Do Pesticide Hazards to Human Health and Beneficial Insects Cause or Result from IPM Adoption? Mixed Messages from Farmer Field Schools in Nicaragua

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Abstract

This paper analyzes the interaction between farmer training in pest management and effects on acute pesticide poisoning and populations of beneficial insects in Nicaragua. Using farm level data from Nicaraguan bean growers, including graduates of Farmer Field Schools (FFS), other integrated pest management (IPM) outreach methods, and farmers without exposure to IPM, we found that small farmers are influenced by pesticide-related acute illness experiences when adopting IPM practices and making decisions about pesticide use. However, exposure to IPM extension programs failed to reduce the use of highly toxic pesticides and increased the number of self-reported acute illness symptoms during the most recent bean crop season. IPM training did result in growth of beneficial insect populations.

JEL classification code: Q16

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I. Introduction

Integrated Pest Management (IPM) has been proposed as an alternative pest control method that could reduce the negative consequences posed by the overuse of agrochemicals over human health and natural environment (Kenmore 2002). In developing countries where illiteracy, lack of technical assistance and unawareness of some pesticide secondary effects increase the likelihood of experiencing these negative consequences (WHO 1990, Ecobichon 2001, Heong et al 2001), researchers and development agencies have expected IPM to be widely adopted among farmers exposed to it. However, adoption rates in most of the developing world have tended to be low, in spite of widespread extension efforts (Addo et al 2001, Chaves and Riley 2001, Orr 2003)

Economic analysis about IPM adoption in developing countries has mainly concentrated in changes on the level of knowledge about IPM (Rola et al 2002, Godtland et al 2004) or in measuring farm-level effects (Walker & Crissman 1996, Swinton 2005, Feder et al 2003). While farmers' knowledge of IPM usually increases after participating in IPM training programs, studies about IPM profitability have shown mixed results and no clear advantages of IPM over chemical control options (Morse & Buhler 1997). In spite of the growing recognition that there exist hidden costs related to the environmental and health effects derived from pesticide use (Rola & Pingali 1993, Crissman et al 1998 and Maumbe & Swinton 2003), these cost have been omitted from virtually all prior impact studies of IPM adoption. Incorporating these environmental and health effects in the analysis could help to better understand farmers' decisions about pest control.

This paper takes a first step toward inclusion of these neglected environmental and health attributes by examining their interaction with the adoption of IPM practices. It first tests whether past pesticide-ascribed acute illness symptoms or the perceived population of beneficial insects influence farmers' decisions about the adoption of IPM practices and the level of pesticide use. Then it analyzes the determinants of changes in the level of acute health symptoms and in the on-farm beneficial insect population during the last cropping season in order to ascertain whether prior exposure to IPM extension programs influences these household health and environmental functions. The recent diffusion of Farmer Field Schools (FFS) among Nicaraguan bean growers serves as a case study.

The paper follows by introducing the context of pest management and pesticide use in Central America, evidence of the links between pesticide use and outcomes for human health and environmental quality, and the recent history of IPM diffusion programs in Nicaragua. Section III presents the analytical framework and section IV the empirical implementation. Section V reports and discusses results, followed by section V, which offers the conclusion and implications.

II Pesticide use, environmental and health effects, and the diffusion of Integrated Pest Management in Nicaragua

Among developing countries, Central American agriculture is characterized by high agrochemical use. In Nicaragua, a recent survey reported that 88% of small farmers use pesticides while only 8% use non-chemical pest control and 4% did not report any pest control (MARENA 1999). Pesticide imports grew from 34 to 45 million kg between 1994 and 2000, giving Central America the world's highest rate of pesticide consumption per capita at 1.5 Kg per person per year (PAHO 2002).

The relatively high agrochemical consumption among small farmers has started to harm human health and insect biodiversity in this area. For Central America, the Pan American Health Organization (PAHO) estimates that incidence of acute pesticide poisoning (APP) is roughly 20 cases per 100,000 population. In Nicaragua and El Salvador this rate is estimated to exceed 35 cases per 100,000 population (PAHO 2002). Worse yet, a recent study estimates that underreporting in the region's official statistics approaches 98%, implying that 400,000 poisonings may occur each year with 5% of people exposed to pesticides experiencing illness symptoms (PANNA 2002). In addition many papers have reported that farmers in Central America recognize that the overuse of pesticides is destroying the beneficial insect population (Bentley and Andrews 1996). These facts have encouraged the search for alternative less harmful farming options.

Integrated Pest Management (IPM) is a group of pest control methods aimed to reduce environmental and health risks by using information about the biology of the pest-crop system. An important principle in IPM is the economic threshold: the pest level at which controls measures are necessary to prevent decline in net returns (Bajwa and Kogan 2002). Based on farmers' better understanding about pest dynamics in their farms, lower chemical input dependence and the use of alternative pest management, IPM is intended to reduce economic and environmental risk without significantly affecting farm profits.

IPM training has a history of more than 20 years in Nicaragua and other countries in Central America. Many research and development institutions have developed extension programs targeted to reduced the use of agrochemicals and increase the adoption of IPM (Staver & Guharay 2003, Cobbe 1998). However, the adoption of IPM practices has been low, and one reason given for such little impact has been the reliance of extension efforts on vertical strategies (PROMIPAC 2001).

Due to the low adoption of IPM in the region, the Project for IPM in Central America (PROMIPAC) has recently developed Farmer Field Schools (FFS) as an alternative extension method. This method aims to increase IPM adoption by using a variety of participatory techniques and following the "learning by doing" approach. FFS cover a large number of activities related with crop management, plant health, weed density and the observation of life cycles of pest and beneficial insects (Quizon et al 2000).

III Analytical approach: Interaction between pesticides health & environmental effects and IPM adoption

We analyze farmers' decisions about pest controls following the household production model approach (Singh et al 1986). We give special attention to the interaction between pesticide use and the adoption of IPM activities (typical production decisions) and the effects that these decisions could have over household welfare (and therefore over consumption decisions).

Defining household utility as:

$$U = U(X, \ell, H, E)$$

We assume that households derive utility from consumption of on-farm and off-farm goods (X), leisure (ℓ), household health (H) and environmental services (E). We also assume that on-farm goods, household health and environmental goods can be produced according to the following household production functions:

$$Q = Q(L(H), Z_c, Z_{nc}, A / C_H)$$

$$H = H(X, Z_h, Z_c / C_H)$$

$$E = E(E_0, Z_c / C_H)$$

The production of on-farm goods (Q) depends on labor (L) that could be family (L_f) or hired (L_h), chemical inputs (Z_c), non chemical inputs (Z_{nc}) and fixed inputs (A) like land. All of these inputs contribute positively to the production level. It is also expected that farm labor availability is increasing in household health ($L'(H)>0$). Health can be augmented by consuming goods (especially food) and health inputs (Z_h) like health care services and protective devices, but health is assumed to be diminished by the use of chemical inputs ($H'(Z_c) \leq 0$). Environmental quality, represented by the beneficial insect population in this article, depends on the natural endowment of beneficial insects (E_0) and is reduced by chemical use ($E'(Z_c) \leq 0$). It is also assumed that the three production functions are influenced by exogenous household characteristics (C_H), socioeconomic, cultural and otherwise.

Household production and consumption are linked through the household full income constraint: household production plus labor sells equates labor purchase plus the consumption of goods and services. Assuming that each household maximizes utility subject to the production function full income constraints, and that P_Q, P_{Zc} and P_{Znc} represent exogenously determined output price and chemical and non-chemical input prices, we derive the following first order conditions:

$$\frac{\partial U}{\partial H}\frac{\partial H}{\partial Z_c}+\frac{\partial U}{\partial E}\frac{\partial E}{\partial Z_c}+\frac{\partial U}{\partial L}\frac{\partial L}{\partial H}\frac{\partial H}{\partial Z_c}+\lambda(P_q\frac{\partial Q}{\partial Z_c}-P_{Zc})=0$$

$$\frac{\partial U}{\partial Q}\frac{\partial Q}{\partial Z_{nc}}+\lambda(P_q\frac{\partial Q}{\partial Z_{nc}}-P_{Znc})=0$$

Or:

$$P_q\frac{\partial Q}{\partial Z_c}=P_{Zc}-\frac{\frac{\partial U}{\partial H}\frac{\partial H}{\partial Z_c}+\frac{\partial U}{\partial E}\frac{\partial E}{\partial Z_c}+\frac{\partial U}{\partial L}\frac{\partial L}{\partial H}\frac{\partial H}{\partial Z_c}}{\lambda}$$

$$P_q\frac{\partial Q}{\partial Z_{nc}}=P_{Znc}-\frac{\frac{\partial U}{\partial Q}\frac{\partial Q}{\partial Z_{nc}}}{\lambda}$$

Unlike the case of profit maximization, in the utility maximization with health and environmental risks, optimal behavior does not entail simply equilibrating the marginal value product of chemical input (Z_c) to its market price. Instead, the optimality condition specifies that MVP_{Zc} equal the market price of Z_c plus the marginal effects of pesticide on household utility through health and environmental effects, adjusted for the marginal utility of income (λ). This implies that anticipating the negative impact of pesticide use over health and natural environment, farmers who care about these things will adjust the level of pesticide use to optimize this decision. In the case of non-chemical inputs, the cost side includes the input price as well as its marginal effect on household utility, again adjusted for the marginal utility of income.

Considering the input use optimality conditions, and letting w and P_{Zh} represent exogenously the determined wage and health input price, we can derive the household demand function for chemical inputs (pesticides) and non-chemical inputs (IPM activities) as follows:

$$Z_c = Z_c(P_q, P_{Zc}, P_{Znc}, w, A)$$

$$Z_{nc} = Z_{nc}(P_q, P_{Zc}, P_{Znc}, w, A)$$

Then, plugging the optimal values of pesticide use and IPM adoption we can also derive the household supply of health and environmental services as follows:

$$H = H(P_q, P_{Zc}, P_{Znc}, P_{Zh}, w, A)$$

$$E = E(P_q, P_{Zc}, P_{Znc}, P_{Zh}, w, A)$$

In the following sections of the paper we estimate the household demand for pesticides and IPM adoption in order to test whether pesticide use and IPM activity adoption is influenced by past acute illness symptoms ascribed to pesticide use or by the perceived population of beneficial insects. Then we estimate the household supply of pesticide-ascribed acute health symptoms and observed on-farm beneficial insect populations during the last cropping season as a function of the categories of variables above, including prior exposure to IPM extension programs.

IV. The empirical strategy

4.1 Sample design and data gathering

We collected farm-level data between May and August 2004 with a cross-sectional survey of 436 Nicaraguan households that produced beans. The survey was designed following a double stratification (Deaton, 1997) to compare the effect of different IPM training participation (FFS and other programs), to include diverse settings and enable survey regression analysis. We interviewed Nicaraguan bean growers in 74 rural communities, including 13 where FFS where implemented, 29 selected randomly among villages in the same provinces but where no FFS exists but where non-governmental organizations (NGOs) and some governmental organizations provided IPM extension services, and 26 communities selected randomly where no IPM extension was present. In each community, households were selected randomly and included clients and non clients of NGOs. The sample distribution includes FFS graduates, farmers participating in other IPM programs, FFS graduates who also attended other IPM programs, and farmers who no prior contact with formal IPM extension.

4.2 The econometric estimation

The general empirical strategy is to use survey regression models in order to account for the 74 primary sampling units (communities) and 5 strata (groups of farmers with different NGO linkages) included in the sample. Model specification includes dependent variables that are continuous, dichotomous, and ordered. Given the nature of the data, we use survey regression methods for linear models, probit models and ordered probit models. Survey estimation methods reduce potential endogeneity that could be caused by the correlation between the unobserved community-level variables and the explanatory variables of interest in each model (Deaton, 1997). We conducted Hausman endogeneity tests, but we fail to reject the hypothesis that the endogenous effects of the variables of interest (acute symptoms, beneficial insects and IPM training participation) are not meaningful.

Pesticide demand is represented by the quantities of active ingredients of insecticides, herbicides, fungicides and molluscicides used during the last bean season. We specify four linear models with the following general form:

$$Z_{cij} = P_{ik}\beta_p + I_{it}\beta_T + H_{ih}\beta_H + E_i\beta_E + S_i\beta_S + U_i$$

The quantity in kg/ha of active ingredients of each group of pesticides used by household i in bean production during the last season depends on vectors of k output and input prices (P_{ik}), T IPM extension and institutional linkages (I_{iT}), h self-reported past acute health symptoms (H_{ih}), perceived beneficial insect population levels (E_i), socioeconomic characteristics (S_i) and unobservable community-level effects, with disturbances assumed to be independently distributed (U_i).

The demand for IPM activities is specified as a set of dichotomous models for adoption of insect scouting, botanical insecticides and/or yellow traps. This binary variable is defined as follow:

Z_{ncj} = 1 if Z_{ncj} was adopted
0 if Z_{ncj} was not adopted

Given that many IPM practices are disseminated during the same IPM training program, we expect that farmers make adoption decisions about different IPM activities simultaneously. Thus, we expect that unobservables of the adoption of different IPM practices would be correlated (Cov (U_i,U_j) $\neq 0$). Testing for the orthogonality of probit models, we found that bivariate probit model[1] represented the adoption of IPM practices better than univariate probit. The general specification is

$$Z_{ncj1} = P_{ik}\beta_p + I_{it}\beta_T + H_{ih}\beta_H + E_i\beta_E + S_i\beta_S + U_{i1}$$

$$\begin{aligned} Z_{ncj2} &= P_{ik}\gamma_p + I_{it}\gamma_T + H_{ih}\gamma_H + E_i\gamma_E + S_i\gamma_S + U_{i2} \\ &= Z_{ncj1}\delta_1 + Y_i + U_{i2} \end{aligned}$$

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[1] The Stata 9 software used did not offer a trivariate probit option that would have allowed joint estimation of all three IPM adoption/input demand models

Where Y_i is a vector of other exogenous variables and the dichotomous k variables follow the rule:

$$Z_{ncjk} = \begin{cases} 1 & \text{if } Z_{ncjk} \text{ was adopted} \\ 0 & \text{if } Z_{ncjk} \text{ was not adopted} \end{cases}$$

The groups of explanatory variables are similar to the previous linear model specification.

Health outcomes are measured as changes in the level of acute health symptoms experienced by households after applying pesticides during the last bean season. The dependent variables measure whether household experienced an increase, a decrease or the same level of incidence of each acute health symptom during the last season compared to the common incidence of these symptoms in the past. We calculated changes in the reported number of acute health symptoms and in the incidence of respiratory difficulties, skin rash, eye irritation, stomach ache, vomit, head ache, diarrhea, muscle pain and blurred vision. However, in the regression models we specified for the last four symptoms, we fail to reject the hypothesis of that the explanatory variables are jointly insignificant. Hence, we concentrate only in changes in the number of symptoms and in the first five acute symptoms.

For changes in the number of acute health symptoms we use a survey regression for linear models following the form:

$$H_{uni} - H_{\ln i} = T_{Hi}\beta_{TH} + I_{it}\beta_I + Z_{hi} + S_i\beta_S + U_i$$

The changes in the number (n) of symptoms experienced in the last (l) bean season by household i (H_{lni}) compared to the household's historic (u) reported number of acute symptoms is assumed to depend on the health toxicity level present during the last season (T_{Hi}), the different IPM extension and institutional linkages (I_{iT}), health inputs used during the last season (Z_{hi}), including protective devices and any curative medical treatment, plus conditioning socioeconomic characteristics (S_i) and unobservable variables linked to the community (U_i). The on-farm health toxicity level is represented by a human toxicity index for each household *i*, calculated as the sum over all *k* pesticide active ingredients used by the household of the doses of each of the *k* active ingredients (ai_{ik}) divided by each active ingredient's mammalian toxicity, as measured by the minimum dose per gram of body weight that is lethal to 50% of a test rat population (LD50, as reported in USDA, 1998). The human toxicity index, shown below, is proportional to the LD50; it is increasing in lethality.

$$HTI_i = \sum_k \frac{ai_{ik}}{LD50_{ik}}$$

The changes in the incidence of each acute symptom present three possible outcomes: an increase, a decrease or unchanged in the incidence level, making the dependent variable, specified below, suitable for ordered probit:

-1 If the incidence of the acute symptom was reduced
H_{ui}-H_{li} = 0 If the incidence of the acute symptom was unchanged
1 If the incidence of the acute symptom was increased

The structural specification of the five ordered probit models contains the same explanatory variables as the model for changes in the number of acute symptoms.

Changes in the reported population of beneficial insects is measured in two ways: 1) with respect to the observed population level during previous season on a discrete high - normal - low scale, and 2) according farmers' assessment of whether the beneficial insect population level was enough to control pest problems at least partially. We again use an ordered probit model for the first specification and a probit model for the second specification, both specified as survey regressions. We are measuring impact on beneficial insects by calculating the field Environmental Impact Quotient (Kovach et al., 1992) by multiplying the quantity of each active ingredient used by the household times the portion of the EIQ index built to measure the effect of pesticides over beneficial insects (Kovach et al., 1992). The specification for the level of beneficial insect population is:

1 Farmers observed fewer beneficial insects
E_i = 2 Farmers observed a normal level of beneficial insects
3 Farmers observed more beneficial insects

The structural equation for environmental impact on beneficial insects is:

$$E_i = T_{Ei}\beta_{TE} + I_{it}\beta_I + S_i\beta_S + U_i$$

The observed on-farm level of beneficial insect population for household i (E_i) depends on the toxicity index for beneficial insects (T_{Ei}), the different IPM extension and institutional linkages (I_{iT}), conditioning socioeconomic characteristics (S_i) and unobservable variables linked to the community (U_i).

The last specification is for a probit model with a dependent variable that measures whether farmers considered that the level of beneficial insects during the last season to have been adequate for controlling, at least partially, the pest problems in beans. We have the following model:

E_{ie} = 0 If farmers considered the level of beneficial insects inadequate
1 If farmers considered the level of beneficial insects adequate

The same explanatory variables used in the previous model are specified. Details of variables used in the regression analysis can be found in Table 5.

V. Results and Discussion

5.1. Conditional factors in the sample

5.1.1 Agrochemical use among Nicaraguan bean growers surveyed

In our sample, 75% of the farmers used insecticides and 60% used herbicides during the last bean season in 2004 (Table 1). On average, Nicaraguan bean growers used 0.6 lt/ha each of insecticides and herbicides during the season. Molluscicides and fungicides are also used for bean production, but only by a few growers; hence the sample average was low. But among pesticide users, the four groups of pesticides show high rates of use (Table 1). Moreover, the predominant insecticides and herbicides employed contain highly toxic active ingredients (metamidophos and paraquat, respectively). Metamidophos in particular has a relatively high field EIQ as well as a very high acute human toxicity index. The average number of pesticide applications and the average dose among interviewed farmers also confirm a high use of agrochemicals in the region.

5.1.3 Pesticide acute health effects

Farmer households reported having suffered a variety of acute symptoms (Table 2). At least 68% of the respondents reported suffering at least one symptom and the average number of symptoms was three. The most common symptom reported was head ache (48% of the respondents) and the least common was diarrhea (only 2% of respondents). In the most recent bean season, farmers reported a general reduction in the incidence of all acute symptoms, especially those related to dizziness, eye irritation, skin rash, muscle pain and vomiting (Table 2).

Although two-thirds of respondents reported that their household members had experienced one or more symptoms of acute pesticide poisoning, only 8% of the cases were severe enough that farmers went to a local doctor and 6% required to travel to a city hospital for treatment. Only 21% of households had city hospitals located within 5 km; 43% had them between 5 and 10 km; and the remaining 36% of households were more than 10 km from a city hospital. For some in this last group, getting to a hospital could take more than 4 hours.

Protective devices were used by roughly a quarter of bean growers in Nicaragua. In all, 27% of the farmers reported using a face mask, special clothing or gloves while applying pesticides. Some farmers (23%) also reported using homemade protective devices like plastic or handkerchief for covering their back or face.

5.1.3 The adoption of IPM activities in Nicaragua

IPM activities were adopted by between 16% and 35% of the farmers interviewed (Table 3). However, these figures exaggerate the true number of IPM adopters, because the sample was stratified to over represent IPM practitioners in order to compare the effect of different IPM extension programs (Table 3). Among farmers with no IPM contact, IPM activities were adopted by only 5% of these farmers

The three main IPM activities disseminated by most of the IPM extension programs in the region are agro-ecosystem analysis, botanical pesticides, and yellow sticky traps. Insect scouting is the main activity in the set referred to as "agro-ecosystem analysis" that is broadly disseminated by Nicaraguan IPM training programs. Botanical pesticides are a broad category that consists in natural substitutes for chemicals and is aimed to control insect pests and diseases. The most common botanicals include the species *Gliricidia cepium*, *Azadaricheta indica* and *Capsium anum*, or household products like detergent, soap, sugar, salt and others. The yellow traps use a sticky solution that traps the insects after being attracted by its yellow color.

5.1.4 Knowledge of beneficial insect population

The identification of beneficial insects and the knowledge of which pests they can control has been broadly disseminated by IPM extension programs in Nicaragua. However, it is uncommon to find farmers unexposed to IPM extension who know about beneficials and even rarer for them to know about specific pests that can be controlled. In our sample 79% of the farmers who recognize beneficials had been exposed to IPM training programs. Overall, 22% of the respondents had observed beneficials during the last bean season. Of this total, 8% observed more beneficials than in the previous season, 5% observed the same level and 10% observed fewer.

5.1.5 The cost and net returns of producing beans

Table 4 describes the cost structure of bean production in Nicaragua. We also calculate net returns in this cropping activity in two ways: 1) including the cost family labor, valued at the market wage, and 2) excluding family labor. On average, pesticide costs accounted for only 9% of total cost without labor or 14% of total costs including labor to apply pesticides. When its cost is included, labor is by far the most costly production input, with seed coming in second but well above the cost of pesticides.

In general, net returns to land and management among bean growers were low when family labor was charged, averaging $30-130 per ha, depending on the category of IPM extension exposure (Table 4). Farmers participating in either FFS or in other, non-FFS IPM training programs had average net returns under $40/ha and only slightly higher than farmers with no exposure to IPM extension. By contrast, the "FFS-influenced" farmers who live in the same communities where FFS was offered but without formal IPM training had the highest net returns at $130/ha. Farmers with both FFS and non-FFS IPM training had the second highest earnings if labor costs are included and equal to the FFS-influenced group if no labor costs are counted. The patterns are similar across groups for the proportion of bean farmers who experienced financial losses during the most recent bean season (Table 4). It seems that farmers with higher profitability in bean production were not selected for participating in FFS.

In general we observed little difference in pesticide expenditures between farmers exposed to IPM training and those insulated from any IPM contact (Table 4). Only farmers who had had previous IPM training and participated later in FFS spent less money in pesticides.

5.2. Regression Results

5.2.1 Determinants of pesticide use

Farm households that had previously suffered acute pesticide poisoning symptoms applied significantly less pesticide. The same was true of households that had observed a larger insect population during the last prior bean season (Table 6). These observations are consistent with the hypothesized effect of prior experience with health and environmental effects of pesticides.

The quantity of insecticide active ingredients decreased by 0.33 liters/ha last season among farmers that had a higher frequency of diarrhea symptoms. Similarly, farmers who adopted insect scouting and also observed a greater beneficial population last season used 0.37 liters less of insecticide active ingredient per hectare (Table 6). The fact that most farmers who applied insecticides used the very toxic metamidophos (Table 1) is consistent with this result. Also observation of bean pests and the reliance on natural pest controls appears to reduce insecticide use (Table 3).

On the other hand, molluscicide rates are not correlated with past acute symptoms suffered by household members, perhaps because metaldehyde, the main mulluscicide, has low human toxicity (Table 1). They are, however, reduced where farmers previously observed an increase in the beneficial insect population. More beneficials in combination with the adoption of insect scouting reduced the use of molluscicides by 0.32 kg per hectare (Table 6).

The use of fungicides is significantly influenced by the frequency of past household experience with diarrhea and dizziness. In both cases, households reduced the use of fungicides in the last bean season (Table 6). Beneficial insect populations, which are unrelated to plant disease, did not influence the level of fungicide use in the same bean season.

The predominant use of the toxic herbicide gramoxone explains why households that had experienced a higher frequency of blurred vision in the past used less herbicide per hectare than households with lower frequency of this symptom. A surprising result on the herbicide demand regression was the fact that households with more acute symptoms in the past tended to apply slightly more herbicides (an increase of 0.06 liters per hectare). However, a much stronger contributor to herbicide demand was the fact of having hired a laborer to apply the herbicide (Table 6).

Apart from the variables of focal interest, other variables also contributed to explaining the level of pesticide use reported by bean growers. As expected, the price of metamidophos and gramoxone inversely influenced the use of insecticides and herbicides. However the magnitude of these effects was very low. Only big pesticide price changes can produce a large change in agrochemical use. Other production variables that affect pesticide use, but also with a low magnitude, are farm altitude (associated with humidity), seed price, and distance from the farm to municipal center. Two household socioeconomic characteristics had very significant effects. Female-headed households applied 0.32 kg/ha less molluscicides on average than ones headed by men. Also, households with electricity at home (a proxy for wealth) used 0.31 l/ha more fungicides than ones without electricity. Not surprisingly, the area of land managed by households was associated with increased herbicide use, but the magnitude of the effect is small. Finally, households with more children under 14 years used less insecticide.

5.2.2 Determinants of the adoption of IPM practices

The effects of prior acute pesticide poisoning and appreciation of beneficial insects are weaker on adoption of IPM practices than on direct reduction of pesticide use (Tables 7a and 7b). Acute poisoning experiences seem not to influence the adoption of insect scouting, but they do influence the adoption of botanical insecticides and yellow sticky traps (Table 7a and 7b). Households with higher past frequency of diarrhea and vomiting symptoms are more likely to adopt botanicals. Those who suffered from vomiting have 5% more probability of adopting botanicals (Table 7a). In the case of yellow sticky traps, households that suffered from head ache or skin rush were more likely to adopt this IPM practice (Table 7b).

Participation in any IPM training program had a positive and highly significant effect on the adoption of all IPM practices (Table 7a and 7b). Farmers exposed to IPM extension programs were 40-80% more likely to jointly adopt insect scouting and botanicals. For all three IPM practices, FFS graduates have a greater probability of adopting than any other farmer groups (Tables 7a and 7b).

As for other variables conditioning IPM adoption, bean prices were negatively associated with the adoption of IPM. A higher bean price decreases the probability of adopting insect scouting and botanicals; however this effect has a very low magnitude (0.06%). The negative sign could be explained by the risk averse behavior of these farmers. A higher bean price creates a stronger incentive to protect the bean harvest, and pesticides may be viewed as more reliable than botanicals to guard yield.

Several socioeconomic characteristics also affected IPM adoption. Female-headed households were much less likely to adopt insect scouting or botanicals. This result may be due to the fact that Nicaraguan farm women tend to be more involved in marketing and vegetable growing than in production of staple crops. Age also affected IPM adoption; the older the household head, the more likely to adopt insect scouting or yellow sticky traps.

5.2.3. Determinants of changes in pesticide poisoning symptoms

The six econometric models of changes in levels of acute pesticide poisoning symptoms revealed surprising results. FFS participation did not reduce the incidence of acute poisoning (Table 8). To the contrary, it increased the total number of symptoms reported by households and specifically the incidence of skin rash and eye irritation during the last season (Table 8). FFS and other IPM training programs in no instance reduced the change in acute poisoning symptoms during the latest bean season compared with prior experience.

Higher herbicide toxicity also decreased the number of acute symptoms and the level of incidence of acute symptoms like respiratory difficulties and vomit experienced by household after applying herbicides (Table 8). While this result is unexpected, the mean effect comes from a low base; the mean human toxicity index value for herbicides is almost four times lower than for insecticides (Table 1).

As expected, more toxic insecticides produced more symptoms of acute pesticide poisoning and eye irritation (Table 8). Similarly, more toxic fungicides increased the incidence of respiratory difficulties and eye irritation. Likewise, more toxic molluscicides increased the number of acute symptoms and the incidence of eye irritation, stomach ache.

Farmers using protective measures against pesticide negative health effects have also a significant effect on the incidence of acute symptoms. Purchased protective gear, such as face masks, impermeable clothing and gloves, reduced the number of acute symptoms and the incidence of respiratory difficulties (Table 8). Some farm households also used homemade protective devices, but these were not effective at protecting household members against pesticide poisoning symptoms. Farmers who used this type of protection increased the incidence of skin rash. Hiring an applicator of pesticides seems to constitute another measure for protecting household members against pesticide ascribed illness. Hired pesticide applicators were associated with reduced incidence of eye irritation during the most recent bean crop season (Table 8). Finally, the distance to hospitals where people can be treated after getting poisoned had mixed effects; while greater distance increased the incidence of eye irritation, it reduced the incidence of stomach ache.

Table 8 does not report a set of socioeconomic variables that were used in the regressions due to space limitations, but we found that female-headed households experienced fewer problems of skin rash. Older household heads reported more respiratory difficulties and skin rash problems but less stomach ache. Household heads with more years of education also had higher incidence of eye irritation and stomach ache. Having more children increased the reported respiratory difficulties after using pesticides as well as the total number of acute symptoms. Finally, wealthier households, as indicated by those with electricity at home, more land and receipt of remittances from relatives working abroad, had fewer acute symptoms in general (Table 8).

5.2.4. Determinants of beneficial insect population on farm

IPM outreach program participation had a very significant effect on beneficial insect populations (Table 9). Farmers who participated exclusively in FFS or graduated from FFS after receiving previous IPM training were more likely to have beneficial insect populations large enough to at least partially control their pest problems in bean production. Farmers who participated exclusively in non-FFS IPM training programs or had experienced both FFS and other IPM training had a greater probability of increasing the on-farm population of beneficial insects (Table 9).

Farmers who had adopted insect scouting were more likely to report having an adequate beneficial insect population during the most recent bean season. Other variables that had a significant effect on the level of beneficial insect population were municipal distance and the number of head of cattle, both of which increased the probability of having a higher or adequate level of beneficial insects.

VI. Conclusions and implications

This research offers important insights for policy makers designing IPM diffusion programs. Proponents of IPM often take for granted that the negative environmental and health effects of pesticide use will encourage greater adoption of IPM. However, our results have found mixed results from the interaction of these environmental and health effects and the adoption of IPM activites among Nicaraguan bean growers.

Prior experience with the health and environmental effects of pesticides does influence farmers' decisions about pesticide use and the adoption of IPM activities. Past symptoms of diarrhea and blurred vision, previous workdays lost due to poisoning and a greater beneficial population reduced the use of insecticides and herbicides by Nicaraguan bean farmers. Households with past symptoms of diarrhea, vomiting, head ache and eye irritation had a greater probability of adopting botanical insecticides and yellow sticky traps. As expected, exposure to IPM training programs tended to increase the adoption of IPM practices, and FFS graduates were especially likely to adopt IPM practices.

Although exposure to IPM extension induced farmers to adopt IPM practices, it failed to reduce the use of highly toxic pesticides that pose significant health risks. IPM-trained farmers may observe pest and beneficial insects carefully in order to determine the best moment to apply pest control. But the evidence shows that farmers continue to rely upon chemical pest control. This situation has resulted in an increase in the number of reported acute symptoms of pesticide poisoning, including skin rash and eye irritation. Exposure to IPM training clearly is not producing the expected health benefits to farmers.

IPM training is, however, producing desirable results for beneficial insects, one measure of agricultural ecosystem health. Both FFS graduates and other farmers exposed to IPM training were more likely to report either that the beneficial insect population was adequate for at least partially controlling their pest problems in bean production or that the beneficial insect population had increased.

A profitability analysis does not show advantages for FFS graduates or other IPM training participants. Net returns to bean production by these groups of farmers did not differ from farmers lacking exposure to IPM. Farmers living in the same villages as FFS graduates but not participating in the program had the greatest net returns and the lowest rates of net losses from bean production. These results raise questions about whether the more profitable bean farmers were excluded from FFS or did not elect to participate.

Future research should undertake to combine these mixed results into a comprehensive impact analysis in order to assess the overall effect of IPM training. A proper impact evaluation should also compare levels of investment across different IPM training programs with the corresponding overall benefits achieved.

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Table 1. Pesticide use among 436 Nicaraguan bean growers, 2003-04.

	Insecticides	Molluscicides	Fungicides	Herbicides
% farmers using	75%	18%	22%	60%
% of FFS graduates using	72%	22%	14%	52%
% of other IPM farmers using	79%	17%	30%	56%
average use (lit/ha)	0.59	0.25	0.22	0.59
Standard deviation	0.67	0.73	0.64	0.64
average use among only users	0.78	1.37	1.01	0.97
Standard deviation	0.67	1.20	1.04	0.53
Main active ingredient used	Metamidophos	Metaldehyde	Mancozeb	Paraquat
% of farmers using main a.i	54%	16%	14%	53%
% of users using main a.i	61%	89%	60%	88%
Aver. number of applications (users)	2.3	2.8	1.8	1.3
Average dose (ml per 20 lts) (users)	36.2		48.5	38.7
Average toxicity index (health)	0.0463	0.0028	0.0010	0.0109
Standard Deviation	0.0907	0.0098	0.0070	0.0189
Average toxicity index (beneficials)	36.03	9.68	11.15	39.60
Standard deviation	52.46	33.43	49.36	85.04

Table 2. Percentage of farm households having experienced acute symptoms of pesticide poisoning, 436 Nicaraguan bean growers, 2003-04.

Symptoms	In the past	During last season	Increased symptoms	Keep level of symptoms	Decreased symptoms
Head ache	48%	19%	1%	90%	9%
Eye irritation	43%	16%	1%	72%	27%
Dizziness	38%	11%	1%	70%	29%
Stomach ache	31%	8%	1%	84%	15%
Skin rash	29%	8%	0%	78%	22%
Blurred vision	28%	8%	2%	79%	19%
Muscle pain	26%	8%	0%	80%	20%
Vomit	25%	8%	3%	77%	20%
Respiratory difficulties	11%	4%	1%	92%	7%
Diarrhea	2%	1%	0%	99%	1%

Table 3. Farmer participation in extension programs and IPM adoption, 436 Nicaraguan bean growers, 2003-04.

Participation in IPM extension programs	
Farmer Field School (FFS)	21%
Previous IPM programs	34%
FFS and previous IPM programs	8%
Non participants living in same village of IPM programs	7%
Farmers with no extension contact	30%
Adoption of IPM activities	
Insect scouting	28%
Botanical insecticides	35%
Yellow traps	16%

Table 4. Budget and net returns to land and management per hectare of beans (in US$), 436 Nicaraguan bean growers, 2003-04.

	FFS	Other IPM	FFS&IPM	Influenced	Insulated
Number of farmers	91	149	35	31	131
Gross revenues	240	233	304	274	209
Input costs					
Animal traction	12	15	12	8	14
Seed	25	24	25	23	23
Fertilizer	19	17	13	6	10
Pesticides	16	18	10	17	19
Herbicides	6	7	4	8	8
Insecticides	6	8	3	6	9
Molluscicides	2	1	1	1	1
Fungicides	2	2	2	2	1
Non chemical inputs	3	1	12	0	0
Labor costs	138	135	148	100	124
For spraying chemicals	10	11	8	9	10
Other activities	128	124	140	91	114
Net returns 1 (cost with family labor)	38	35	92	130	30
% farmers with losses	42%	41%	29%	29%	44%
Net return 2 (cost without family labor)	132	120	190	190	109
% farmers with losses	24%	26%	17%	10%	17%

Table 5. Mean and variance of other variables used in the regression analysis.

Variables	Mean	Std dev
Production Variables		
Price of beans (US$ per kilo)	0.34	0.08
Price of Maize (US$ per kilo)	0.12	0.04
Price of metamidophos (US$ per kilo)	4.64	0.76
Price of gramoxone (US$ per kilo)	5.68	0.66
Wage for spraying chemicals (US$ per man-day)	1.75	0.40
Distance to municipal capital (Kms)	11.30	7.90
Farm altitude (m.a.s.l)	762.90	232.20
Farming season		
Postrera (%)	84	
Primera (%)	10	
Apante (%)	6	
Farmers who observed high pest levels (%)	8	
Other Health variables		
Households that visited local doctor after pesticide poisoning (%)	8	
Households that visited city hospital after pesticide poisoning (%)	6	
Households that reported workdays lost (%)	17	
Household that reported the use of protective devices (%)	27	
Beneficial insect variables		
Households that observed a sufficient level of beneficials (%)	9	
Households that observed a higher level of beneficial insects (%)	15	
Households that observed the same level of beneficial insects (%)	7	
Households that observed a lower level of beneficial insects (%)	11	
Household characteristics		
Female-headed households (%)	15	
Age of household head (years)	45.03	13.80
Education of household head (years)	3.17	3.20
Female proportion of household members (%)	49	
Members under 14 years old (%)	34	
Total area of land (hectares)	8.37	12.50
Area under irrigation (hectares)	0.21	0.59
Cattle (number of head)	3.61	6.72
Households with electricity at home (%)	45	
Household receiving remittances from relatives (%)	21	

Table 6. Determinants of pesticide use, OLS survey regression results for 436 Nicaraguan bean growers, 2003-04.

Variables	**Insecticides**	**Molluscicides**	**Fungicides**	**Herbicides**
Gramoxone price	---	---	---	**-0.0421*****
				(0.0077)
Metamidophos price	**-0.0096****	---	---	---
	(0.0043)			
Altitude	**-0.0008*****	-0.0001	0.0001	-0.0001
	(0.0002)	(0.0002)	(0.0003)	(0.0002)
Municipal distance	-0.0050	**0.0105***	**0.0208*****	**0.0109***
	(0.0055)	(0.0064)	(0.0061)	(0.0059)
Botanicals adoption	-0.1143	**0.1933***	**0.2695****	---
	(0.1174)	(0.1048)	(0.1160)	
Yellow trap adoption	0.1864	**0.1824***	---	---
	(0.1260)	(0.1083)		
More beneficials x insect scouting adoption	**-0.3666*****	**-0.3168****	---	---
	(0.1416)	(0.1463)		
Apante season	**-0.8321*****	0.1369	0.0298	0.1044
	(0.2907)	(0.2322)	(0.1954)	(0.2395)
Improved seed	---	---	0.2125	---
			(0.1671)	
Diarrhea frequency	**-0.3257*****	-0.0127	**-0.3024*****	0.1279
	(0.1297)	(0.1247)	(0.1066)	(0.2084)
Blurred vision frequency	0.0526	0.0924	0.0186	**-0.1396*****
	(0.0641)	(0.0836)	(0.0570)	(0.0528)
Number of protective devices	**0.1291****	0.2413	0.0372	-0.0730
	(0.0632)	(0.0604)	(0.0444)	(0.0465)
Workdays lost	**-0.2529***	-0.0005	-0.0201	-0.0033
	(0.1382)	(0.1163)	(0.1237)	(0.1020)
Hired main applicator	0.1040	0.0239	-0.0237	**0.2659*****
	(0.0937)	(0.1078)	(0.1110)	(0.1055)
Female Househ. Head	0.1331	**-0.3192*****	0.1375	-0.1054
	(0.1088)	(0.1045)	(0.1347)	(0.1165)
Number of members<14 years	**-0.0634*****	-0.0026	0.0142	0.01412
	(0.0214)	(0.0295)	(0.0195)	(0.0247)
Total land	-0.0003	-0.0002	0.0003	**0.0008*****
	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Has electricity	0.0726	0.0413	**0.3117*****	0.0201
	(0.0866)	(0.1149)	(0.0960)	(0.0763)
F Statistic	2.69	1.42	1.45	7.07
R^2	0.1480	0.0915	0.1485	0.3133

Table 7a Bivariate probit regression for adoption of insect scouting and botanical insecticides, 436 Nicaraguan bean growers, 2003-04.

Variables	**Insect scouting**	**Botanic pesticides**	**Marginal effects**
Beans price	**-0.0029***	**-0.0033****	**-0.0006****
	(0.0015)	(0.0015)	(0.0002)
Maize price	-0.0039	**0.0056***	0.0001
	(0.0036)	(0.0032)	(0.0005)
Wage for spraying chemicals	-0.0010	**-0.5184*****	**-0.0044***
	(0.0150)	(0.0165)	(0.0024)
Altitude	0.0004	**0.0010****	**0.0001****
	(0.0004)	(0.0004)	(0.0000)
Departmental distance	**0.0100*****	**0.01156*****	**0.0019*****
	(0.0040)	(0.0038)	(0.0006)
Only beans FFS	**2.6288*****	**2.6738*****	**0.8009*****
	(0.3075)	(0.3402)	(0.0512)
Other FFS	**1.7579*****	**2.2147*****	**0.6683*****
	(0.7017)	(0.6766)	(0.1968)
Other IPM program	**1.3355*****	**2.2065*****	**0.4072*****
	(0.2738)	(0.2973)	(0.0573)
Only bean FFS & other IPM	**2.3411*****	**3.2283*****	**0.8240*****
	(0.3693)	(0.4171)	(0.0634)
Other FFS & other IPM	2.9306	**3.0360*****	**0.8779*****
	(0.7213)	(0.6672)	(0.0523)
Frequency of diarrhea	-0.0070	**1.3774***	0.1125
	(0.5768)	(0.7423)	(0.0894)
Frequency of vomiting	0.2175	**0.3352****	**0.0486****
	(0.0998)	(0.1452)	(0.0213)
Visit city doctor	-0.1715	**-0.7242***	**-0.0615***
	(0.4102)	(0.4239)	(0.0327)
Number of protective devices	0.1090	**0.1749***	0.0249
	(0.1020)	(0.1053)	(0.1563)
Apante season	-1.0234	**-1.2795****	**-0.0987*****
	(0.6356)	(0.6485)	(0.0232)
Female household head	**-0.5721****	**-0.4949****	**-0.0735*****
	(0.2543)	(0.2537)	(0.0234)
Years of education	**0.0592***	**0.0771****	**0.0121*****
	(0.0311)	(0.0327)	(0.0048)
Female proportion	**1.2328****	0.3309	**0.1467***
	(0.5169)	(0.5225)	(0.0777)
Wald Chi2	196.05		
Chi2 Statistic	31.74		
Prob (insect scouting & botanicals)			0.0927

Table 7b Bivariate probit regression for adoption of botanical insecticides and yellow sticky traps 436 Nicaraguan bean growers, 2003-04.

Variables	**Botanicals**	**Insect yellow traps**	**Marginal effects**
Beans price	**-0.0032****	0.0194	-0.0001
	(0.0016)	(0.0485)	(0.1113)
Maize price	**0.0057***	0.0012	0.0002
	(0.0032)	(0.0035)	(0.2485)
Wage for spraying chemicals	**-0.0509*****	-0.0068	-0.0020
	(0.0165)	(0.0159)	(2.1092)
Transport cost	0.0188	**-0.0504***	-0.0022
	(0.0193)	(0.0271)	(1.0772)
Municipal distance	-0.0121	**0.02841****	0.0012
	(0.0128)	(0.0141)	(0.5541)
Departmental distance	**0.0100*****	-0.0004	0.0003
	(0.0037)	(0.0038)	(0.3555)
Only beans FFS	**2.6380*****	**1.8664*****	0.4889
	(0.3440)	(0.3525)	(215.22)
Other FFS	**2.2228*****	-4.5598	**-0.0372*****
	(0.7035)	(54225)	(0.01156)
Other IPM program	**2.1666*****	**1.5549*****	0.2856
	(0.2981)	(0.3328)	(174.66)
Only bean FFS & other IPM	**3.1405*****	2.4227	0.7623
	(0.4162)	(0.4142)	(151.06)
Other FFS & other IPM	**3.1066*****	**1.6501****	0.5391
	(0.6970)	(0.7367)	(208.99)
Frequency of diarrhea	**1.4434****	0.1301	0.0532
	(0.7467)	(0.4986)	(57.648)
Frequency of headache	0.11.21	**0.3029*****	0.0204
	(0.1018)	(0.1036)	(14.756)
Frequency of skin rash	0.1505	**0.2452****	0.0184
	(0.1129)	(0.1145)	(14.153)
Frequency of vomiting	**0.3157****	-0.0679	0.0063
	(0.1403)	(0.1389)	(9.2275)
Visited city doctor	**-0.7401***	0.4193	-.0102
	(0.4286)	(0.4496)	(18.803)
Number of protective devices	**0.1745***	0.1033	0.01130
	(0.1073)	(0.1071)	(10.043)
Apante season	**-1.0793***	0.2409	-0.0243
	(0.6443)	(0.6916)	(28.062)
Female household head	**-0.4657***	-0.3213	-0.0254
	(0.2568)	(0.0036)	(23.04)
Years of education	**0.0687****	0.0474	0.0048
	(0.0319)	(0.0314)	(4.1913)
Female proportion	0.3244	**0.8923***	0.0599
	(0.5177)	(0.5400)	(43.265)
Household has relative working in another country and sending money	0.2095 (0.2095)	**0.3686*** (0.2261)	0.0327 (22.691)
Wald Chi2	168.84		
Chi2 Statistic	11.30		
Prob (insect scouting & Botanicals)			0.03512

Table 8. Determinants of changes in the level of household acute health symptoms (Linear and Ordered Probit survey regressions), 436 Nicaraguan bean growers, 2003-04.

Variables	**Change in # of symptoms (Linear)**	**Change in respiratory difficulties**	**Change in skin rash**	**Change in eye irritation**	**Change in stomach ache**	**Change in vomit**
Herbicide toxicity	**-17.1424****	**-11.5972****	-3.2147	-0.3723	-5.3461	**-11.0767****
	(7.8656)	(5.8513)	(4.5867)	(4.7528)	(5.1891)	(5.1770)
Insecticide toxicity	**2.3097****	1.1398	1.3222	**1.6880*****	1.4658	0.7095
	(1.0050)	(0.9310)	(1.1245)	(0.6218)	(0.9796)	(0.8348)
Fungicide toxicity	13.9008	**10.3061****	15.7159	**15.7743*****	-7.9793	0.2693
	(12.0178)	(5.0628)	(13.1855)	(6.0443)	(10.4667)	(6.3970)
Molluscicide toxicity	**50.9715*****	14.0462	-4.6766	**25.9456***	**30.7786***	**24.8847*****
	(20.0395)	(13.7338)	(16.3845)	(13.7882)	(17.9222)	(9.6301)
Farm altitude	0.0003	**0.0008***	-0.0001	-0.0004	**0.0009****	**0.0005***
	(0.0006)	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0003)
Postrera season	-0.3249	0.2576	0.2506	-0.2069	**-0.6153****	-0.1493
	(0.3662)	(0.2547)	(0.2289)	(0.2681)	(0.2648)	(0.1907)
Apante season	0.2272	**1.1684*****	0.5679	0.4095	-0.3634	0.2521
	(0.5490)	(0.3111)	(0.3874)	(0.4144)	(0.3665)	(0.3735)
Distance to hospital	0.0014	0.0124	-0.0091	**0.0192****	**-0.0283*****	-0.0051
	(0.0015)	(0.0148)	(0.0082)	(0.0086)	(0.0097)	(0.0111)
Purchased prot. devices	**-0.2870***	**-0.1880***	-0.0393	-0.1076	-0.1440	-0.0322
	(0.1769)	(0.0117)	(0.0889)	(0.0864)	(0.095)	(0.0892)
Homemade prot. devices	0.2389	0.1993	**0.2491***	0.0824	0.0830	-0.1298
	(0.2116)	(0.1621)	(0.1543)	(0.1344)	(0.1826)	(0.1396)
Hire pesticide applicator	0.1273	0.2068	0.0267	**-0.3361***	0.2112	0.2121
	(0.2950)	(0.2476)	(0.1937)	(0.1815)	(0.2114)	(0.1962)
FFS	**0.6027****	0.1415	**0.4707*****	**0.4982*****	0.0107	0.0062
	(0.2801)	(0.2554)	(0.1890)	(0.1824)	(0.2077)	(0.1989)
Other IPM program	-0.2231	0.0445	0.0691	-0.0119	-0.0768	-0.2472
	(0.2977)	(0.2675)	(0.1689)	(0.1727)	(0.1931)	(0.1737)
FFS & IPM	-0.3955	0.0004	-0.2725	-0.4103	0.0465	-0.3804
	(0.4729)	(0.3115)	(0.3013)	(0.2937)	(0.3369)	(0.2501)

Table 9. Determinants of beneficial insect population on farm (Ordered Probit and Probit survey regressions), 436 Nicaraguan bean growers, 2003-04.

Variables	Level of beneficials	Enough beneficials on farm
Toxicity for benenficials	-0.0014	-0.0018
	(0.0011)	(0.0014)
Insect scouting adoption	0.0050	**0.8662*** **
	(0.2489)	(0.2738)
Botanical insecticide adoption	0.3087	0.1192
	(0.2713)	(0.2624)
Yellow trap adoption	-0.1211	0.1874
	(0.2159	(0.2704)
Municipal distance	**0.0291** **	0.0195
	(0.0129)	(0.1364)
FFS	0.7271	**0.6860** **
	(0.6148)	(0.3685)
Other IPM	**1.2932** **	0.1706
	(0.5973)	(0.3136)
FFS & other IPM	**1.5648** **	**1.2445*** **
	(0.6631)	(0.3925)
Cattle number	0.0092	**0.034** **
	(0.0269)	(0.0168)
F test	0.0403	0.0000
Number of observations	144	436