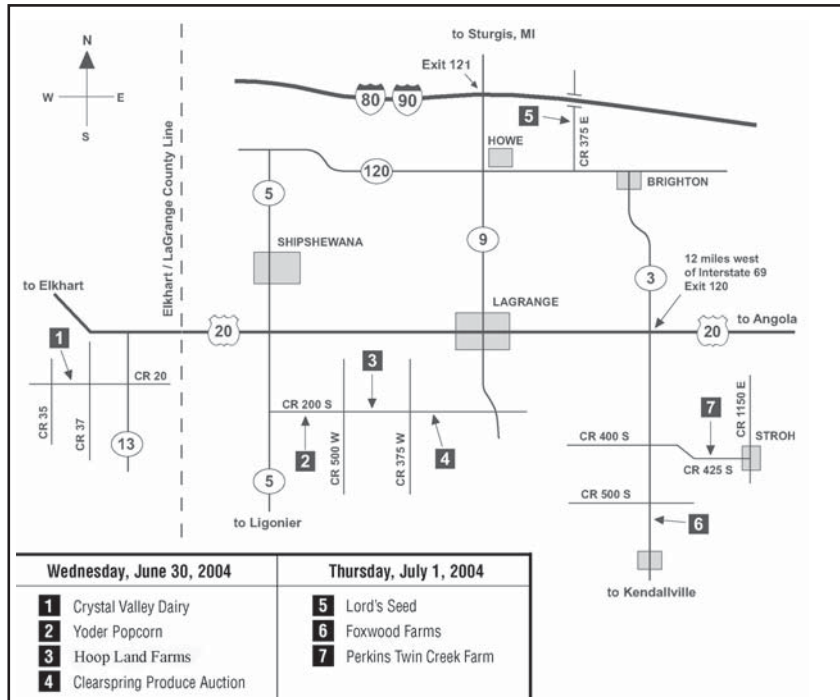


6) Foxwood Farms — LaGrange County — General interview at 10:45 a.m. Mini-tours at 11:30 a.m. include a woodland walk focusing on farm woodland management, and a Golden Harvest corn yield test plot.

R. D. Wolheter is the only full-time employee of Foxwood Farms. With the help of his family and part-time employees, he currently manages over 2000 acres, with an average field size of only 30 acres. In addition to his participation in the Soil Water Conservation District Board, R. D. has been named a *River Friendly Farmer of Indiana* for his use of production practices that reduce soil erosion; he adopted no-till in 1981. In 2003, the Wolheters restructured the farm, which affected their payment limitations associated with the 2002 Farm Bill. We'll discuss that topic.



7) A sponsored lunch will be served at 12 noon at Foxwood Farms.



Participants must pre-register for lunch by June 18 by calling 1-888-EXT-INFO or the Elkhart County (219-533-0554) or LaGrange County (260-499-6334) Purdue Extension office. This is the only convenient place to eat lunch.

Chris Hurt, Purdue Extension Marketing Specialist, will update the outlook for grains, soybeans, and livestock after lunch is served.

8) Perkins Twin Creek Farm — LaGrange County — Interview at 2:00 p.m. Mini-tours on dairy herd health management, milking parlor/free stall barn, and farm supply business at 2:45 p.m.



Creating an opportunity for a son or daughter to return to the home farm is a challenge for many farm families. The Perkins family has found a variety of means, combining farm and farm-related activities, to meet that challenge. Jim, who is largely retired, and his sons Kirk, Todd, Eric, and Rod are all involved in Perkins Twin Creek Farm. They currently farm about 2,500 acres of crops and milk 160 cows. (100 cows are milked three

times a day.) Eric manages Stroh Farm Supply, which provides feed, custom spraying, and other services to farms in the area. Kirk sells seed. Crop and dairy expansion provided opportunities for Rod and Todd. Learn about the family's plans to remain competitive in the dairy business, as well as their customer orientation to landowners and neighbors for environmentally friendly farming.

Hotels

This is peak tourist season, so reserve early. The Farmstead Inn, Shippshewana, IN, has 25 rooms for the Purdue Farm Management Tour through May 31. Call 260-768-4595. Call 800-254-8090, or visit www.backroads.org for other lodging alternatives.

Information

Call 1-888-EXT-INFO.



W. Alan Miller is a Farm Business Management Specialist. He is coordinator of the farm management tour and Secretary of the Indiana Farm Management Association.

Managing the Corn Rootworm

Results of an Indiana Farmer Survey

Anetra L. Harbor and Marshall A. Martin

Pest management and yield losses are estimated to cost U.S. corn producers over \$1 billion annually. Recently, the corn rootworm has proven to be especially challenging in some regions of Illinois, Indiana, Michigan and Ohio. Growers in these areas are faced with managing a rootworm “variant” that has developed the ability to circumvent traditionally effective biological control provided by a corn-soybean rotation. Most growers have increased their reliance on soil insecticides.

How widespread is the rootworm variant problem? How have farmers responded to the emergence of this new type of pest? Further, are there rootworm management alternatives available or potentially available that are acceptable to corn growers? If so, what information avenues can producers use to learn more about these alternative techniques? Determining the answer to these questions is important to corn producers for successful rootworm management; to researchers as they develop extension education efforts; and to farm input suppliers as they design more effective product marketing programs.

Brief Background on Rootworm Management and the Variant Emergence

Corn rootworms adversely impact growers in two ways. First, farm profitability may be reduced when a producer has to incur the cost of applying insecticides to manage rootworm infestations. Soil insecticides are usually applied at planting time to control rootworm larvae, while aerial sprays can be applied later in the growing season in order to suppress adult rootworm beetle populations in cornfields. Second, rootworm infestations can impact yields. Rootworm larvae feed on the corn root system, which can hinder plant growth and contribute to plant

lodging. Larvae that reach the adult stage feed on the silk and pollen, which can interfere with pollination, thereby reducing yields.

Corn growers in Indiana typically control rootworms through the routine application of soil insecticides, the use of a crop rotation, or both. Historically, adult rootworm beetles would feed, mate, and lay eggs *only* in cornfields during summer months. Rootworm eggs deposited in a cornfield during late summer remained dormant during the winter and hatched into a rotated soybean crop the following spring. In the past, soybean roots were considered an inadequate food supply for rootworms, and the larvae starved. Until the 1990’s, adult rootworm beetles had not been known to lay eggs in soybean fields. So a field rotated back to corn after a soybean crop was not threatened by rootworm larvae infestations.



The primary benefit of rotating annually between corn and soybeans is the disruption of the rootworm life cycle. Hence, the need for soil insecticides is eliminated when corn is grown in alternate years with soybeans. However, when corn is grown continuously in the same field, there is no break in the rootworm life cycle, and soil insecticides are generally applied to control rootworms.

The aggressive adoption of a corn-soybean rotation over the past quarter-century appears to have contributed to the emergence of a western corn rootworm strain capable of laying eggs in soybean fields (Sammons et. al., 1997). The evolution of such a variant beetle has reduced or eliminated the effectiveness of a corn-soybean rotation in much of the Eastern Corn Belt, including a significant portion of Indiana.

The Indiana Corn Rootworm Management Survey

To assess the severity of and management response to the emergence of the rootworm variant, a rootworm management survey was mailed to a random sample of Indiana corn and soybean producers. Questionnaires were mailed to 6,000 farmers during February and March 2001. Respondents were asked to: 1) assess the effectiveness of crop rotation for controlling rootworms on their farm, 2) indicate alternative management tactics they used when they perceived a failure of crop rotation to control rootworms, 3) report any acceptable management practices that they would be willing to use in the future, and 4) specify the information avenues they use when seeking information on new and emerging rootworm management strategies. Information on farm and farmer characteristics, producer attitudes, and management information sources also was collected. A total of 1,135 usable surveys were returned (19% response rate). Every county in the state was represented with the exception of Crawford, Floyd, and Ohio, which are not major corn producing counties and have not reported problems with the corn rootworm variant.

Rootworm Problem Areas in Indiana

Entomological data suggest that the variant problem is not uniform throughout Indiana. Variant pressure is greatest in the northern portion of the state. It is generally accepted that the variant phenomenon originated in east-central Illinois in the late 1980’s, and then spread in a north-eastwardly direction into Indiana (Levine and Oloumi-Sadeghi, 1996). Consequently, counties located on the Illinois/Indiana border north of Interstate 70 are being impacted the most by the variant, while corn producers in southern Indiana appear to be largely unaffected.

Accordingly, Indiana was stratified into four geographical regions based on variant infestation levels. These levels were determined by county-level, multi-year (1998-2001) Western Corn Rootworm Sweep Net Surveys in soybeans reported by Purdue University entomologists. The Severe Rootworm Problem Area experiences the greatest levels of rootworm variant pressure and is comprised of ten counties located near the Indiana/Illinois border (Figure 1). These ten counties have experienced extremely high average rootworm beetle numbers in soybeans. The Emerging Problem Area in central Indiana does not have average beetle counts as high as those in the Severe Rootworm Problem Area, but beetle counts in soybean fields have been persistent in recent years. The Potential Problem Area has beetle counts that are moderate to low and typically includes counties located in the northeastern section of the state. Finally, the Unaffected Area comprises the vast majority of the state located south of Interstate 70 and represents those counties that have virtually no adult rootworm beetles present in soybean fields.

One hundred sixty-two usable surveys were obtained from farmers in the Severe Rootworm Problem Area. Emerging Problem Area data included responses from 317 surveys. The largest number of questionnaires (386) was received from the Potential Problem Area. A total of 286 questionnaires were received from the Unaffected Area.

Effectiveness of Crop Rotation

What is the extent of the rootworm variant problem in Indiana? Survey responses reveal that crop rotation is less effective in those areas of the state with greater corn rootworm variant pressure. As variant pressure increases, so does the likelihood of reporting that crop rotation was less effective for controlling rootworms. Over one-third of the producers operating in the Severe Rootworm Problem Area (36%) indicated that crop rotation was less effective in 2000 when compared to the early 1990's. Nearly a fourth of

respondents from the Emerging Problem Area also so indicated. In contrast, only eighteen percent and 12% of respondents from the Potential Problem Area and the Unaffected Area, respectively, indicated that crop rotation was less effective.

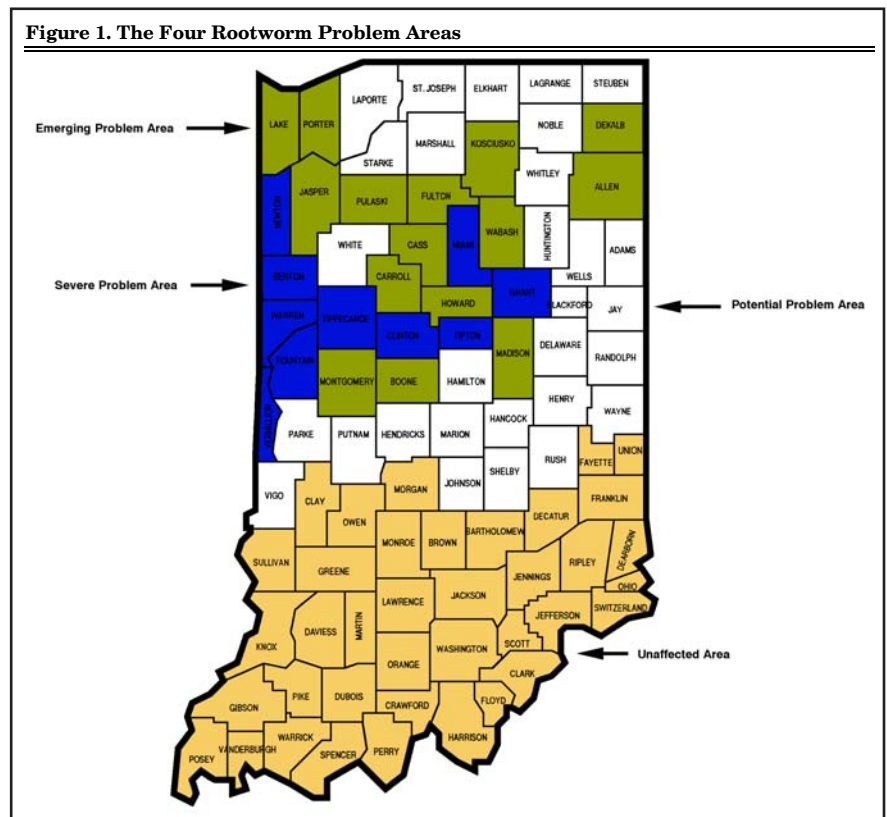
The likelihood of having problems with rootworm larvae in first-year corn is highest in areas with greater rootworm variant pressure as reported in the entomologist's sweep net surveys. Based on the farmer survey responses, the region of the state that is most affected by the rootworm variant is the Severe Rootworm Problem Area. Corn producers operating in this area have a 14% probability of having a major problem with rootworms in first-year corn. The Emerging Rootworm Problem Area has the second highest probability, with 8% of producers indicating that they have a major problem. The Potential Corn Rootworm Problem Area has the third highest probability, while in the Unaffected Area barely 1% of producers had a major problem with rootworms in first-year corn in 2000.

About half (51%) the respondents from the Severe Problem Area reported that rootworms were a minor problem in rotated corn acres. The percentages decrease across areas as the rootworm pressure becomes less severe. Forty-one percent of the farmers in the Emerging Problem Area had a problem with rootworms in first-year corn in 2000. The remaining two areas had 30% of the producers who reported a minor problem with rootworms.

In all, nearly two-thirds of the producers operating in the Severe Rootworm Problem Area reported a problem with rootworms in corn rotated after soybeans. Forty-nine percent of respondents from the Emerging Problem Area indicated that they had a problem in 2000 with rootworms. Thirty-five percent from the Potential Problem Area had a problem, while the lowest percentage of farmers who had a problem was located south of Interstate 70 (31%).

Management Response to the Corn Rootworm Variant

Because crop rotation is no longer an effective biological control measure in



many areas of Indiana, affected farmers appear to have increased their reliance on soil insecticides. This may pose a problem because the U.S. Environmental Protection Agency (EPA) may limit the use of some soil insecticides. The Food Quality Protection Act (FQPA) of 1996 requires the EPA to review the tolerances for pesticide residue in food. Organophosphates, the primary compound in several commonly applied soil insecticides, are currently under review.

A comparison of production characteristics among the four areas indicates that farm managers in Indiana now rely heavily on soil insecticides. In 1999, the Severe Problem Area had the highest proportion of rotated corn acres to total corn acres (94%) as well as the highest percentage of treated first-year corn acres (73%). The percentage of treated rotated corn acres in the Severe Problem Area increased to 77% in 2000. In 1999 and 2000, the Emerging and Potential Problem Areas had similar proportions of first-year corn acres to total corn acres, 87% and 88%, respectively. However, the Emerging Problem Area appears to have applied soil insecticides to a greater proportion of rotated corn acres than the Potential Problem Area in both years. In 1999, the difference is about 9-percentage points, with growers from the Emerging Problem Area treating 42% of first-year corn, and farmers from the Potential Problem Area treating 33%. In 2000, the gap narrowed to 5-percentage points.

The group of counties classified as the Unaffected Area had the smallest

percent of first-year corn acres (82%) in both years. As expected, this area also had the lowest percentage of first-year corn acres treated with insecticides in 1999 and 2000 (28%).

Survey results further reveal that in certain areas there has been a decrease in the number of farmers who use crop rotation as a management practice to control rootworms. The number of Severe and Emerging Problem Area producers who chose to alternate between corn and soybeans as a management practice to control rootworms has fallen since the early 1990's (Graph 1). There has been no change in the number of growers who alternate crops for rootworm management in the Potential Problem Area. However, in the Unaffected Area crop rotation has actually increased by 8% since the early 1990's.

Alternatives to Soil Insecticides

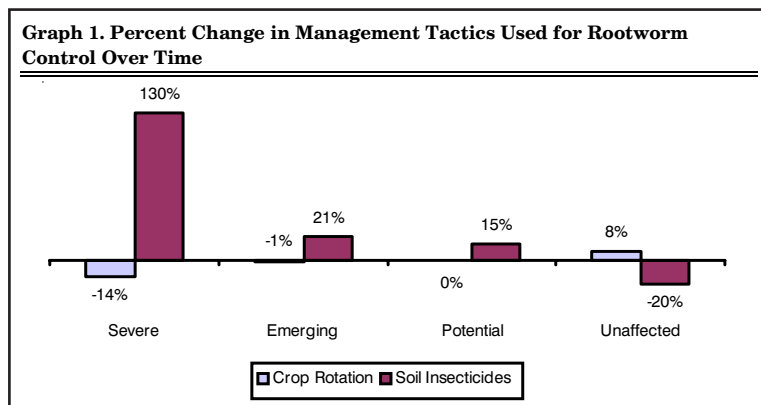
Given the recent failure of crop rotation, and the potential future restrictions on chemical controls used to manage corn rootworms, alternative control measures must be identified. The recent approval of transgenic corn resistant to rootworms is expected to offer producers affected by the corn rootworm variant a viable alternative management option.

In early 2003, Monsanto Company announced that it received registration approval from the EPA for its YieldGard rootworm resistant technology. Monsanto initiated the commercialization of the first transgenic corn designed to control the corn rootworm pest during the 2003 season (Monsanto 2003).

Bio-engineered corn can produce substantially higher yields in situations where there is heavy rootworm pressure (Caspers-Simmet, 2004). As long as costs to use transgenic corn are comparable to that of applying soil insecticides, the use of rootworm resistant corn may rival that of insecticides. Transgenic corn is also advantageous for farmers because of a decreased exposure to chemicals (Caspers-Simmet, 2004). In addition, the use of rootworm resistant corn reduces the amount of pesticides released into the environment (Caspers-Simmet, 2004).

In addition to transgenic corn, experimental programs such as Areawide Pest Management (AWPM) have been evaluated as an approach to rootworm control. AWPM programs involve integrating control tactics over many adjacent fields with similar crops and target pests with the goal of suppressing rootworm populations over time. A sixteen square mile site was established in 1996 located in Benton and Newton Counties in Indiana, and Iroquois County in Illinois. The site was a joint USDA-ARS/Land Grant University Research Project. The AWPM approach involves scouting and selective aerial spraying of neighboring fields with a semiochemical bait to suppress adult rootworm beetles and reduce egg laying.

Responses from the Indiana farmer survey indicate that collaborating with neighbors appears to be an acceptable option for about a third of the corn producers. About 37% and 31% of Severe and Emerging Problem Area producers expressed a willingness to collaborate with neighbors in an AWPM program (Graph 2). Slightly less than a third of Potential Problem and Unaffected Area producers (29%) reported that working with fellow producers is a feasible alternative to applying soil insecticides. A higher percentage was expected in the Severe Problem Area. This may reflect greater producer awareness of the USDA-ARS research to determine the feasibility and effectiveness of AWPM that was conducted in this region. These findings are similar to those obtained from a recent survey (2003) of AWPM



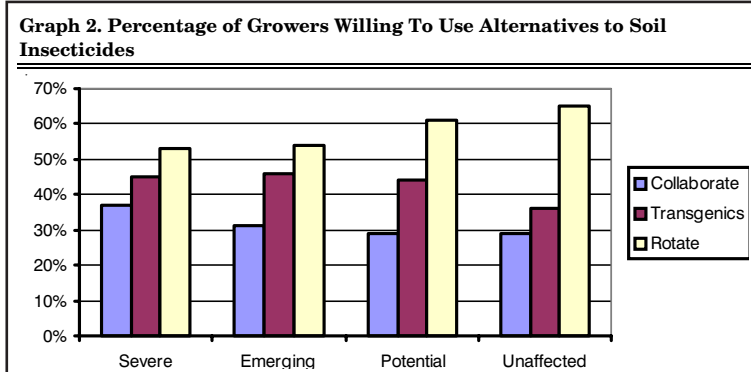
program participants (Howell, 2004). Survey responses from Howell's survey suggest that at most, about 18% of farmers in the Indiana/Illinois area would be willing to participate in an AWP program in the future.

More interest in transgenics exists among corn farmers in those counties impacted by the variant. Nearly half of the corn growers who operated in the three affected areas indicated that they would consider growing bio-engineered corn as a feasible option to soil insecticides (Graph 2). In Howell's 2003 survey of the Illinois/Indiana AWP participants, more than 90% expressed an interest in growing rootworm-resistant corn. Although there is no apparent variant problem in the Unaffected Area of the state, farmers there also are interested in growing bio-engineered corn. Thirty-six percent of growers located south of Interstate 70 expressed a willingness to use transgenic corn as an alternative to soil insecticides.

Many corn growers reported that they would be willing to rotate with another crop besides soybeans in an attempt to control rootworms. Fifty-three percent of Severe Problem Area growers favor rotation with a non-soybean crop as a feasible alternative (Graph 2). Results further indicate that as the variant problem becomes more severe across Indiana, interest in rotating with another crop increases. Fifty-four percent, 61%, and 65% of the Emerging, Potential, and Unaffected Area growers, respectively, expressed an interest in alternative crops to rotate with corn. In Southern Indiana, double cropping soybeans with wheat is common, and thus a higher interest in alternative crops is expected. However, in Northern Indiana, no other economically viable crop has been identified which can be rotated with corn on a large-scale basis. Hence, the challenge is to identify a profitable crop that can be rotated with corn and can biologically disrupt the corn rootworm life cycle.

Rootworm Management Information Sources

Producers were asked to identify their primary source of information



concerning corn rootworm management. Information sources included farm suppliers or chemical dealers, crop consultants or scouting services, news media and trade publications, the Internet, and extension educators and specialists. About three-fourths indicated farm suppliers or chemical dealers were the primary source of information on rootworm management. Other major information sources are producer associations and publications, Purdue extension specialists, and county extension educators (Table 1). There is relatively little difference in information sources across the four rootworm pressure areas.

Farmers located in the northern region of the state more often use Purdue University Extension Specialists than county educators as information sources on rootworm management. In contrast, Unaffected Area respondents are more likely to rely upon management suggestions from county educators. The probability of a Severe Problem Area respondent utilizing University extension resources is 37%, and the likelihood for an Emerging Problem Area producer is 31% (Table 1). Twenty-nine percent of Potential Problem Area producers get

information from Purdue University Extension educators, while only twenty-four percent of Unaffected Area respondents do the same.

Concluding Remarks

Corn growers operating in the northern portion of Indiana appear to be the most affected by the Western corn rootworm variant. More specifically, growers located along the Indiana/Illinois border appear to have experienced the greatest problems with adult rootworm variant beetles. To date, an increase in the application of soil insecticides has been the primary response. Indiana growers are interested in transgenic corn as well as to a very limited extent in an areawide approach to manage corn rootworms.

The results of this rootworm management survey have implications for extension specialists and educators as well as for input suppliers. Under EPA guidelines for the approved use of transgenic corn to control rootworms, farmers must plant a 20 percent refuge of non-YieldGard Rootworm corn adjacent to or within the YieldGard rootworm cornfield (Monsanto, 2004). Educational programs and materials

Table 1. Primary Information Source for Rootworm Management Recommendations^{1,2}

	Severe	Emerging	Potential	Unaffected
Farm Supply or Chemical Dealer	78%	74%	77%	76%
Producer Associations And Publications	33%	34%	34%	29%
County Extension Educator	26%	29%	25%	27%
Purdue University Extension Specialist	37%	31%	29%	24%

¹ By percent of area survey respondents.

² Respondents could check more than one category.

from extension educators and seed dealers are critical to ensure that farmers comply with EPA regulatory requirements.

Very few Indiana farmers have expressed an interest in adopting the areawide management approach to rootworm control (Harbor, 2002; Howell, 2004). Input suppliers and/or extension educators will need to provide considerable organizational leadership if the areawide approach is to be adopted by Indiana corn growers.

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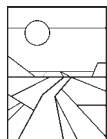
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