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Pest Management, Productivity and Environment: A Comparative Study of IPM and Conventional Farmers of Northern Districts of Bangladesh

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Abstract: Experts recognized that there are huge global harvest losses due to pests and effective pest control is thereby of much important to ensure the attainable production. Concerns about the sustainability of conventional agriculture have prompted widespread introduction of Integrated Pest Management (IPM), an ecologically-based approach to control of harmful insects and weeds. IPM is intended to reduce ecological and health damage from chemical pesticides by using natural parasites and predators to control pest populations. Since chemical pesticides are expensive for poor farmers, IPM offers the prospect of lower production costs and higher profitability. However, adoption of IPM may reduce profitability if it also lowers overall productivity or induces more intensive use of other production factors. Using survey data, this paper attempts such an accounting for rice farmers in Bangladesh. We compare outcomes for farming with IPM and conventional techniques, using input-use accounting and conventional production function estimation. All of present results suggest that the productivity of IPM rice farming is not significantly different from the productivity of conventional farming. But as IPM reduces pesticide costs with no countervailing loss in production, it appears to be more profitable than conventional rice farming. Present results also suggest substantial health and ecological benefits. Successful IPM adoption is needed thereby requiring institutional support for collective action.

Key words: Integrated pest management, conventional farming, pesticides, profitability, productivity, sustainability, health and environment

INTRODUCTION

FAO[1] estimated the global harvest losses due to pests to be about 42 % of attainable production. It highlighted the paradox between the increase of global crop losses over time and the growth of chemical pesticide use. Experts believe that if current trends continue dependence solely on chemical pesticides will not be a sustainable solution from either an economic or an environmental point of view. Integrated Pest Management (IPM) is seen as the way forward to achieve sustainable agricultural production with less damage to the environment. While IPM has no standardized definition, it is commonly referred to as a diverse mix of approaches to manage pests and keep them below damaging levels, using control options that range from cultural practices to chemicals. In practice, IPM ranges from chemically based systems that involve the targeted and judicious use of synthetic pesticides, to biologically intensive approaches that manage pests primarily or fully through non-chemical means.

Approximately 84% of Bangladesh's people are directly or indirectly dependent on agriculture for their livelihood and agriculture contributes about 18% of gross domestic product[2]. Rice is the major staple crop, accounting for 70% of the cultivated area, 78% of the irrigated area, 52% of agricultural GDP and 71% of caloric intake[3]. Plant, animal and insect pests pose a constant threat to rice production, inflicting losses conservatively estimated at 10-15% annually[1]. Farmers have used toxic chemicals extensively for pest control, because of their reputation for speed and effectiveness. However, rising use of chemical pesticides has also posed serious health risks, as well as threatening widespread ecological damage. These problems will undoubtedly increase if Bangladeshi farmers respond to rapidly-rising food demand by intensifying their use of chemicals for pest control. In response to rising concern about the sustainability of conventional agriculture, the government has collaborated with international assistance agencies to promote Integrated Pest Management (IPM). Since chemical pesticides are expensive for poor farmers, IPM also offers the prospect of lower production costs and higher profitability. Of course, adoption of IPM may reduce overall profitability if it also lowers productivity, or induces more intensive use of other production factors. However, application of IPM techniques may also raise overall productivity, by encouraging more effective use of other inputs. Data scarcity has hindered a full accounting of IPM's impact on profitability, health and local ecosystems. Using new survey data, this paper attempts such an accounting for farmers in Bangladesh. We compare outcomes for farming with IPM and conventional techniques, using simple input-use accounting and estimation of conventional production functions, along with farmers' assessments of their own health status and local ecological conditions.

THEORETICAL FRAMEWORK

IPM concepts and definitions: IPM includes divergent approaches ranging from methods based on rational management of chemical pesticides to systems based on ecosystem management that include health issues and human capital development. Ten indicators were selected to classify the IPM definitions used by the different organizations. Most organizations use IPM definitions that combine several of the elements mentioned here. Meanings of such IPM definition indicators are as follows:

- Mix of Techniques: This includes the basic techniques of IPM without indicating a preference. In practice, this can mean the use of chemical pesticides as a default option if preference for these strategies is heavily entrenched.
- Economic Factors /Economic and damage threshold levels: Farmers base their decisions on a comparative assessment of the potential crop loss and the costs of pest control. In many cases, this may lead to a rationalization of previous overuse of chemical pesticides. However, actual substitution of other pest management practices for pesticide use hinges critically on the availability of locally adapted information about thresholds and the risk and time preferences of the farmers.
- Selective Pesticide Use: The most suitable pesticide is used, considering potential interruption of the agro-ecosystem functions and environmental and health aspects. There are no provisions on how the integration with non-chemical pest management practices should take place.
- Preference to Non-Chemical Measures: Alternative methods of pest management are chosen over the use of agro-chemicals wherever feasible.
- Minimization/ Reduction of Pesticide Use: IPM practices are favored that involve a reduction of pesticide use. This is particularly appropriate if there is a positive correlation between pesticide use levels and negative impacts. However, no preference is given for replacing the most problematic pesticides with more benign practices.
- Minimization/ Reduction of Risks to Health, Environment: IPM practices are favored that reduces the risks to the environment and public health. In other words, the most problematic pesticides are addressed first. Pesticide risk reduction is preferred, with the development of sound agronomic practices relegated to a lower priority.
- Ecosystem Management: IPM is regarded as a management system that is based on understanding the entire ecosystem of the field and related areas.
- Recognition of Farmer Knowledge (participatory): IPM is developed by using the farmer's indigenous knowledge and knowledge of his/her own field.
- Favoring Local Solutions: Preference is given to local decision making over external and centrally planned interventions.
- Sustainability Concept: IPM is regarded as a holistic approach for sustainable development combining economic, social and environmental aspects.

Almost all of the definitions agree on some basic elements of what constitutes IPM. These basics include the technical and economic dimensions, as well as the reduction of health and environmental risks and a farmer-centered view. Only one contentious area still exhibits a lack of consensus: the role of chemical pesticide use in IPM approaches. Some organizations link IPM to a reduction in chemical pesticide use; others avoid this link.

Trends affecting pest managemen: While farmers have been doing pest management since the onset of agricultural production, the discovery of the pesticidal properties of synthetic chemicals in the middle of the twentieth century revolutionized agriculture. DDT was discovered as an insecticide in 1939 and was used extensively in agriculture and for public health programs. Subsequently, other insecticides, herbicides and fungicides were developed. Their large-scale use started in farming in industrialized countries, resulting in large increases in production and/or cost savings on labor. The first green revolution, which began in the1960s, made high-yielding crop varieties available to developing countries, especially in Asia. Exploitation of the production potential of these varieties stimulated the use of fertilizer and pesticides. This dynamic led to large increases in food production in many countries but also to growing pesticide use.

Rationale for IPM: During the 1960s, due to problems with pesticide resistance in insect populations, a backlash against the agricultural pesticide revolution took place.

Integrated Pest Management (IPM) was developed by entomologists as a technical system to minimize the occurrence of resistance and to sustain the long-term effectiveness of pest control[4].

A second major factor that boosted interest in IPM was the concern about environmental impacts of pesticides, particularly the group of organochlorines. Rachel Carson's book, Silent Spring[5], raised public awareness and prompted policymakers to regulate pesticide use. In the early 1970s, DDT was banned in many industrialized countries. The 2001 Stockholm Convention on Persistent Organic Pollutants enacted a global ban of DDT, except for limited use in public health. Since then, evidence of the health and environmental side effects of other pesticides has become known and led to further restrictions in pesticide availability. Thus, the rationale for IPM comes from two different angles: (1) the limitations in the long-term effectiveness of synthetic chemicals for pest management and (2) the concerns about the negative health and environmental side effects of their use.

IPM is more an approach to sustainable crop protection than a technology or a technology package. In IPM, the available techniques are combined in an integrated management strategy aimed at keeping pest levels below a desirable level. From Schillhorn-Van Veen *et al.*,[6] we can summarize the main features of IPM involving the use of non-chemical methods of pest control:

- Biological controls: the use of the natural enemies of crop pests, often called beneficials which include parasites, predators and insect pathogens. Environmentally friendly chemical interventions sometimes are included in biological controls, such as the use of semiochemicals, including pheromones and feeding attractants and biopesticides, for example, specific and beneficial friendly insecticides.
- Cultural and crop or livestock management controls: tissue culture, disease-free seed, trap crops, cross protection, cultivation, refuge management, mulching, field sanitation, crop rotations, grazing rotations and intercropping.
- Strategic controls: planting location, timing of planting and timing of harvest.
- Genetically based controls: insect- and disease-resistant varieties and root stocks.

Thus IPM combines natural forms of control, taking advantage of ecological relationships in the agricultural system, with economically derived rules for the application of pesticides. However, the pesticide use in IPM differs from the approach used in conventional pest control. When possible, IPM relies on pesticides that target specific pests, can be applied at lower rates and are less toxic to beneficial organisms. New application methods are being developed that employ biological material such as pheromones and feeding attractants to lure the target pest to the pesticide. Application rates, timing and frequency are chosen to minimize effects on beneficials. Pesticides that can be substituted for one another are interchanged to slow the development of pest resistance to pesticides. Often, the level is determined by the damage in economic terms. Implementation of IPM comprises:

- knowledge about the techniques,
- Management skills to adapt the available tools to the conditions of the local agro-ecological environment and
- information concerning the status of pests, predators and other environmental factors influencing crop damage.

Therefore, IPM is a more complex approach to pest management than a purely chemicals-based control strategy, the latter often following calendar dates or growth stages of the crop. The following factors also will affect the adoption of IPM: the state of the agro-ecology; the history of pesticide use; the farmer's access to knowledge, information and inputs; his or her attitude toward pest management and risk avoidance; and the prices of inputs and commodities. It is quite evident that the use of purely chemical pesticides rarely qualifies for being called IPM if this choice is not preceded by an information-intensive decision-making process. However, purely biologically based pest management strategies often are economically viable only over the longer term, because the biological equilibrium of the soil requires time to adjust. In such cases, rationalization of pesticide use may be the first step toward making pest management more sustainable. Benbrook *et al*,[7] descsibes the adoption of IPM can best be described as a continuum ranging from low to high use of biologically based techniques. A similar approach was used in a recent study of IPM adoption in the United States[8]. Approximately 70 % of the growers adopted 1 of 4 categories of pest management practices: prevention, avoidance, monitoring, or suppression. The USDA counted use of any one of these practices as fulfillment of the IPM target set by the government. However, most of these farmers used practices that could not be directly related to the reduction of chemical pesticides. According to the FAO study, these practices could be called rudimentary IPM but would not qualify for a biologically based definition of IPM. For example, the FAO study assessed that biologically based IPM techniques--protecting beneficial organisms, disrupting pest mating, using biological pesticides and using crop varieties genetically modified to resist insects in corn--were used by only 18 % of the growers.

TRENDS IN BANGLADESH AGRICULTURE

Pesticide use: Like many developing countries, Bangladesh has promoted the use of pesticides to expand agricultural land and increase output per acre. Promotional activities have included extension services and significant subsidies. Table 1 shows that pesticide use has more than doubled since 1990, rising from 1532 million metric tons to 3159 million metric tons in 2000. An FAO[1] analysis of pesticide composition in Bangladesh has revealed high shares of toxic chemicals that epidemiological studies have found to cause cancer, genetic damage, fetal damage and severe allergic responses in exposed populations.

Many pesticides used in Bangladesh are banned or restricted under international agreements[9]. In addition, several studies have shown that inadequate product labeling and farmers' lack of information have led to widespread overuse or misuse of dangerous pesticides. Substantial anecdotal evidence suggests that pesticide poisonings and ecological damage have become common in Bangladesh[10].

Table 1:Trends in pesticide use, 1990-2000 (in Million MetricTons)

Years	1990	1991	1992	1994	1995	1996	1997	1998	1999	2000
Pesticides	1532	1547	1453	1487	1702	1919	1993	2141	2520	3159

Source: FAO,[1].

IPM in bangladesh agriculture: Bangladesh's IPM activities began with rice in 1981 and the FAO played a strong catalytic role with government officials and the donor community. The program provided capacity-building for the Department of Agricultural Extension (DAE), introduced Farmer Field Schools and trained representatives of local NGO's. Subsequently, the government and NGO's initiated several IPM projects for rice and vegetables with donor funds. At present, the Plant Protection Wing of the DAE is responsible for the implementation of IPM activities[1]. In this context the National Agricultural Policy of Bangladesh in Pest Management is noteworthy which is expain as .

National agricultural policy of bangladesh: pest management policy: Integrated Pest Management (IPM) will be the main policy for controlling pests and diseases. More importance will be given to the following activities for pest control under the Agriculture Policy:

- Farmers will be motivated to use more pest resistant varieties of crops. Modern cultivation practices will be followed so that the incidence of pest infestation is reduced.
- Use of mechanical control measures such as light trap, hand net, etc. will be increased and popularized. Biological control measures will be used to destroy harmful insects and preserve the useful ones.
- Regular training and discussion programs on IPM will be conducted among the farmers under the supervision of Union Agricultural Development Committee with a view to successful introduction and popularization of the method at the farmers' level.
- Pest surveillance and monitoring system will be strengthened.
- Chemical pesticides will only be used in cases where IPM fails to control the pests. The following measures will be taken in respect of distribution and use of chemical pesticides in the light of existing rules and regulations:
- Production, import, distribution or use of any chemical pesticide will be banned which is directly or indirectly harmful for human, animal and aquatic health.
- Use of any chemical pesticide harmful for natural environment will be discouraged and eventually banned.
- The system of approval of pesticides at the national level will be continued and its monitoring along with the testing of effectiveness of approved pesticides will be strengthened.

PRESENTATION AND RESULTS OF THE SURVEY DATA

This study is based on a field level survey of some 200 Bangladeshi farmers from seven northern districts in Bangladesh in the year of 2004. We used structured questionnaires to collect information on conventional and IPM farming techniques, pesticide use and practices, applicator precautions and damage-averting behaviour, health effects and environmental impacts. To provide greater depth, we also interviewed 100 randomly selected rice farmers who currently use IPM. We also surveyed 100 farmers who use chemical pest controls. Table 2 shows the regional distribution of farmers in our sample.

Table 2:District-wise distribution of survey respondents

Districts	Conventional farmers	IPM farmers
Rajshahi	15	15
Nawabganj	20	15
Bogra	15	15
Naoga	15	15
Natore	15	10
Pabna	10	15
Joypurhat	10	15
Total	100	100

Among the surveyed IPM farmers, reported techniques include manual removal of pests (74% of the sample), use of natural parasites and predators (62%), light traps (15%), crop rotation (10%) and smoke (5%). All of the surveyed IPM farmers received formal training, with more than 90% identifying Agriculture Ministry officials as the providers. The farmers attributed their adoption of IPM to Ministry officials' recommendations (51%); cost-saving from reduced pesticide use (43%); environmental benefits (22%) and improved health (66%). About 46% reported increased output and reported pesticide use fell by 58%.

ADOPTION OF IPM AND THE DETERMINANTS

IPM programs have existed in our survey areas for twenty years, so it is reasonable to assume that most farmers have at least some information about them. Farmers' adoption of IPM may depend on a variety of factors, including personal characteristics such as education and experience, farm characteristics such as production scale and selective judgments by Agriculture Ministry official charged with promoting such programs. Some personal and farm characteristics that influence IPM adoption could also affect productivity, so it may be important to introduce controls for these variables in a comparison of IPM and conventional farming. In present study we construct and estimate the following regression equation to chalk out the determinants of IPM :

$$IPM = EDU + AGE + EXP + FSC + OWN + TRN + PHL + E \quad (1)$$

Where: IPM= Integrated Pest Management
EDU= Level of education of the farmer
AGE= Age of the farmer
EXP= Experience of the farmer
FSC= Firm's scale of production
OWN= Level of ownership
TRN= Training on IPM techniques
PHL= Poor health of the farmers
E= the error components of the regression equation

Using linear probability and probit models, we test for the effects of age, education, farming experience, ownership status, prior training in pesticide use, production scale and health status on IPM use. Our prior expectation is that education; farm ownership, prior training and poor health are positively related to IPM adoption, while age and farming experience may be negatively related. More educated farmers may be more receptive to new techniques; owners and unhealthy farmers may perceive greater long-run gains from adoption; prior training in pesticide handling may encourage IPM adoption, by sensitizing farmers to the hazards of pesticide use; older farmers and those with long experience in conventional farming may resist new approaches. We are agnostic about production scale.

Table 3: Determinants of IPM adoption in rice production

Indicators	Linear Probability Estimate	Probit Estimate
Age	0.016 (3.51)**	0.034 (3.54)**
Education	0.078 (5.57)**	0.29 (5.41)**
Ownership	0.134 (2.22)*	0.45 (2.64)*
Training	0.37 (4.17)**	1.15 (3.69)**
Experience	-0.004 (1.37)	-0.018 (1.30)
Farm Scale	0.001 (0.14)	0.003 (0.14)
Poor Health	-0.066 (1.72)	-0.211 (1.63)
Constant	-0.223 (2.44)**	-2.412 (6.45)**
Observations	100	100
R-squared	0.18	

Absolute value of t statistics in parentheses * significant at 5%; ** significant at 1%

Present estimation results (Table 3) confirm some of our prior expectations but contradict others. Education, ownership, prior training, experience and poor health all have the expected signs and the first three variables are highly significant by the conventional criteria. However, age has an unexpected, positive effect on adoption probability. Production scale is insignificant, suggesting (ceteris paribus) that farmers do not perceive greater scale economies in IPM than in conventional rice production. We conclude that personal and farm characteristics are significant determinants of IPM adoption and we control for these characteristics in our production function estimation because they may affect farming efficiency as well.

COMPARATIVE INPUT USE, PRODUCTIVITY AND PROFITS

We use two quantitative techniques for assessing IPM and conventional techniques in rice production: Comparative estimates of input-output relationships and production function estimation. In both cases, we control for farmers' characteristics (age, education, farming experience, ownership status, prior training, production scale, health status) that may affect both productivity and the propensity to adopt IPM.

Input-Output Results: For each farm in the sample, we calculate Input-Output (IO) coefficients for land, family labor, hired labor, capital, irrigation, seed, fertilizer and pesticide. We test for significant differences between mean coefficients for conventional and IPM farming by regressing the IO coefficients on a dummy variable for IPM use. We estimate the regression equation in the following form:

Y=B+LND+FLB+HLB+CAP+IRR+SED+FER+PST+IPM+E (2)

Where: Y= Input-Output (IO) coefficient
B= Constant coefficient of the equation
LND= Land size of the farmer
FLB= (size of) Family Labour of the farmer
HLB= (size of) Hired labour by the farmer
CAP= Amount of capital or the costs of capital
IRR= Costs of irrigation
SED= Costs of seed
FER= Costs of fertilizer
PST= Costs of pesticides
IPM= Use of IPM, the dummy variable
E= Error components of the equation

Since all distributions of IO coefficients are highly skewed, we guard against outlier effects by estimating log regressions as well as linear regressions. The results, shows in Table 3, are similar for both specifications. Family and hired labor inputs per unit of output are generally lower for IPM production, suggesting that time savings from reduced pesticide applications more than compensate for reallocation of some labor to IPM-related activities. Seed inputs are also significantly lower per unit of output. As expected, pesticide inputs per unit of output are significantly lower for IPM production in both the linear and log models. However, IO coefficients for land, capital, irrigation and fertilizer are not significantly different in the two modes of production.

Present results suggest that IPM may be more profitable than conventional farming, since no IO coefficient is significantly higher for IPM and several are significantly lower. For pesticides, the savings are clear: Conventional farmers use an average of 2.23 kg of pesticides per acre, while IPM farmers use .60 kg/acre. Pesticide purchase shares of variable costs for non-IPM and IPM farmers are 9.4 and 2.6%, respectively.

HEALTH EFFECTS OF IPM ADOPTION

Present survey results suggest that farmers' exposure to toxic pesticides is quite serious in Bangladesh, while our productivity analysis suggests that any direct benefits from pesticide use have been offset by adverse impacts on soil organisms, natural pest predators and farmers' health and productivity[11]. Exposure can produce numerous acute effects, depending on a pesticide's toxicity and the dose absorbed by the body. For pesticides with high acute toxicity, exposure can produce intoxication symptoms within minutes or hours, including headaches, flu-like symptoms, skin rashes, blurred vision and other neurological disorders[12].

Prolonged exposure can lead to more serious cardiopulmonary, neurological and hematological symptoms, as well as skin disease[13]. A detailed health examination of farmers in our survey was beyond the scope of this study. Instead, our analysis relies on self-reported health effects. Among conventional farmers, 32% report frequent health problems such as eye irritation, headaches, dizziness, vomiting, shortness of breath, skin effects and convulsions. Among IPM farmers, 22% report similar health problems. Of these, 56% report that the health of the laborers working in their fields improved after they switched to IPM. Although IPM farmers have a lower reported incidence of health effects, we find that the difference between the two groups is not significant at the 95% confidence level. The difference may be greater for farmers who have used IPM for an extended period, but our survey has not recorded IPM adoption dates. For more recent adopters, our result may be biased by a simultaneous relationship between IPM

Table 4: Impact of IPM on Input-Output Ratios for Rice Production

	Input							
	Land	Family Labor	Hired Labor	Capital	Irrigation	Seed	Fertilizer	Pesticide
Linear Estimates								
IPM	0.000	-0.005	-0.005	-0.052	0.141	-0.055	0.000	-0.001
	(0.21)	(3.01)**	(1.83)	(1.31)	(1.48)	(2.25)*	(0.09)	(6.02)**
Constant	00.002	00.017	00.022	00.654	01.062	00.300	00.084	00.002
	(44.44)**	(21.42)**	(19.21)**	(33.56)**	(28.23)**	(31.26)**	(38.55)**	(22.31)**
Obs	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00.00
R2	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.04
Log Estimates								
IPM	0.051	-0.213	-0.215	-0.048	-0.049	-0.153	0.009	-0.666
	(1.21)	(2.25)*	(3.15)**	(0.86)	(0.87)	(2.23)*	(0.21)	(3.54)**
Constant	-008.649	-004.326	-004.215	-00.841	-00.126	-01.221	-02.266	-006.151
	(489.75)**	(109.17)**	(140.22)**	(23.44)**	(0.51)	(55.85)**	(116.45)**	(128.23)**
Obs	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
R2	0 .00	0.01	0.01	0.00	0.00	0.01	0.00	0.02

Absolute value of t statistics in parentheses
significant at 5%; ** significant at 1%

use and health: Adoption of IPM may well improve health, even in the short run, but farmers who attribute their poor health to pesticide use may be more likely to adopt IPM. At present, we do not have sufficient evidence to attribute strong health improvements to IPM adoption in our sample.

ENVIRONMENTAL EFFECTS

Recent evidence suggests that pesticide use in Bangladesh has damaged organisms not targeted by applications, while pesticide run off has polluted many waterways. For example number of newspapers in Bangladesh[14-16] reported the poisoning and death of thousands of birds in Ustad by Cypermethrin- treated eggplant fields in the Dakatia village of Jessore, a district in the Western border region of Bangladesh. A government study conducted in 1995 found that 11% of tested water samples contained pesticide residues higher than WHO guidelines[17]. Much of the damage can be attributed to the timing, frequency and dose-intensity of applications, as well as use of inappropriate products and lack of information about toxicity. When asked about environmental effects, nearly 70% of the IPM farmers in present survey report improvements in soil, water and air quality after adoption of IPM, as well as increased numbers birds, fish and soil organisms such as earthworms.

POLICY SUGGESTIONS

Sustainable agricultural development requires multi-dimensional approach and introducing IPM is the one important of those. However from the growing concern over increasing food security, marketable surplus from agriculture and for the purpose of the sustainable development of the farm and the farmer of the developing countries following steps could be taken:

- IPM's importance for addressing food safety and quality should be especially recognized by the private sector and the NGOs.
- IPM should target as an important element in the development of export markets for high- value agricultural products as the domestic consumers are yet to take this positively.
- It is important to prepare national pesticide residue standards to comply with the market and food quality regulations in cooperation with the industrial countries.
- Training farmers to rely less on pesticide more depend in IPM, while trying to optimize profits.
- A stronger role for the pesticide industry in promoting IPM need to concur with the commitment to reduce pesticide use.

CONCLUSIONS

In this study survey data on rice production have been used to assess the net economic, health and environmental benefits of switching to Integrated Pest Management in Bangladesh. We have assessed the net economic benefits of IPM adoption in two productivity comparisons, using input ratios and standard production functions. In both the cases, we have found no significant difference in productivity for IPM and non-IPM rice farming. Pesent results hold when we control for hypothesized farm-efficiency factors that also affect the probability of IPM adoption. Present evidence suggests that IPM adoption increases profits for rice farmers, since pesticide costs are reduced with no countervailing reduction in output. The reported incidence of sickness is lower for IPM farmers, although the difference is not statistically significant in our sample. Most IPM farmers also report that environmental conditions improved after adoption of the new technique. To summarize, our evidence suggests that further promotion of Integrated Pest Management for Bangladeshi rice farmers will yield economic, health and environmental benefits for rural communities. As we have noted, local adoption of IPM is a collective decision because farmers' pesticide applications affect their neighbors' fields as well. Effective promotion strategies should therefore emphasize collective gains from adoption, as well as training of individual farmers in the relevant skills.

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