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ABSTRACT---

Organic farmers are dependent on alternative, biology-based insect control methods and are innovative in their on-farm experimentation with new strategies. By understanding the factors that influence the insect management portfolio chosen by organic farmers, research and education programs to promote sustainable insect management practices for all farmers may be devised. A negative binomial model of the factors influencing the number of alternative practices adopted is applied to survey data from American organic farmers. It is found that college-educated farmers with smaller acreages, more than half their acreage in horticultural production, and extensive experience with organic production have the greatest diversity in their insect management portfolios. There is a strong indication that on a regional basis, uncertainty over institutional and infrastructure support for organic agriculture results in the adoption of more strategies.

-----KEY WORDS-----

insect management, negative binomial model, organic farming, technology adoption

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Promoting Sustainable Insect Management Strategies: Learning from Organic Farmers

Introduction

A gap between exists in our understanding of the factors that influence adoption of alternative, biology-based insect management practices. In theory, farmers combine practices to optimize farm returns for their own particular economic and agronomic circumstances. In practice, American farmers do not always choose sustainable practices, even when they can improve their farm economic and environmental conditions by doing so.

Although many non-chemical options for plant protection exist, most have not been widely employed. Comer *et al.* (1999, pp. 30-31) noted that "despite economic and non-economic disadvantages of conventional agriculture, farms have been slow to adopt [sustainable agricultural] practices, and adoption appears to vary widely by region and crops." Magleby (1998) reported that certain "green practices" such as integrated pest management (IPM) are widely accepted by farmers, but other proven techniques, including biological methods, crop rotations, and cultural practices, are not.

Wilson and Tisdell (2000) theorized that farmers adopt pesticides as a defensive economic strategy, in the face of supply and price effects of short term yield improvements and cost reductions that accrue to early adopters. As the environmental consequences of a particular pesticide are realized, resistance in the target pest occurs and yields drop. At this stage, the natural insect ecology is so disrupted that a switch to a biological management-oriented method is more costly than if it had been adopted in the first place. Natural insect control methods are more sustainable than synthetic chemical controls along several dimensions, including minimizing non-renewable inputs, maximizing natural biological processes, and promoting local biodiversity

(Rigby *et al.*, 2001) as well as generating greater risk-adjusted average net returns (Mahoney *et al.*, 2001).

Organic farmers typically have a well-defined set of entrepreneurial goals, leading Duram (1999) to comment on the propensity of organic farmers to adopt and develop new production and management methods. In its 1997 national survey of American organic farmers, the Organic Farming Research Foundation (OFRF) found that 87% of 1,192 respondents had conducted their own on-farm experiments, of which 33% experimented with pest management systems (Walz, 1999). Observation of and experimentation on their own farms and information gathered from books, other farmers, and researchers were reported by more than 70% of respondents to be very important elements in shaping their personal knowledge base (Walz, 1999).

Contrast this spirit of innovation with the cautiousness of conventional farmers. From a review of USDA input use and management surveys, Magleby (1998) concluded that techniques that rely primarily on knowledgeable producers and management expertise are less likely to be adopted than chemical methods, even if they reduce direct costs to the farmer. The majority of farmers still rely on pesticides for insect control. Organic farmers represent the most informed group to study regarding the reasons for adoption because they have the greatest awareness of alternative practices. By understanding the factors that influence the insect management portfolio chosen by organic farmers, we may better inform the research and outreach design process to assist all farmers in becoming more sustainable.

Our study documents which insect management practices organic farmers have found most cost-effective. We modeled the factors that influence the adoption of insect management practices by organic farmers, and used statistical analysis to identify the key elements in the management portfolio decision. Unique to our model is the accounting of intensity of management, measured by the number of alternative practices selected. The data are from the only national survey of American organic farmers and represent a cross-section of crops, production regions, management status, and farm sizes. The results reveal underlying factors in the insect management decision that are not observable from the summary data alone, and suggest ways to design research and education programs to improve agricultural sustainability.

Modeling Intensity of Adoption

Management decision making has long been a subject of agricultural economics research, although why specific combinations of practices are selected has been little examined. Previous studies described the adoption decision as a dichotomous choice - the technology or set of technologies was either adopted or not. For the most part, individual management practices were aggregated prior to analysis, so that the level of commitment to alternative practices could be determined. As a consequence, these models simply explained whether a farmer adopted alternative practices, neglecting the intensity and diversity of practices that were employed.

Fernandez-Cornejo *et al.* (1994) evaluated adoption of IPM practices by vegetable producers in three states. A farmer was classified as an IPM adopter if the grower used *any* of the techniques listed in the survey, including scouting for pest damage, use of parasites, biochemicals or microbial agents, and cultural practices such as crop rotations. The study explained the IPM adoption decision on this aggregate dichotomous (yes-no) variable, overlooking the significance of the number and types of practices chosen to the level of commitment to IPM.

In an extension of the dichotomous adoption variable, Fernandez-Cornejo *et al.* (2001) used the percentage of acreage on which genetically engineered crops and precision agriculture technologies were applied as a measure of intensity of adoption. This approach allowed the effect of independent variables on the adoption decision to be interpreted as increasing or decreasing the number of adopters and the proportion of acreage under adoption. However, the adoption variable was still predicated on a yes-no decision, constructed by multiplying one (yes) or zero (no) by the share of acreage, and did not capture the diversity of options inherent in multi-practice technologies such as IPM, soil conservation, and precision agriculture.

When evaluating conventional farmer decisions, as both the cited studies did, it is perhaps sufficient to test whether a farmer adopts *any* alternative practice, not *how many* practices are used. As Magleby (1998) noted, at most 7% of conventional vegetable growers used biological control methods of any type before 1995. In the same period, up to 75% of organic vegetable growers used at least one biological control practice. Thus, in examining the insect management decisions of organic growers, failure to quantify the intensity of adoption, measured by types or numbers of strategies implemented, obscures the differences among farmers.

Refining the decision variable to measure intensity of adoption permits the decomposition of the group of all organic farmers into sufficiently small subgroups to identify factors that explain why fewer or more practices are implemented. After estimating separate adoption models for each of ten soil and nutrient management practices, Soule (2001) concluded that the *number* of adopted practices is the appropriate decision variable to assess how farmers choose a suite of complementary practices. We selected this approach as the best measure of intensity of adoption for a portfolio of management strategies.

Conceptual Framework

The farmer's decision to adopt an insect management technique is based on a comparison of the farm profits associated with each practice. Following Feather and Amacher (1994), let each farming practice employ a set of inputs X_i. Farmers face an output price P and input costs

w. Input requirements for the i^{th} practice are X_i with resulting output $f_i(X_i)$. Initial fixed capital investment costs, C_i, unique to the adoption decision may also be incurred. The profit function π_i for the i^{th} practice is defined as

$$\pi_i(X_i) = Pf_i(X_i) - wX_i - C_i \quad . \qquad \textbf{(1}$$

If the profit from using the i^{th} practice exceeds that of the benchmark set of current practices, π_0, so that $\pi_i(X_i) \geq \pi_0$, then the insect management practice is adopted. A farmer assesses each practice in this way to construct a portfolio of strategies that makes up the management system. Embedded in the profit analysis is the cost-effectiveness of each strategy in terms of insect control, so that the practices should be complementary to each other. The farmer selects the best package of practices for the specific economic and agronomic conditions faced. This context is further defined by both farm level and regional variables that describe the conditions the farm faces. The influence of these variables must be understood to develop effective research and education programs on alternative insect management strategies.

We constructed a model to describe the effects of farm level and regional variables on the alternative insect management decision. We estimated the model using an econometric regression technique appropriate to the definition of the dependent variable as the intensity of adoption, measured by the number, or "count," of alternative practices adopted. The resulting "count data" regression model was

$$\ln(NumAdopt_{ij}) = \beta_0 + \beta_1 F_{ij} + \beta_2 R_j + \epsilon_{ij} \qquad \textbf{(2)}$$

where $NumAdopt_{ij}$ measures the number of insect management techniques by farmer i in region j, F_{ij} is a vector of relevant farm level variables, and R_j is a vector representing the regional characteristics. The model in equation (2) was estimated using a negative binomial regression recognizing that the number of adopted management strategies was recorded as count or integer data (Greene, 2000).

Information accessibility is of particular importance in the adoption of alternative insect management strategies. As Padel and Lampkin (1994) pointed out, direct costs of information and experience gathering constitute major barriers to organic conversion. In the absence of widely available technical information, organic farmers must exert effort to identify information sources, obtain the information, and then test it for the farm conditions they face. Farmers might use a single source intensively or obtain information from a variety of sources. Adequacy of technical and economic advice on conversion reduces the risk of financially or environmentally costly management errors. In the context of this model, information variables were included in the vector of farm specific variables.

Data Description

Only two organizations have conducted national surveys of the practices used by American organic farmers - the USDA's National Agricultural Statistics Service (NASS) and the OFRF. Analysis on a scale broad enough to be generalizable must draw from one of these two data sets. However, there are limitations associated with each.

NASS surveys on farm chemical use were the first to collect data on organic producers, beginning with the 1994 Vegetable Chemical Use Survey. These surveys offer important insights into pest management strategies and information sources for horticultural growers. However, the surveys are conducted biannually (fruits-nuts and vegetables in alternate years) only in the top conventional vegetable and fruit producing states, which may not represent the top organic producing states (Fernandez-Cornejo *et al.*, 1996).

For example, the 1994 Vegetable Chemical Use Survey was conducted in 14 states, of which 13 had organic growers. Of these, only two of the states with the most respondents to the survey (California and Oregon) also had the most organic acreage in vegetables (Greene, 2001). In all, 43 states grow certified organic vegetables, compared with the 14 surveyed by NASS. Of more than 1,500 organic vegetable growers, the NASS survey obtained responses from only 303 (Fernandez-Cornejo *et al.*, 1996). Through redesign the surveys will refine the questions on organic farms, but currently available data were not sufficiently representative to test the adoption model in equation (2).

The OFRF is a private not-for-profit organization that supports and conducts research on organic production systems and public policy. Since 1993, the OFRF has conducted biannual surveys of organic farmers in the U.S., each year increasing its sample base until, in its 1997 survey, the entire U.S. certified organic farm population was surveyed. The 1997 OFRF survey was based on grower lists maintained by organic certification organizations and was designed by a committee of nationally recognized organic practitioners, extensionists, researchers, and government specialists. The stated purpose was to "...provide the most comprehensive picture currently available about the state of organic farming in the United States, *from the organic farmer's perspective*" (Walz, 1999, p. 1). Thus, the OFRF survey set out to deliberately create a census of organic growers, rather than to construct a representative sample.

Comprehensive data on production and marketing practices of organic farmers were gathered, as well as details of production and marketing problems, information sources, and demographic information (Walz, 1999). The data represent all crops grown organically, and all regions in which organic production is conducted. Of the 1,192 surveys returned to the OFRF (26% response rate), sufficient detail was provided in 1,027 responses to test the model. The data were obtained by special agreement with the OFRF as part of a project to assess the U.S. organic sector.

The limitations of the OFRF survey are similar to those found in the NASS results, but less severe. The survey coordinator noted proportionately fewer responses from high income (over $500,000) and Southern farmers, although it is not clear whether this was due to response bias or simply the structure of the organic production sector. Of 49 states with organic producers in 1997, 44 states were represented in the OFRF survey (Greene, 2001; Walz, 1999). No organic farmers from Alaska, Arkansas, Delaware, Mississippi, Nevada, nor Wyoming responded to the OFRF survey, although these states represented only 1,492 acres, or 0.18% of the total 850,177 certified organic cropland acres in 1997 (Walz, 1999; Greene 2001). Thus, the OFRF data were more representative than the NASS survey results and were deemed to be suitable for testing the insect management adoption model.

The Dependent Variable

In constructing the dependent variable, the adoption of practices, we relied on responses to the question “Which of the following insect pest management strategies and materials do you use, and how frequently?”(see Question 5.3, Walz, 1999, p. 80). The OFRF survey listed a portfolio of 11 strategies or techniques for managing insect pests and the surveyed farmers indicated how frequently they used the strategy by selecting from among four categories. Frequency of use could be checked as “never” use, use “rarely or as a last resort,” use “on occasion” or “frequently or regularly” use.

We coded as “adopters” organic farmers who used a given technique on an occasional or regular basis, while farmers who rarely or never used that strategy were coded as “nonadopters." For each of the 11 strategies, a farmer was either an adopter or non-adopter, and could be an adopter for some and a non-adopter for others.

Figure 1 shows the rate of adoption for the 11 alternative management techniques of the 1,027 farmers in the sample used in this study. The top three pest control strategies adopted by organic farmers were crop rotations (74%), development of beneficial insect habitat (48%), and *Bacillus thuringiensis* (Bt) treatments (39%). The evenness and scale of the percentages of adopters across the remaining categories (more than 20% for all but two strategies) is an indicator of the need to combine management practices when synthetic chemicals are eliminated.

Contrast these percentages with adoption of alternative control methods by conventional farmers. Nearly all conventionally grown field crops in the US use crop rotations for pest control, ranging from 33% of cotton acreage to 89% of soybean acreage in 1996 (Anderson *et al.*, 2000). However, the other alternatives used by organic farmers, such as Bt application, release of beneficial insects, diseases or nematodes, and use of pheromones or mating disruptors were applied on less than 5% of conventional field crop acreage and less than 50% of conventional vegetable and fruit acreage. Adoption rates by conventional farmers are negatively influenced by the availability of chemical alternatives, which argues for examining organic farmers' practices in evaluating the most useful alternatives to chemical insect controls for all farmers.

Table 1 shows the variable descriptions and summary statistics for the dependent and independent variables estimated for equation (2). To quantify the intensity of adoption, we recorded the number of management strategies adopted by each organic farmer. Of the eleven strategies, the 1,027 farmers in the sample adopted an average of 3.29 different techniques. The least number of strategies adopted by any grower was zero and the most was 10.

Figure 2 shows the number of practices adopted by the percentage of farmers in each group. The largest percentage of farmers (22%) used only one practice from the list, but the second largest percentage (14%) used four strategies. Slightly more than 30% adopted five or more practices. Those 9% who were classified as nonadopters in our study used the listed techniques "rarely or as a last resort" or "never." This does not imply that some organic farmers have no insect management strategies. Not all possible management strategies were included in the OFRF survey list. For example, water management, planting resistant varieties, adjusting planting dates, mulch tillage, and mechanical controls help control insect problems but are adopted primarily for other purposes such as weed management.

The Independent Variables

Constrained by legal requirements for organic certification, lack of technical information on alternative practices, and the risk of yield loss if the agro-ecological balance is upset, organic farmers must be even more cautious than conventional farmers in selecting their management complement. Information is the key to successful organic farming. Thus, the portfolio adoption model had to reflect the organizational, financial, and demographic factors that affect information collection and experimentation, as well as describing information availability.

Table 1 describes the variables as well as the question from the OFRF survey results in Walz (1999) that corresponds to each variable. The OFRF report gives details of the questions asked, the response categories offered, and the response rates for the entire OFRF sample. We used a subset of this total sample. The first 10 variables on Table 1 comprise the farm level effects given by F_{ij} in equation (2) and the final four account for regional effects contained in $R_{j.}$

The first two explanatory variables on Table 1, SoleProp and Corporat are suggestive of the flexibility accorded the farmer in making management decisions. Sole proprietorships bestow the greatest share of management power to the farmer because they involve the least number of other decision makers. Corporations offer the least flexibility and the most demanding fiscal requirements. In our sample, 72% of farms were sole proprietorships and 6% were corporations. In the U.S. as a whole, proprietorships compose about 90% of all farms, and partnerships make up from 5% to 6% (Hoppe *et al.*, 2001). Other structures that were grouped together as being of intermediate flexibility included partnerships, cooperatives, and property management firms. To avoid a dummy variable trap, this group was omitted from the regression estimation.

Factors that might predispose a farmer to greater knowledge about the farm ecology and the suitability of a new practice for the production system include time spent on the farm and experience with organic farming. Educational attainment could be important in that higher educated farmers typically are aware of and seek out more information sources. A college degree in an agricultural science would be helpful in interpreting technical production advice.

About 37% of the producers in our sample were engaged in farming on a full time basis (FullTime), compared with 39% of all U.S. farmers (Hoppe *et al.*, 2001). Experience in organic farming averaged 10 years (YrsOrg), although a few farmers reported no previous experience. With experience ranging up to 70 years, farmers' ability to match practices to the specific agro-ecosystem should exhibit significant variability in this sample. About 59% completed a college degree or attained a higher educational level (Educ), much higher than the national average of 19% for all U.S. farmers (Hoppe *et al.*, 2001). Of the organic farmers who specified a major field of study, 36% listed agricultural-related disciplines. The information on major was not included in the model due to inconsistencies in reporting this response.

A scale effect for farm size is likely to hold, in that larger farms have streamlined their enterprises to minimize production costs and numbers of cropping practices. In this sample, the smallest farm was 0.125 acre, the largest was 6,000 acres, and the mean farm size was 137 acres (OrgAcre). The average amount of land operated per farm unit nationally in 1998 was 453 acres for all types of farms, but the average of owned land operated was 262 acres (Hoppe *et al.*, 2001).

High gross incomes might be expected to support more practices because revenues are sufficient to offset the financial risk of experimentation with multiple practices. The twelve response categories for total gross organic farming income provided by OFRF (see Question 8.8, Walz, 1999, p. 103) were combined into five classes for more meaningful comparison with USDA definitions of farm structure (Hoppe *et al.*, 2001) and requirements of the National Organic Program Final Rules.

About 25% of the OFRF respondents in our sample made less than $5,000, the threshold income at which a farmer is required to certify the production system. Another 22% received between $5,000 and $14,999 from organic farming. The USDA's lowest sales class is for less than $10,000, and is comprised of 52% of all U.S. farms. In our sample, 37% of respondents grossed between $15,000 and $99,999, comparable to the USDA's "low sales" small farms (sales from $10,000 to $99,999) making up 30% of all U.S. farms. "High sales" small farms are defined by the USDA as earning between $100,000 and $249,999, a group constituting 9% of our sample and 9% of all U.S. farms. About 7% of our sample and 8% of all U.S. farms grossed at least $250,000, sufficient to qualify as "large farms" by the USDA definition.

Although not treated separately in this study, the percentage of farms falling into the category of "very large farms" (sales at least $500,000) is 3% in both our sample and for all U.S. farms. This indicates not only that the organic sample has an income distribution remarkably similar to all U.S. farms, but also that the structure of organic agriculture is as complex as that of the conventional farming sector. Organic production is not just a small farm alternative.

The income variable (OrgInc) has a mean value of 2.30, which means that the average farm income, weighted by the shares in each of the five income classes used, is between $5,000 and $99,999. This places the average organic farmer in the sample into the USDA "low sales" class, the same as for the majority of conventional U.S. farmers.

Insect regimes and management responses depend largely on the types of crops grown. Higher valued crops are worth more effort and expense to protect. Greater diversity in enterprise mix could require a broader portfolio of strategies to protect all the crops. With the exception of crop rotations, the alternative practices described in this study were used far more extensively in conventional agriculture by fruit, nut, and vegetable producers than by field crop producers in the early to mid-1990s (Anderson *et al.*, 2000). For example, foliar applications of Bt were used on 1% of corn and 2% of cotton acreage in 1997, compared with 16% of apple and 11% of grape acreage in 1997, and 33% of head lettuce and 64% of fresh tomato acreage in 1996. It is reasonable to assume that similar differences hold with organic crops.

The variable PctHort was constructed to capture this difference in the model. Total acreage in vegetables, including herbs, flowers, and ornamentals, fruits, nuts, and tree crops was divided by the total organic acreage to obtain the share of acreage per farm in horticultural crops. The mean share of horticultural acreage (PctHort) was 52%, with both 0% (no horticultural crops) and 100% (all acreage in horticultural crops) represented in the sample.

Kalirajan and Shand (2001) suggested that a main constraint in achieving technical efficiency in agricultural production is the lack of information about the "best management practices." With limited information farmers benefit from gradual "learning by doing" in adopting new production and management methods. Thus, information sources that are closest or most familiar to the farmer should have the most influence on adoption patterns.

Information about organic production methods may be classified along two dimensions: the personnel or organizations that provide expertise and the media sources or outlets that are accessed by producers. The OFRF survey provided a list of 12 personal information sources and 9 information outlets and asked respondents to indicate the usefulness of each and the frequency of use (see Question 2.2, Walz, 1999, p. 38). Since we were most interested in the effort required to obtain information, we constructed variables that counted the number of personal sources contacted (NumWho) and the number of information outlets used (NumWhat). We assumed that the more sources that were required to obtain the information needed to develop the insect management portfolio, the more effort was being expended. The average number of personal contacts in our sample (NumWho) was 5.4, with a low of 0 and a high of 12. The mean number of outlets used (NumWhat) was 3.5, with a low of 0 and a high of 9.

The OFRF list was more disaggregated than the list of five personal contacts and three outlets that the USDA provides in its national surveys. For example, in the USDA surveys, “extension advisors” are the only public information source, while the OFRF survey lists “university-based researchers,” “cooperative extension advisor(s),” “state agriculture departments,” “USDA national or regional office(s),” and “other government agencies (ATTRA, etc.).” Despite this, it is clear that conventional and organic farmers rely on different sources of information.

Conventional growers overwhelmingly choose the farm supply or chemical dealer as the main personal source of information on pest management for most crops (Anderson *et al.*, 2000). Professional scouting services (fruit and vegetables) or crop consultants (field crops) and extension advisors are the second most used among conventional producers. Other farmers and producers are the least likely personal information sources for conventional growers, but the primary sources for the organic farmers in our sample. Of secondary importance for the organic growers were other private sources (field consultants, input suppliers, organic certifiers, and buyers). Organic farmers rated the extension service very low in terms of average frequency of use and moderately in terms of usefulness of information.

Conventional growers use print and electronic media very little for pest management information (Anderson *et al.*, 2000). Organic farmers are reliant on information sources such as farm and gardening periodicals and books, conferences and seminars, on-farm demonstrations, videos, internet websites, email groups, radio, and television, of which books and conferences are most intensively used. Organic growers used media outlets nearly twice as frequently as personal contacts, and found outlets about equally useful as personal contacts (Walz, 1999).

There are several sources of variation in insect management strategies that are detectable at the regional level, including climate, insect regimes, crop production practices, regulatory environment, and support infrastructure. The USDA classifies regional distinctions strictly in terms of production and resource differences, giving rise to nine Resource Regions.

Since we wanted to assess institutional support and information availability for alternative insect management practices, we used the four USDA Sustainable Agriculture Research and Education (SARE) regions (see http://www.sare.org/htdocs/sare/about.html for a listing of states in each region). These regions reflect the federal government’s demarcation for sustainable agriculture extension-research support, which we hoped to proxy in the model. A dichotomous variable was created for each region, equal to one if the respondent’s farm was in that region, and zero otherwise. In our sample, 35% of farmers were in the SARE 1 region (West), 32% in the

SARE 2 region (NorthCent), 8% in the SARE 3 region (South), and 25% in the SARE 4 region (Northeast).

Results

Coefficient estimates and asymptotic standard errors for the count data model for insect management portfolio adoption are presented on Table 2. The marginal effects presented were calculated following an adaption by Brännäs (1992) for the negative binomial model used in estimation. The marginal effects show the responsiveness of the dependent variable to changes in the specific independent variable, so that the effect is to either increase or decrease the mean number of practices. All marginal effects were determined for the “average” farmer in the sample, defined by the mean values for all variables.

The variance parameter, α, is included on Table 2 to confirm the appropriateness of the negative binomial distribution as the choice for the regression model. Based on the auxiliary regression tests proposed by Cameron and Trivedi (1990), we rejected the null hypothesis of equality between the conditional mean and the variance of the dependent variable at the 5-percent critical z-value. Rejecting this null hypothesis of no overdispersion supports the choice of the negative binomial model.

Neither of the business structure variables (SoleProp, Corporat) significantly affected the choice of how many practices to adopt. This suggests that farmers choose the practices without undue outside influence from corporate partners. Of the education and experience variables, the estimated coefficient for FullTime was not significant. There is no difference between full time and part time farmers in the number of practices in the portfolio, indicating that part time farmers are not less informed about farm agroecology than are full time farmers.

The coefficients for YrsOrg and Educ were both positive and significant. Greater experience and higher formal educational attainment both lead to more practices being adopted. Farmers with these attributes are more likely to be able to manage a wider portfolio of practices and to be open to and even aggressive in learning about new strategies. These results are consistent with findings by Lohr *et al.* (1998) who showed that among 1,124 conventional farmers in the Midwest, more experienced, better educated farmers were willing to accept greater yield losses to avoid environmental risks from insecticides. Lohr *et al.* (1998) found that more experience and education confer the necessary skills and knowledge to creatively adjust insect management strategies to compensate for reduction in chemical applications. More pointedly, Fernandez-Cornejo *et al.* (2001) identified education and experience of conventional corn and soybean farmers as significant factors in the adoption of specific technologies requiring greater managerial skills, particularly information collection and interpretation.

College education has a much greater influence on the number of strategies adopted than does organic farming experience. The marginal effect of YrsOrg predicts that for each ten-year increase in organic farming experience above the mean of 10.19 years, the average number of practices will increase by 0.2 practice, from 3.3 to 3.5. practices. This means that 205 farmers in our sample of 1,027 would adopt an additional practice if the group's average farming experience were 20 years instead of 10 years. For each 10% increase in the probability of having completed a college degree (Educ) compared with the mean of 59%, there is an increase of 3.5 practices in the portfolio, raising the average to 6.8. In other words, if 69% of the farmers had a college degree, all 1,027 farmers in the sample would add at least three more practices, and 513 farmers would add four practices.

The farm size coefficient (OrgAcre) was negative and significant. This means that smaller farms are more likely to adopt a more diverse set of alternative insect management practices, a finding that is not typically observed in adoption models. In a review of studies on conventional vegetable farming, Hrubovcak *et al.* (1999) concluded that larger farms were more likely to use IPM, on the theory that such technologies required more intensive management and that the needed skills and time were more readily available on larger farms. However, the only alternative insect management practice actually used by most conventional farms, whether small or large, is crop rotation, limiting this finding of positive scale effects to this one practice (Anderson *et al.* 2000). Upon decomposing the positive effect of size on adoption of precision agriculture and herbicide-tolerant corn, Fernandez-Cornejo *et al.* (2001) found that factors related to the fixed costs of the technology, rather than size *per se* were the determinants of adoption.

Most of the alternative insect management strategies in the OFRF list require intensive monitoring and management to be successful, which would be easier to do on smaller farms. Most of the practices do not require large fixed investments nor changes in land allocation, so costs are not disproportionately high for small farms. Since the same type of monitoring is required to judge the performance of and make adjustments to several of the alternatives, there are lower marginal costs for certain combinations of practices and larger size is not an advantage.

The marginal effect of OrgAcre predicts that if organic farms on average increased to 237.1 acres, close to the national average farm size of 262 owned acres, the mean number of insect management practices would decrease by 0.06. This represents 62 farmers in the sample of 1,027 reducing their insect management portfolio by one practice if the average organic farm size increased by 100 acres.

The income variable (OrgInc) had no effect on the selection of the insect management portfolio. This is consistent with results for conventional farm technology adoption for soil conservation practices (Soule, 2001) and for genetically engineered crops and precision agriculture (Fernandez-Cornejo *et al.*, 2001). This means that rising or falling organic farm income does not cause the manager to select a different number of insect management strategies.

The coefficient for PctHort was significant and positive, indicating that horticultural farmers employ more insect management strategies. This is consistent with findings for conventional agriculture (Fernandez-Cornejo *et al.*, 1994; Anderson *et al.*, 2000). The marginal effect for PctHort predicts that increasing the share of horticultural crops on the average farm by 10% to 62% would increase the mean number of practices by 7, from 3 to 10. Even a 1% increase in horticultural acreage share would raise the number of practices to an average of 4. The strength of this effect is not surprising since horticultural enterprises can greatly increase the management requirements on the entire farm. Greater crop diversity implies greater complexity of insect regimes and a management response of a broader portfolio of control strategies.

Since most fruit is produced by perennial crops and most vegetable production is from annuals, it might be argued that a difference should exist in the number of insect management strategies used. We tested whether this was true by estimating the count model in equation (2) with separate coefficients for share of production in vegetables (including herbs, flowers and ornamentals) and share in fruit, nut and tree crop production. Based on a Wald test of equal slope coefficients, the number of practices used was not influenced differently by the two categories. Acreage allocated to either (or both) vegetable and fruit/nut/tree crop production is significantly positively related to the number of strategies in the insect management portfolio.

Both information measures, NumWho and NumWhat, were positive and statistically significant, meaning that greater diversity of information sources resulted in a broader portfolio of insect management strategies. A Wald test of the regression coefficients failed to show a statistical difference between the effects of these two variables on the number of practices adopted, which was consistent with the finding that both types of sources are equally useful to farmers (Walz, 1999). The marginal effect of media outlets was about twice that of personal contacts, consistent with the relative frequency of use for the two categories reported by Walz (1999). For each additional personal contact consulted, the marginal effect predicts 82 farmers in our sample of 1,027 would add a practice, whereas if an additional media outlet is used, 174 farmers would add another practice.

The regional effects were significant for two of the four SARE regions, positive for the South and negative for the North Central regions. According to the marginal effects, if the share of all organic farms located in the Southern SARE region increased by 10%, the national average number of practices would rise by 1.9. If the share of farms in the North Central region rose by 10%, the national average number of practices would decline by 2.7. In the South region, 48% of farmers use at least 5 practices, while in the North Central region, 64% use at most 2 practices.

Cropping system diversity is the most obvious reason for this difference. To the extent that horticultural production is more diversified (more different crops per farm) and requires more insect management practices in the portfolio, regional variation in cropping system could account for the observed result. We defined a horticultural producer as having more than 50% of farm acreage in fruit, nut, and vegetable production, and a field crop producer as having less than 50% in these crops. In our sample, 63% of farms in the South region were primarily horticultural producers whereas in the North Central region, only 18% were. Thus, Southern adoption rates might reflect the larger share of horticultural producers among organic farmers.

Regional differences may also be apparent in support for alternative practices. There is a common perception that Southern states are less likely to offer institutional and infrastructure support for organic farming. Problems obtaining information about production practices and obtaining or properly using inputs may cause a grower to adopt more practices to offset the uncertainty caused by lack of information.

The OFRF survey asked respondents to indicate the degree to which 10 specified constraints inhibited production, using a scale from 1 (“not a constraint or problem”) to 5 (“serious constraint or problem”) (see Question 6.3, Walz, 1999, p. 91). Comparing the percentages of farmers in the South and North Central regions who rated each constraint a 4 or 5, we found that Southern farmers were more likely to perceive infrastructure and institutional problems as serious barriers.

The OFRF data revealed the top three problems in both regions to be the same, but the percentage listing the problem as serious diverged significantly. The top problem, “uncooperative or uninformed extension agents” was listed as serious by 80% of Southern respondents compared with 54% of North Central respondents. The next three most important problems showed smaller disparities in ratings as serious constraints, but always more Southern farmers rated the problem as serious. These problem were “distance or transport of allowable organic inputs” (64% of respondents in the South region vs. 51% in the North Central region), “cost of allowable organic inputs” (61% vs.47%), and “sourcing or finding allowable organic inputs” (51% vs. 40%).

The much stronger perception of institutional and infrastructure constraints in the South is correlated with the adoption of a greater number of insect management strategies. The opposite effect results for the North Central region. Greater confidence in the ability to obtain information and inputs reduces the need to broaden the insect management portfolio.

Implications of the Results

Taken as a whole, college-educated farmers with smaller acreages, more than half their acreage in horticultural production, and extensive experience with organic production methods have the greatest diversity in their insect management portfolios. There is a strong possibility that on a regional basis, uncertainty over institutional and infrastructure support for organic agriculture results in adoption of more insect control strategies.

The strongest influence on the number of practices adopted is the percentage of horticultural acreage farmed, a result echoed in the regional effects. As more organic farmers attempt to increase direct access to local food markets, the average share of horticultural acreage will increase because these markets demand mainly fresh produce. Nationally, about 22% (188,417 acres) of all certified organic cropland in 1997 was in horticultural crops (Greene, 2001). If horticultural acreage increases by only 1%, or 1,884 acres, other cropland being held constant, this would increase the number of alternative practices used to an average of 4 per farm.

Since direct marketing of fruits and vegetables is the most likely entry point for new organic farmers, and since addition of horticultural acreage is a way to rapidly add crop and income diversification, a 1% increase is likely an underestimate of the projected change in horticultural share. Not only do we expect current horticultural farms to get larger, but more farmers will grow horticultural products, up from the current share of 57% of all organic farmers.

The educational attainment of organic farmers also influences their adoption of alternative insect management strategies. Degree major notwithstanding, a college degree is an indicator of ability or interest in pursuing nonexperiential information, such as is required in identifying and obtaining information on organic farming. A 10% increase in the percentage of college educated organic farmers results in the adoption of 3 more practices, on average.

Although the U.S. farming population as a whole is becoming better educated as younger generation farmers pursue formal education before taking over family operations, it is unlikely that such a dramatic increase will be seen. However, if information on organic production systems becomes as widely available and as easily accessible in multiple formats as is conventional production advice, we would expect to see the education variable lose its significance. Under such circumstances, it would not be necessary to be highly motivated and well versed in research methods in order to find and effectively use needed information.

With increasing experience in organic production, farmers choose more insect control strategies, averaging 0.2 more practices for each 10 years of experience. Ways to gain needed experience in organic production include serving internships or apprenticeships under experienced farmers, participating in mentoring programs that pair more and less experienced farmers, participating in own-farm field research or hands on organic short courses, and otherwise adding intensive training that speeds the ascent up the learning curve. Retaining organic farmers long enough for them to obtain the necessary experience to develop successful management practices would deepen the national pool of organic-specific knowledge that will serve future beginning and transitional farmers.

Extrapolated to all 4,638 organic farmers surveyed by OFRF in 1997, the effects of information variables suggest that if one more personal contact was used, 370 more farmers would add another insect management practice to their portfolio. If one more media outlet was used, 785 more farmers would adopt an additional practice.

We expect there would be more adopters if all farmers had equal access to all the personal and media sources listed. Currently, university-based researchers, extensionists, and government agency representatives specializing in organic agriculture are more available to organic farmers in some states than others, California being a notable example. Certain of the media outlets, such as internet websites and email groups, require specialized training and equipment to use successfully.

Relevance of these results to the total population of all farmers depends on sample representativeness. From the previous discussion, the sample of organic farmers in this study is highly representative of all U.S. farmers, with the exception of educational attainment. However, among early adopters of all types of organic and conventional technology, a high percentage of farmers has completed some formal education beyond high school. Thus, the results here are representative of adopters. The most resounding conclusion is that a broader portfolio of alternative insect management practices would be adopted by organic and conventional farmers, particularly horticultural producers, if reliable information were available and accessible.

It would be well for public research and educational institutions to prepare for the growing insect management information needs in both the organic and conventional communities. Current government and private programs that support farmer information exchanges and set up farmer mentoring programs should actively recruit participation by organic farmers. The readiness of organic farmers to explore new practices should be exploited by providing more funds for farmer driven organic research, with active participation by university researchers and extensionists to validate the outcomes and deliver results to broader populations.

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Table 1. Variable descriptions and summary statistics

Variable	Description	Mean	Standard Deviation	Survey Question[a]
NumAdopt	Number of adopted insect management strategies, sum of practices, from 0 to 11	3.29	2.32	5.3
SoleProp	Farm is a sole proprietorship, 1 if yes	0.72	0.45	8.2
Corporat	Farm is a corporation, 1 if yes	0.06	0.24	8.2
FullTime	Operator is full time farmer, 1 if yes	0.37	0.48	8.3
YrsOrg	Years as an organic farmer, from 0 to 70 years	10.19	8.18	8.10
Educ	Education, 1 if completed college or higher	0.59	0.49	8.14
OrgAcre	Acreage farmed organically, from 0.125 to 6,000 acres	137.15	382.58	8.6a
OrgIncm	Total gross organic farming income, integer variables for 5 categories	2.50	1.16	8.8
	Share of all farmers by income category			
	1 if less than $5,000	0.25		
	2 if $5,000 to $14,999	0.22		
	3 if $15,000 to $99,999	0.37		
	4 if $100,000 to $249,999	0.09		
	5 if at least $250,000	0.07		
PctHort	Share of total organic acreage in horticultural crops, calculated	0.52	0.46	3.1, 3.2, 8.6a
NumWho	Number of personal information sources contacted, sum of contacts, from 0 to 12	5.4	2.9	2.2a
NumWhat	Number of secondary information outlets used, sum of outlets, from 0 to 9	3.5	2.2	2.2b
West	Farm is in SARE Region 1, 1 if yes	0.35	0.47	8.12
NorthCent	Farm is in SARE Region 2, 1 if yes	0.32	0.47	8.12
South	Farm is in SARE Region 3, 1 if yes	0.08	0.27	8.12
Northeast	Farm is in SARE Region 4, 1 if yes	0.25	0.25	8.12

[a] The question number in Walz (1999) corresponding to each variable.

Table 2. Regression coefficients and marginal effects from the adoption model with 1,027 observations.

Variable	Coefficient	Marginal Effect
SoleProp	-0.026	-0.084
	(-0.47)	(-0.45)
Corporat	-0.135	-0.444
	(-1.28)	(-1.22)
FullTime	-0.038	-0.124
	(-0.75)	(-0.71)
YrsOrg	0.007*	0.023*
	(2.48)	(2.30)
Educ	0.106*	0.348*
	(2.32)	(2.17)
OrgAcre	-0.0002*	-0.0006*
	(-3.10)	(-2.83)
OrgInc	0.011	0.035
	(0.46)	(0.44)
PctHort	0.229*	0.755*
	(4.40)	(3.87)
NumWho	0.024*	0.079*
	(2.74)	(2.53)
NumWhat	0.051*	0.168*
	(4.43)	(3.91)
West	0.070	0.232
	(1.82)	(1.82)
NorthCent	-0.277*	-0.912*
	(-6.81)	(-6.81)
South	0.192*	0.631*
	(3.15)	(3.15)
Northeast	0.015	0.049
	(0.37)	(0.37)
Variance parameter, α	0.132*	
	(5.76)	

Asymptotic t-values are in parentheses. A single asterisk (*) represents significance at the 0.05 level.

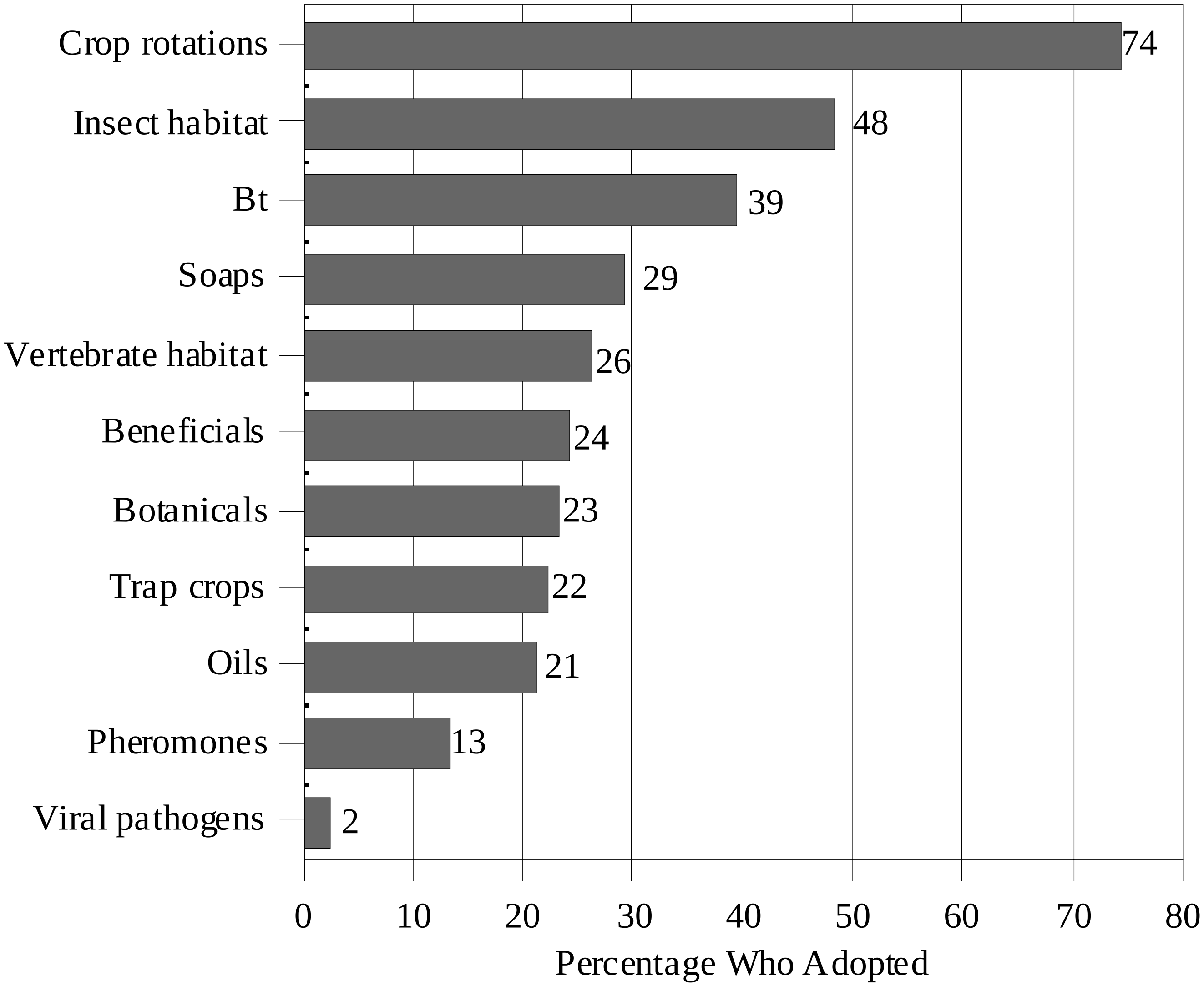

Figure 1. Alternative insect control strategies adopted, by percentage of farmers adopting, 1997

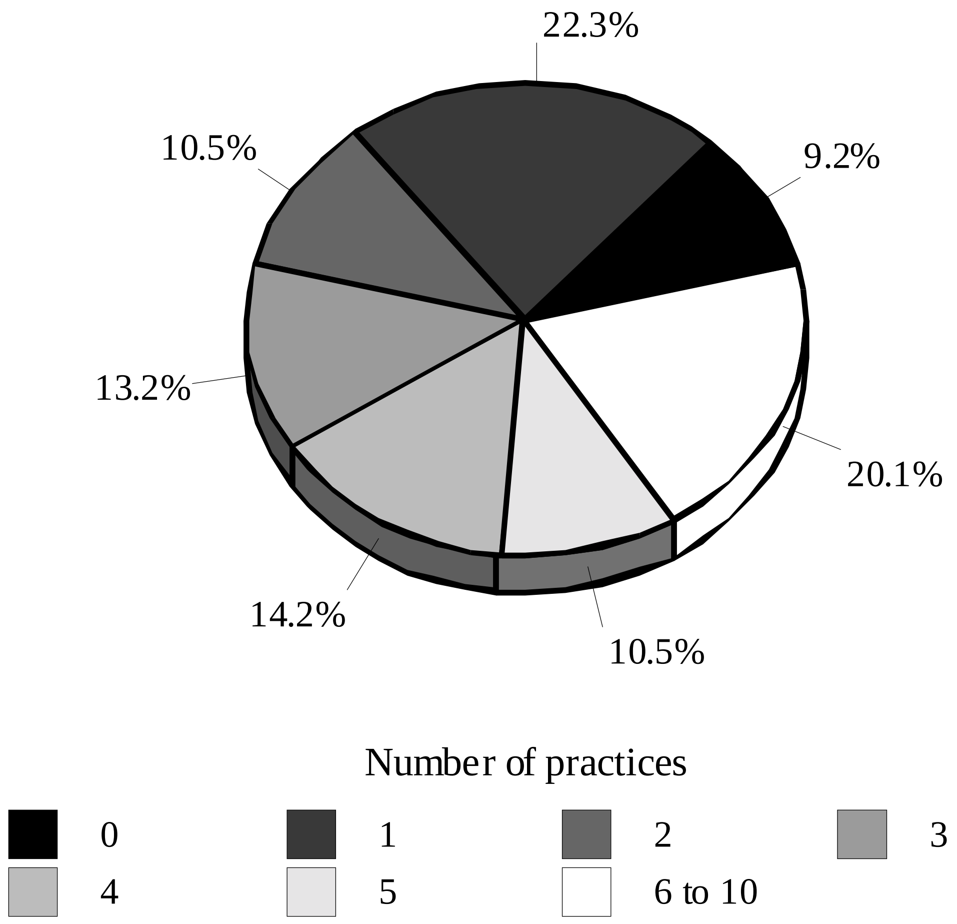

Figure 2. Number of practices adopted by organic farmers, by percentage of organic farmers adopting, 1997