Adoption of Integrated Pest Management Technologies: A Case Study of Potato Farmers in Carchi, Ecuador

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BACKGROUND

Introduction

Agricultural development is essential for improved well-being in rural Ecuador. Approximately 40% of the population relies on agriculture as its primary source of income. In the highlands, potatoes are a major staple, and more than 90,000 producers grow them on about 60,000 hectares of land. Potato production is associated with heavy use of chemical inputs--pesticides and fertilizers--to manage pests and optimize profits. Concerns have emerged about the sustainability of Ecuador's potato crop as rising input costs have created a cost squeeze and public health officials are increasingly concerned about adverse consequences of pesticide over use. These consequences include short and long-term health problems, water and soil contamination, buildup of resistance in pest populations, and the killing of beneficial insects. Most pesticides are applied in liquid form using backpack sprayers and not all farmers utilize protective equipment while spraying (Crissman et al., 1998). Besides negative health and environmental impacts, pesticide use incurs a significant economic cost for producers. Pesticide expenditures typically comprise between 12% and 20% of production cost (Barrera et al., 2003).

Since the 1940s, Carchi province in northern Ecuador has been steadily increasing its share of potato production and currently produces more than any other region. Carchi farmers average between 15 and 20 tons per hectare (Barrera et al., 1999) while average yields for Ecuador are around 7 tons per hectare. Of all cultivated crops in Carchi, potatoes use the largest quantities of pesticides and fertilizers (citation). Producers need alternative pest management approaches that are feasible, economically sustainable, and effective at controlling pests.

Integrated Pest Management (IPM) is an approach that can help lower production costs, reduce exposure to pesticides, and improve long-term sustainability of the agricultural system. The national agricultural research institution in Ecuador (INIAP), supported in part by the IPM Collaborative Research Support Project (IPM CRSP) funded by USAID, has developed technologies to manage potato pests. Information regarding these technologies reaches farmers through several diffusion mechanisms, including farmer field schools (FFSs), field days, exposure to other farmers, and written media (e.g. pamphlets). Given only limited involvement of the public sector in technology transfer, decision makers need to understand the relative cost effectiveness of information dissemination methods. This understanding can help promote better technology transfer and, in so doing, effectively help sustain potato production in Ecuador.

This study had several objectives: (1)to analyze the extent of IPM use in Carchi and identify the determinants and constraints to IPM adoption; (2)to evaluate how IPM technologies are spread among potato farmers in Carchi, Ecuador; and (3)to compare the cost-effectiveness of the FFSs to other information dissemination methods. Carchi is of interest because it is Ecuador's primary potato production region, its potato producers suffer damage from the three major potato pests, and because it shares a border with Colombia. There is interest in generating stable agriculture-based livelihoods in the region.

IPM Solutions

Three main pests significantly impact potato production in Ecuador. They are, in order of economic significance, late blight (*Phytophthora infestans*), Andean Potato

Weevil (*Premnotrypes vorax*), and the Central American Tuber Moth (*Tecia solanivora*). Studies in the 1990s in northern Ecuador reported that nearly 100% of farmers reported being affected by late blight, 80% by Andean Weevil and 6% by tuber moth (INIAP, 1998). The IPM CRSP conducted original research (complementing existing research) to develop strategies for effective management of these three pests.

Late blight is a fungal disease that attacks potatoes around the world. Yield losses depend on the virulence of the fungal strain and whether farmers have the resources to use available fungicides. Studies on lower virulence strains estimate losses at 15%-30% of the crop (Lang, 2001). Without chemical intervention, more lethal strains put farmers at great risk of losing much of their crop.

The prime means of control for late blight is fungicide applications. Farmers in Carchi spray their fields between 1 and 11 times during a crop cycle, with most farmers spraying 6 times (Barrera et al., 2003; Crissman et al., 1998). Because late blight is difficult to control once the disease has become established, farmers spray as a preventative strategy. IPM CRSP recommendations include: (1)use of resistant varieties[1], (2)field sanitation, (3)crop rotations, (4)monitoring to determine need for spray applications , and (5)alternating different types of fungicides to prevent the buildup of resistance.

The Andean Weevil can also cause significant damage without proper management. Up to 80% crop damage has been estimated in infested fields in Ecuador (Muñoz and Cruz, 1984). Farmers typically use three strategies against the Andean Weevil: (1)insecticides to target the larval stage of the insect, namely Carbofuran and

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[1] Varieties were developed through a series of CIP-sponsored and IPM CRSP research including breeding and consumer acceptance surveys.

Methamidofos (both of which are restricted in the U.S. because of high toxicity), (2)crop rotations, and (3)use of undamaged seed.

The main mistake in the conventional approach is targeting the larval stage of the insect. Insecticidal sprays are more effective when targeting adult populations. The IPM CRSP recommends the use of traps to monitor and target adult populations. Traps consist of foliage from potato plants baited with Acefato, (a relatively low-toxicity insecticide). If populations reach a specific threshold, farmers are advised to spray insecticide at the base of plants since adult weevils tend to remain at soil level. At harvest, all tubers should be completely removed from the field. Farmers are advised to wait 30 days before replanting, causing larva to die off before the next crop of potatoes is established.

The tuber moth is not yet a big problem for farmers in Ecuador (Barrera et al., 1999), however, it has an affinity for temperate valleys like those found in Carchi. It can cause damage to pre-harvested tubers, as well as stored potatoes. In either case, current methods of control use highly toxic insecticides (Carbofuran and Carbosulfan).

In the field, IPM techniques include: (1)pheromone traps to monitor and track adult populations and (2)spraying low doses of Profenos when populations reach a specified threshold. In storage farmers are advised to use baculovirus to kill insects and keep the harvested potatoes covered. Other recommendations include: (1)earlier planting and harvests to avoid the dry season (tuber moths prefer dry weather to slip between cracks in the soil), (2)hilling up of soil around plants, (3)crop rotations, and (4)disinfecting seed with low-toxicity pesticides such as Carbaryl and Malathion.

IPM vs. Conventional Technologies: Is IPM Profitable?

Because of the absence of public support for agricultural extension in Ecuador, the IPM CRSP had to explore alternate means of technology dissemination. From 1998-2003, with funding from FAO and later the IPM CRSP, 18 FFSs were set up in the Carchi region. In three FFS field trials, cost-benefit analysis was used to compare conventional to IPM techniques. In all cases, input costs were significantly lower on IPM plots. Yields were higher in two out of three cases. In the third case, yields were the same but the costs of production were lower on the IPM plot. Potential factors influencing differences in yield and production costs include changes in fertilization, type of seed and pest management strategies. Taking into account costs and benefits, net profits were higher in all cases for the FFS/IPM plots. Using field data from all 18 FFSs, yield per dollar of pesticide input was higher in 17/18 cases for IPM over conventional plots. A similar analysis was done for yield per dollar input of pesticides and labor. In this latter case, IPM plots were more productive in all cases (Barrera et al., 2003). IPM is a cost-effective choice for potato farmers and requires no additional capital. Extra labor only appears to be necessary at harvest time. Inputs such as pesticides and fertilizers are used less in IPM plots and offset the increase in costs from purchase of improved seed.

Farmer Access to IPM Information

IPM techniques are relatively complex and therefore require sufficient knowledge acquisition for successful implementation to occur. The complexity of the IPM message can affect which method of diffusion will have the greatest impact. More complex messages include knowledge of the pest life cycle, understanding the use of traps and monitoring of pest populations, use of systemic versus protectant pesticides, and use of different active ingredients to prevent buildup of resistance in pests. Other messages can be understood with minimum explanation, such as early harvests, crop rotations, and use of resistant varieties.

FFSs are a relatively recent approach in the education of developing-world farmers. This program was created in response to deficiencies in other agriculture education programs. FFS attempt to improve upon previous methods of educating farmers by using a participatory rather than a top-down approach. FFSs focus on teaching farmers how to think critically about production problems. This system allows farmers to evaluate their farm situation and use available technologies according to their needs. However, because of their high program costs ($30/farmer), FFSs rely upon farmer networks to facilitate the spread of information and adoption to increase the cost-effectiveness of the program. Field days are able to give pest management information to large groups of farmers at one time for a fraction of the cost ($1.50/farmer). However, a farmer will not receive as much information as a graduate of the FFS program. Pamphlets are the least expensive ($.50/farmer), but depend largely on farmer literacy and complexity of the IPM message (Barrera, conversation).

Selection for FFS participants in Carchi is based on four factors: (1)interest in the program, (2)potatoes are the principle crop on the farmer's land, (3)desire to share/diffuse information with other farmers, and (4)farmers who are creative and innovative. The selection criteria raises questions about an inherent bias in the FFS approach that causes researchers to over-estimate the impact of FFS on adoption (Feder et al., 2003) FFSs may simply be educating only those farmers who would adopt regardless of the information source and those that already strive to use alternative strategies.

METHODS

We employed a combination of qualitative and quantitative methods to achieve the study objectives. A comprehensive survey was conducted of 109 potato farmers in Carchi. Respondents included 30 FFS participants, 28 farmers who had been exposed to FFS-participants, and 51 randomly selected farmers. Farmers were asked a series of questions including the following information categories: demographic and socioeconomic, potato production, pesticide usage and handling, IPM knowledge and implemented techniques, and knowledge about the three most significant potato pests. The quantitative information was combined with qualitative interviews, information on budgets and costs from the FFSs, and expert opinion.

The analysis involved three steps: (1) determination of spread of information and sources of information by IPM adoption level and knowledge scores; (2) analysis of the determinants of adoption using an ordered probit model; and (3) use of the econometric results and information on program costs to examine cost effectiveness.

For step (1) farmers were asked a series of questions during the survey to determine knowledge of IPM and use level. Using descriptive statistics and differences in means, we analyzed the relationships between access to information, IPM knowledge, and adoption.

In step (2) we use the IPM adoption index value as the dependent variable in an ordered probit model. The independent variables included three categories of potential determinants of adoption including: farmer characteristics, economic factors, and institutional factors. Technology characteristics (complexity and labor requirements) and farmer perceptions (perceived profitability, risk, and preferences) were not considered as separate variables in the model, but were used qualitatively to provide insights into model results. Specific variables included in the econometric model were: farmer age, education, household size, household members over the age of 14 (indication of labor availability), land holdings (wealth indicator), illness from pesticides, and five variables representing the sources of information for acquiring knowledge about IPM (noted above).

In step (3), marginal impacts of significant variables were calculated to compare the impacts of the significant independent variables. Information on these impacts was compared to per farmer costs for FFSs, field days, and pamphlets to estimate relative cost-effectiveness of these information diffusion mechanisms.

Model of Adoption

The adoption model is based on the theory that farmers make decisions to maximize their expected utility or benefits. Benefits may include increased profitability, health, food security, lower risk, and environmental sustainability. Farmers adopt technologies when their expected utility from the new technology exceeds that of the current technology. Many factors affect farmers' expectations (e.g. farmer characteristics, economic barriers, access to information, technology characteristics, and farmer perceptions).

Farmer characteristics often considered in adoption models include: age, human capital (formal or informal education), and household size. Age is typically found to be negatively correlated with adoption (Adesina and Zinnah, 1993). This relationship is explained by the assumption that as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. Younger farmers are typically less risk-averse and are more willing to try new technologies.

Formal education increases the farmer's ability to understand and respond to information concerning new technologies (Feder and Slade, 1984). Human capital increases the ability to think analytically, make practical adoption decisions, and use a technology appropriately (Rahm and Huffman, 1984). Studies show that farmers with more formal education tend to adopt more agricultural technologies (Chaves and Riley, 2001; Strauss et al., 1991; Feder et al., 1985). Adoption also occurs from increases in knowledge and human capital due to FFS participation (Bonabana, 1998), participation in farmer groups (Caviglia-Harris, 2003; Strauss et al., 1991; Adesina et al., 2000), and exposure to extension information (Bonabana, 1998).

Household size is another consideration of adoption. Larger households adopt new technologies more often than smaller households, holding other factors constant (Bonabana, 1998; De Souza Filho et al., 1999). Households containing members able to participate in on-farm activities enable farmers to adopt labor-intensive technologies (Feder et al., 1985). If technologies are capital-intensive, household members may work off-farm to generate income to purchase farm inputs.

Economic barriers may discourage or prevent adoption including: wealth (farm size, income), access to credit, and labor availability. In general, populations with higher incomes exhibit a willingness to accept more risk and adopt complex technologies (Batz et al., 1999; Fliegel and Kivlin, 1966). Farmers with larger farms invest more in information acquisition and accumulate knowledge that leads to adoption (Feder and Slade, 1984). On the other hand, wealth can be associated with the use of more pesticides. Some studies suggest that farmers prefer capital-intensive over labor-intensive technologies (Goodell et al., 1989; Orr, 2003).

Access to information affects farmers' perceptions of risk. Having sufficient knowledge about the technology enables farmers to optimize these decision-making processes (Feder et al., 2003). Feder et al found that farmers consider other farmers to be the most important source of agriculture information, but prefer more specifically trained sources as the complexity of the message increases. The acquisition of knowledge may lead to a change in farmer perceptions about risk and profitability. Thus, farmers who are knowledgeable about profit-enhancing technologies will choose to adopt (Negatu and Parikh, 1999). Nowak concluded that information is important for the adoption of soil conservation practices because without information, farmers believe that the technologies are unprofitable and risky (Nowak, 1987). Technology characteristics, such as capital and labor requirements, can also affect farmers' decisions to adopt IPM.

The variables affecting adoption included in this study are described in Table 8.

The Empirical Model

Qualitative response models are often used when a dependent variable takes one of a number of discrete values. Most adoption studies model the decision to adopt as a dependent categorical variable. Such models estimate the probabilities of adoption using

Maximum Likelihood Estimation (MLE) while accounting for the discrete nature of the dependent (adoption) variable (Greene, 1993).

Binary response models (e.g. probit, logit) are used where adoption is considered as a yes or no decision by farmers. However, farmers often manage risk through diversification, and this strategy may be reflected in partial adoption of technologies (Ersado et al., 2004). In this study, we look not only at whether adoption occurs, but also at the intensity of adoption. Therefore, the model needs to consider more than two possible responses. With five possible ordered values for Y (adoption levels), a categorical ordered response model is required. An ordered probit model allows for multiple ordered values for the dependent variable and analyzes the effect of each independent variable on the dependent variable. The ordered probit measures the probability that this dependent variable (Y_i , for the i^{th} household) falls in one of five discrete categories conditioned on levels of the independent variables(X_i):

$$P(Y=1|X_i) = P(Y=1|x_1, x_2 ,...,x_k) = E(Y_i|X_i)$$

The general ordered probit assumes there is a latent or unobserved variable (Y_i^*) such that:

$$Y_i^* = X_i\beta + u_i \quad (i = 1, 2,...,n)$$

We observe the actual placement in the discrete category:

$Y_i = 0$ if $Y_i^* < \gamma_1$
$Y_i = 1$ if $\gamma_1 \leq Y_i^* < \gamma_2$
$Y_i = 2$ if $\gamma_2 \leq Y_i^* < \gamma_3$
$Y_i = 3$ if $\gamma_3 \leq Y_i^* < \gamma_4$
$Y_i = 4$ if $\gamma_4 \leq Y_i^* < \gamma_5$
$Y_i = 5$ if $\gamma_5 \leq Y_i^*$

where u_i are the residuals or error term and the β and γ_i's are parameters to be estimated. (see Greene, 1993: pgs. 511-537.)

In this model, Y (the dependent variable) represents the potential level of IPM adoption by farmers. Adoption intensity is defined according to the following five categories:

1 = 0% adoption
2 = 0% - 25% adoption
3 = 25% - 50% adoption
4 = 50% - 75% adoption
5 = 75% - 100% adoption

Adoption percentages were calculated by taking the total number of recommended IPM activities (17) and determining the percentage of activities utilized by each farmer.

Probit model coefficients (β) report on the effect of an independent variable on the probability of adoption in each of the five categories. These coefficients give an indication of positive or negative impact, but do not relay information concerning the magnitude of the effect[2]. Using a transformation function, the model creates a linear index of the probabilities with a cumulative standard normal distribution. The probabilities are evaluated by looking at the linear function $\Phi(X_i\beta)$:

$$\Pr(Y_i = 0) = \Pr(Y_i^* < \gamma_1) = \Pr(X_i\beta + u_i < \gamma_1)$$
$$\Pr(Y_i = 1) = \Pr(\gamma_1 \leq Y_i^* < \gamma_2) = \Pr(\gamma_1 \leq X_i\beta + u_i < \gamma_2)$$
$$\Pr(Y_i = 2) = \Pr(\gamma_2 \leq Y_i^* < \gamma_3) = \Pr(\gamma_2 \leq X_i\beta + u_i < \gamma_3)$$
$$\Pr(Y_i = 3) = \Pr(\gamma_3 \leq Y_i^* < \gamma_4) = \Pr(\gamma_3 \leq X_i\beta + u_i < \gamma_4)$$
$$\Pr(Y_i = 4) = \Pr(\gamma_4 \leq Y_i^* < \gamma_5) = \Pr(\gamma_4 \leq X_i\beta + u_i < \gamma_5)$$
$$\Pr(Y_i = 5) = \Pr(Y_i^* \geq \gamma_5) = \Pr(X_i\beta + u_i \geq \gamma_5)$$

where γ_i's represent the thresholds or cutoffs for placement of Y_i^* in the discrete adoption categories. Marginal effects are calculated using the linear probability index and tell us the effect on the probability of adopting in a particular category for changes in the independent variables ($d\Pr(Y=0,1,2,3,4,$ and $5)/dX_i$).

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[2] See Greene, pp. 512-515 (Binary-response models) and 529-531 (Models for more than two discrete responses).

RESULTS - Descriptive Analysis

Descriptive analysis was used to determine how farmers heard about IPM. Farmers were divided into three populations: (1)FFS-participants (FFS), (2)farmers exposed to FFS graduates (Exposed), and (3)random farmers with no apparent relationship to FFSs or FFS-participants (Random). The main sources of information for 'Exposed' farmers were either field days (43%) or other farmers (39%). Of 'Random' farmers, 35% claimed they had not received information about IPM. Those who had received information did so mostly through pamphlets (20%) or through interaction with other farmers (35%)(Table 1). It is difficult to explain why farmers who claimed to have not been exposed to IPM information (FEXP0), still had knowledge of IPM (Table 2). In Table 4, we see that these farmers also adopted IPM practices. One explanation is that these farmers were not aware their methods were considered IPM.

TABLE 1 - SOURCE OF INFORMATION ABOUT IPM, BY FARMER GROUP

Information Source	FFS (%)	Exposed (%)	Random (%)	Total (%)
FEXP0 (Haven't heard)	0.0	3.6	35.3	17.4
FEXP1 (Attend FFS)	100.0	0.0	0.0	27.5
FEXP2 (Other farmers-FFS)	0.0	21.4	21.6	15.6
FEXP3 (Other farmers-Non FFS)	0.0	17.9	13.7	11.0
FEXP4 (Field days)	0.0	42.9	9.8	15.6
FEXP5 (Pamphlets)	0.0	14.3	19.6	12.8
Total	100	100	100	100

Source: Survey Data, Carchi, 2003-2004

Note: A Pearson chi2 test showed significant differences between farmer groups at the 1% level.

'Exposed' farmers learn about IPM from multiple sources. Many farmers in this group did not name 'other farmers' as their main source of IPM information. About 43% of these farmers attended field days and 14% mentioned pamphlets.

TABLE 2 - DEPTH OF KNOWLEDGE ABOUT IPM BY INFORMATION SOURCE
(Knowledge category was determined by the % of IPM questions answered correctly by farmers)

IPM Knowledge by Category	Information Source FEXP1 (Attend FFS)	FEXP2 (Other farmers-FFS)	FEXP3 (Other farmers--nonFFS)	FEXP4 (Field days)	FEXP5 (Pamphlets)	FEXP0 (Haven't heard)
Category I (0%)	0.0%	5.9%	16.7%	5.9%	14.3%	44.4%
Category II (1-25%)	0.0%	35.3%	41.7%	11.8%	28.6%	27.8%
Category III (25-50%)	3.3%	41.2%	33.3%	35.3%	21.4%	22.2%
Category IV (51-75%)	23.3%	11.8%	0.0%	41.2%	21.4%	5.6%
Category V (76-100%)	73.3%	5.9%	8.3%	5.9%	14.3%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Survey Data, Carchi, 2003-2004
Note: A Pearson chi2 test showed significant differences between information sources at the 1% level.

FFSs contributed the most to high IPM knowledge scores (Table 2), but field days and pamphlets also contributed to high scores. Farmer-to-farmer diffusion (FEXP2 and FEXP3) has some impact on knowledge, but scores are not as high as when other media (field days, pamphlets) are used. Although farmer interactions may not have a strong impact on knowledge, farmers seem to be more likely to acquire additional information on IPM after such interactions.

The Spread of IPM Information

FFSs encourage information diffusion from participants to non-participants. In this survey, FFS participants claimed to have shared information with 11 farmers on average. More than 220 farmers in Carchi were trained in FFSs between 1998 and 2003. If we assume there is no overlap in these interactions, approximately 2500 farmers were exposed to IPM from FFS farmers (more than one third of potato farmers in Carchi)(Table 3). It is likely however, that some overlap does occur, though we do not know to what extent. ‘Exposed’ farmers spread information to some farmers, while ‘Random’ farmers hardly shared information with other farmers. It is clear that FFS participants’ willingness to share information is a significant benefit of the FFS approach.

TABLE 3 - FARMER TO FARMER SPREAD OF IPM INFORMATION

	FFS	Exposed	Random	Total
(#) farmers who spread IPM info to other farmers	28/30	25/28	4/51	57/109
How many total # of farmers did they spread info to?	332	61	14	407
On average, how many individual farmers did each farmer talk to about IPM?	11	2.17	0.27	3.73

Source: Survey Data, Carchi, 2003-2004

Adoption of IPM

Of 109 farmers, 42.2% had moderately high to high adoption (Cat. IV and V), 37.6% had low to moderate adoption (Cat. II and III), and 20% did not adopt any IPM (Cat. I) (Table 4). The majority of high level adopters attended FFS (70%). 'Exposed' farmers used less IPM than the FFS participants but more than random farmers.

TABLE 4 - DEGREE OF ADOPTION OF IPM BY INFORMATION SOURCE

IPM Use by Category*	Information Source						Total (%)
	FEXP1 (Attend FFS)	FEXP2 (Other farmers-FFS)	FEXP3 (Other farmers--nonFFS)	FEXP4 (Field days)	FEXP5 (Pamphlets)	FEXP0 (Haven't heard)	
Category I (0%)	3.3%	11.8%	33.3%	5.9%	21.4%	61.1%	20.20%
Category II (1-25%)	6.7%	29.4%	33.3%	17.6%	21.4%	11.1%	17.40%
Category III (25-50%)	20.0%	29.4%	16.7%	23.5%	21.4%	5.6%	20.20%
Category IV (51-75%)	43.3%	23.5%	8.3%	47.1%	35.7%	22.2%	32.10%
Category V (76-100%)	26.7%	5.9%	8.3%	5.9%	0.0%	0.0%	10.10%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.00%

Source: Survey Data, Carchi, 2003-2004
Note: A Pearson chi2 test showed significant differences between information sources at the 1% level.
*Use categories are defined by % of IPM techniques adopted

FFS were associated with the highest levels of IPM adoption. Category V adoption was mainly observed in FFS-participants (Table 4). The highest adoption rates in Category IV were observed with FFS-farmers, those who attended field days, or those who read pamphlets (partially attributed to correspondingly high knowledge scores). Farmer-to-farmer diffusion seemed to be less effective (FEXP2 and FEXP3) as both knowledge scores and adoption rates were lower. The lowest rates of adoption were observed in the farmers who had heard of IPM from non-FFS farmers (FEXP3) or claimed they had not received information on IPM (FEXP0). Non-FFS farmers may lack the expertise to transfer IPM knowledge effectively. In addition, farmers show a preference for more experienced individuals when learning IPM technologies. (Owens and Simpson, 2002)

Adoption: Technology Characteristics and Farmer Perceptions

More than half of farmers used some form of insect traps (66%), crop rotations (59%), disinfected seed with insecticides (57%), removed crop residues from fields (50%) and harvested early to control tuber moth (58%) (Table 5). The least popular practices were the use of recommended storage bins (9%), traps for Andean Weevil (11%) and the use of fungicides with different active ingredients (discouraging the buildup of resistance in the fungus) (13%).

TABLE 5 - ADOPTION OF IPM BY TECHNIQUE AND FARMER GROUP

IPM Technique	FFS	Exposed	Random	Total	Chi^2
Use recommended storage	23.3%	7.1%	2.0%	9.2%	0.005
Use traps (baited)* for Andean Weevil	30.0%	3.6%	3.9%	11.0%	0.000
Use fungicides with different active ingredients	26.7%	7.1%	7.8%	12.8%	0.029
Use traps (mobile)	50.0%	14.3%	3.9%	19.3%	0.000
Use pheromone traps (Tuber Moth)	33.3%	35.7%	9.8%	22.9%	0.009
Use yellow traps	56.7%	21.4%	9.8%	25.7%	0.000
Use recommended hilling methods	60.0%	53.6%	2.0%	31.2%	0.000
Use irrigation	43.3%	17.9%	31.4%	31.2%	0.112
Use resistant varieties	50.0%	14.3%	37.3%	34.9%	0.015
Use pest stage in control strategy	83.3%	57.1%	3.9%	39.4%	0.000
Use quality seed	56.7%	46.4%	33.3%	43.1%	0.113
Use insecticides according to recommendations	70.0%	53.6%	33.3%	48.6%	0.005
Dispose of residues in the field	70.0%	60.7%	33.3%	50.5%	0.003
Disinfect seed with insecticides	70.0%	75.0%	39.2%	56.9%	0.002
Use early harvest to control tuber moth	73.3%	85.7%	33.3%	57.8%	0.000
Use crop rotations	83.3%	75.0%	35.3%	58.7%	0.000
Use traps	80.0%	75.0%	52.9%	66.1%	0.023

Source: Survey Data, Carchi, 2003-2004

*Traps for Andean Weevil are typically baited with Acefato, or another low-toxicity insecticide

Some interesting relationships between technology attribute and farmer adoption emerge (Table 5). Although adoption intensity was significantly different across farmer groups, the *pattern* of adoption was similar (i.e. least-adopted and most-adopted technologies were consistent across groups). The activities adopted least were recommended storage practices, use of fungicides with different active ingredients, baited traps for Andean Weevil, irrigation, quality seed, and resistant varieties. These activities are among the more complex practices and are those perceived to be most risky and capital-intensive. There is also low adoption on mobile, yellow and pheromone traps (i.e. tuber moth and leaf miner, both not major pest problems in Carchi). Among the most adopted technologies are use of traps (in general), residue disposal, crop rotations, early harvest, disinfection of seeds, and using insecticides as recommended. These technologies tend to be lower risk, of low to moderate complexity, and not capital-intensive. Several of these technologies require additional labor, indicating that labor availability may not be a problem for farmers. Using pest stage as a control strategy has a high adoption rate among FFS farmers, a moderate rate among 'Exposed' farmers and a low rate among 'Random' farmers. Likely, this reflects the high information requirement associated with this more complex technology.

Use of Pesticide Protective Equipment

Comparing farmer groups, FFS-participants wore the most protective gear when spraying pesticides (Table 6). Unexpectedly, 'Random' farmers used more gear than 'Exposed' farmers (Table 6). Lack of information may cause farmers to be more cautious concerning pesticide handling.

TABLE 6 - PROTECTIVE CLOTHING WORN BY FARMERS (BY FARMER GROUP)

Protective Gear	FFS (%)	Exposed (%)	Random (%)	Total (%)	Chi^2 Sig.
Boots	83.3%	78.6%	94.1%	87.2%	0.001
Mask	50.0%	28.6%	21.6%	31.2%	0.108
Glasses	16.7%	0.0%	5.9%	7.3%	0.027
Jacket	70.0%	21.4%	35.3%	41.3%	0.000
Pants	43.3%	0.0%	15.7%	19.3%	0.000
Gloves	83.3%	25.0%	35.3%	45.9%	0.045

Source: Survey Data, Carchi, 2003-2004

Note: The disproportionate use of boots over other protective clothing is simply because in farmer fields boots are the norm.

Farmer Characteristics

Farmers were predominantly male (93.6%) with a primary school education (81.7%). Only 12% had a secondary school education. Ages of farmers ranged from 18 to 86 with nearly half between 31 and 50 (Table 7). Mean farming experience was 25.9 years and 40% had been farming for between 21 and 40 years. Household size (FHHS) was distributed over a range from 1 to 9 members with an average of 4.9 members. The average number of members age 14 and older (HHOLDb) was 3.7 and 1.3 for members under the age of 14. Farmer characteristics (i.e. gender, education and age) from this survey were comparable to other surveys conducted in Ecuador in the last 5 years (Barrera et al., 1999).

TABLE 7 - SUMMARY STATISTICS ACROSS FARMER GROUPS

	FFS Partipants		Exposed Group		Random Sample			
VARIABLE	Mean (n=30)	SD	Mean (n=28)	SD	Mean (n=51)	SD	F-stat	Sig.
FAGE	41.533	13.508	44.500	12.333	44.216	16.453	0.390	0.676
EDUC	0.100	0.305	0.214	0.418	0.078	0.272	1.670	0.194
FHHS	5.067	1.530	4.786	1.641	4.961	2.068	0.170	0.840
HHOLDb	3.633	1.497	3.464	1.347	3.784	1.983	0.320	0.726
FHEAL	0.333	0.479	0.214	0.418	0.196	0.401	1.030	0.360
LSIZ2	1.460	1.543	1.285	1.138	1.013	1.879	0.760	0.470
IPMKNOW***	83.333	17.167	49.000	24.040	23.216	23.570	69.940	0.000
IPMUSE***	58.431	23.828	41.387	20.091	21.915	26.097	22.370	0.000

(**) Indicates significance at the 10% level

(***) Indicates significance at the 5% level

We did not find evidence of an education or income bias in FFS-participants. Across groups, farmer and household characteristics were essentially the same (Table 7), although knowledge and use of IPM were significantly higher for FFS-participants.

Results - Multivariate Statistical Analysis

Model Iterations and Output

Use of the ordered probit model enabled us to look at how particular variables affect adoption holding other factors constant. For example, differences in IPM use may be due to small differences in education, land holdings, household size, etc. The model included the following variables:

TABLE 8 - DESCRIPTION OF VARIABLES AND SUMMARY STATISTICS

	Variable	Type	Description	Mean	SD	Min	Max
	Characteristics of Farmer			(n=109)			
1	FAGE	Continuous	Farmer age	43.550	14.626	18	86
2	EDUC	Binary	Attend Secondary School	0.119	0.326	0	1
3	FHHS	Discrete	Household size including farmer	4.945	1.815	1	9
4	HHOLDb	Discrete	No. in household 14 and older	3.661	1.701	1	9
	Economic Factors						
5	LSIZ2	Continuous	Land holdings per capita (in household)	0.239	0.428	0	1
6	FHEAL	Binary	Farmer has been sick from pesticides	1.206	1.623	0	10
	Institutional Factors						
7	FEXP1	Binary	Attended FFS	0.275	0.449	0	1
8	FEXP2	Binary	Heard of IPM from FFS-farmers	0.156	0.364	0	1
9	FEXP3	Binary	Heard of IPM from non FFS-farmers	0.110	0.314	0	1
10	FEXP4	Binary	Heard of IPM from a field day	0.156	0.364	0	1
11	FEXP5	Binary	Heard of IPM from pamphlets	0.128	0.336	0	1

(The variables 7-11 indicate where the farmer received information about IPM and are hereafter referred to as ‘information variables.’)

To develop the final model, we first looked at socio-economic and health factors (Model 1). We found that only education and pesticide-related illness affected the degree of adoption of IPM. However, when the variables representing the source of information were added (Model 2), education and health effects were overpowered by impacts from information. In Model 2, household size has significance at the 5% level with larger households adopting less IPM.[3] Four of the five information variables are significant.

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[3] Household size did not distinguish between ages of household members. The variable HHOLDb was used to look at household members over age 14 to evaluate labor availability and its affect on adoption. Since

FFS has the strongest impact followed by field days, exposure to other farmers, and pamphlets.

TABLE 9 - SUMMARY OF MODEL ITERATIONS
(dependent variable: Y = IPMCAT = 5 possible categories of adoption defined above)

Variables	Model 1		Model 2	
	Coefficient	Sig.	Coefficient	Sig.
FAGE	-0.0091	(.261)	-0.0002	(.981)
EDUC	-.4028*	(.094)	-0.3668	(.205)
FHHS	-0.0970	(.327)	-.2271**	(0.014)
HHOLDb	-0.0208	(.814)	0.0449	(.619)
LSIZ2	0.1127	(.291)	0.0234	(.837)
FHEAL	.4860*	(.078)	0.4019	(.146)
FEXP1			2.041***	(0.00)
FEXP2			1.005**	(.016)
FEXP3			.507	(.245)
FEXP4			1.521***	(0.00)
FEXP5			0.9849**	(.016)
IPMKNOW				
predknow				
Wald chi2	9.67 (.1395)		74.60 (0.00)	
Pseudo R2	0.0422		0.1534	

n=109
*Indicates significance at the 10% level
**Indicates significance at the 5% level
***Indicates significance at the 1% level

The second model was used to evaluate whether IPM knowledge has an effect on adoption separate from the effect provided by the different information sources. Using a new knowledge variable, "predknow,"[4] we found that while knowledge is an important factor, *how* farmers receive knowledge (through FFS, field days, exposure to farmers or pamphlets) has the most significant effect on adoption. Since knowledge does not impact adoption apart from the effects of information sources, we removed the knowledge variable and focus on Model 2.

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the age 14 was chosen arbitrarily, sensitivity analysis was used to look at other ages, but the variable remained insignificant.

[4] The variable "predknow" is created by using an oprobit model that determined the effects of information sources on 5 categories of IPM knowledge. Using predicted probabilities, we factored in these information impacts to create the new knowledge variable.

TABLE 10 - MARGINAL EFFECTS OF SIGNIFICANT VARIABLES ON ADOPTION RATES

Information Source	Degree of Adoption	
	Category IV (50-75%)	Category V (75-100%)
FEXP1 (attend FFS)	27.1* (0.000)	41.5* (0.000)
FEXP2 (learn from FFS farmers)	21.1* (0.000)	17.4* (0.114)
FEXP4 (attend field day)	21.7* (0.001)	32.4* (0.009)
FEXP5 (used pamphlets)	20.2* (0.000)	17.4* (0.104)
FHHS (household size)	-6.4* (0.023)	-2.3* (0.024)

*Numbers represent the percent increase in the probability of adopting at the Category IV and V rates
Numbers in parenthesis show significance levels
(FEXP3 omitted because of lack of statistical significance in the model)

In the final model (Model 2), we used marginal analysis to compare the relative effects of information dissemination methods for the two highest categories of adoption intensity. Table 10 summarizes the findings for the two highest categories of adoption.

Each additional household member decreased the probability of adopting in Category IV 6.4%. In Category V, the impact was much less at 2.3%. Of the information variables, FEXP1 (FFS-participation) increases the probability that the farmer is in Categories IV and V by 27.1% and 41.5% respectively. Field days had the second highest impacts, increasing the probability of adoption 32.4% (Cat. IV) and 21.7% (Cat. V). In Category V, exposure to FFS-participants and use of pamphlets were not significant. For Category IV adoption, exposure to FFS-participants and pamphlets had similar impacts on the probability of adoption as field days (21.1% and 20.2% increases).

Clearly, FFS-participation had the strongest impact on high-level adoption. Field days also had significant impacts and were followed closely by exposure to FFS-participants and use of pamphlets. Looking at the bigger picture, information access was more significant than any household effects on adoption.

Using marginal analysis from the ordered probit model and cost data we can evaluate the relative cost-effectiveness of information dissemination methods. Estimated costs are $30/farmer for FFS, $1.50/farmer for field days and $.50/farmer for a pamphlet

(Barrera, conversation). If we only consider marginal effects on adoption, we find that although FFSs are 20 times the cost of field days, they have only about 1.25 times the impact assuming that all adopting farmers used the IPM techniques appropriately and retained the information the same (Table 11). We can compare the relative cost-effectiveness of pamphlets and FFSs in a similar manner and find again that pamphlets have more effect considering their low costs. If we take into account diffusion between farmers, (assuming there is no overlap in terms of which farmers are receiving information), we see that the cost differential between FFS, field days, and pamphlets is reduced since FFS-participants spread information to the most farmers. Another relevant factor is the number of field days the average farmer attends or whether a farmer is using several dissemination methods simultaneously. In the survey, we saw that farmers exposed to FFS-participants were more likely to attend field days and read pamphlets. These factors make it difficult to quantify effects on adoption and do an exact cost-analysis. However, we can see that other methods (i.e. field days and pamphlets) appear to be equally or more cost-effective than FFSs.

TABLE 11 - COST-EFFECTIVENESS OF INFORMATION DISSEMINATION METHODS

	FEXP1	**FEXP4**	**FEXP5**	**Cost Ratios**		**Relative Impacts**	
	(Attend FFS)	(field days)	(pamphlets)	FFS/field days	FFS/pamphlets	FFS/field days	FFS/pamphlets
Implementation Costs (per farmer)	$30	$1.50	$0.50	20:1	60:1		
Farmer-to-farmer diffusion							
(On average, no. of other farmers they shared IPM information with)	11	2.7	0.33				
Marginal Effects on Adoption							
Category IV (51-75% Adoption)	27.1	21.7	20.2			1.25:1	1.34:1
Category V (76-100% Adoption)	41.5	32.4	not sig.			1.28:1	
Taking into account diffusion	($30/12)	($1.50/2.7)	($.50/.33)				
(Cost/Total no. of farmers affected)	$2.50	$0.56	$1.52	4.46:1	1.64:1		

Conclusions

FFSs, field days, and pamphlets are effective mechanisms for transferring IPM information to farmers and promoting adoption. Field days and pamphlets are relatively inexpensive and effectively impact farmer knowledge and adoption of IPM. FFSs are expensive, but have some distinct benefits such as: most complete IPM knowledge; share information readily; hands-on experience; and use of protective equipment. Farmers exposed to FFS-participants often go on to learn more about IPM through other dissemination methods. It is safe to say that each of these dissemination mechanisms has a role to play in increasing farmer knowledge and promoting adoption. An approach that integrates the different diffusion mechanisms is recommended.

Implications for the Direction of Future Research

There are two main concerns with the FFS approach. The first concern is program costs. Feder (2003) suggests that FFSs can lower program costs by (1)limiting the number of sessions, (2)using better quality trainers, and (3)focusing on the most significant IPM messages. However, because IPM for potatoes is complex, one must be careful not to oversimplify the message. It is possible that added profitability from adoption of IPM would enable farmers to contribute financially to FFS programs (Thiele, 2001). In addition, participants could be trained to facilitate field days and improve the flow of information from FFS to non-FFS farmers.

The other concern with FFSs is that there is a bias towards more literate and wealthy farmers, encouraging an education and income gap. Less motivated and illiterate farmers will continue to know very little about IPM while motivated and literate farmers will learn and adopt these technologies. Though we did not find evidence of a bias in our study, it is a valid concern for policy making. In addition, Feder (2003) found that quality of FFSs tend to diminish with large up-scaling. Consequently, it is important to have other means of transferring information to farmers who are not likely to attend these schools. Information dissemination mechanisms can supplement each other to reach a larger and more diverse population of farmers. FFSs should be strategically dispersed throughout the region. Analysis needs to be done to identify communities that have not been exposed to IPM and evaluate what is the best approach for that area. Site-specific studies are necessary in order to understand particular circumstances including: crop characteristics, severity of pest problems, current use of pesticides, flexibility and adequacy of IPM packages, and the availability of labor and capital.

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