ISSN: **2958-2776**
Vol.: 01 Issue: 01 December 2022
Journal of One Initiative Research and Development
an international multidisciplinary journal

Effect of Integrated Pest Management (IPM) on Rice Production: A Multivariate Approach Based on Cobb-Douglas Production Function and Propensity Score Matching

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Abstract

Integrated Pest Management has a broad-based approach founded on a sound ecological understanding towards producing and preserving different crops. Now-a-days, IPM has been considered globally as one of the best methods in this regard. The following study was conducted on 405 farmers (108 IPM users and 297 conventional farmers) of Dhaka, Chittagong, Barisal, Rangpur and Sylhet to assess the effect of IPM on rice production. Using statistical software STATA, Cobb-Doulas Production Function was fitted to the data to estimate the effect of IPM on rice production. Also Propensity Score Matching was conducted to identify the factors for adoption of IPM. It was found that IPM can change the production system and it also may reduce production cost. And most important fact is that IPM has some positive effects on the farmer's health except smoke. 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.

Keywords: Integrated Pest Management, Rice production, Cobb-Douglas production function
JEL Classification: O13, Q15, D24, E23

Article Info:
Received: 29 July 2022
Accepted: 14 October 2022
Research Area: Business Statistics
Number of Tables: 04
Authors' Country: Bangladesh

1.0 Introduction

Pests take a heavy toll on food production in Bangladesh, in some cases destroying as much as one-quarter of annual crops. In order to fight pests, farmers in Bangladesh heavily rely on pesticides, while pesticides may temporarily prevent, control or kill pests, their prolonged and intensive use has profound negative impacts. Apart from economic losses, environmental and health concerns are also significant. In different parts of the country, so-called “Integrated Pest Management” (IPM) has helped to reduce the use of chemicals and even increase yields. By reducing the use of pesticides, Integrated Pest Management (IPM) offers an environment-friendly and more effective approach to pest control. An important principle of IPM is to focus on natural solutions, for instance by promoting beneficial insects that attack target pests.

At present, IPM has a broad approach to crop production based on a sound ecological understanding. Even it goes beyond the production as it also includes the storage of crops at all levels. IPM enables farmers to grow a healthy crop and to increase their farm output and income on a sustainable basis while improving the environment and community health at the same time. In the past, pesticides were considered as the ‘panacea’ for the control of agricultural pests. Although pesticides may provide temporary relief, it is now widely accepted that indiscriminate and excessive use of pesticides and the long-term dependency on them threaten the sustainability of agricultural production. Over dependence on chemical pesticides is not only expensive but also leads to negative environmental impacts, in addition to increased health hazards to both the growers and consumers of crops.

Considering the facts that (a) Bangladesh needs to increase its food production on a sustainable basis; (b) Pests continue to cause serious damages to crops; and (c) The use of toxic pesticides is the main method of pest control and that such continued heavy reliance on chemicals would lead to serious environmental and human health problems, pest resurgence, new pest problems and development of resistance- in Bangladesh perspective there is a need for an alternative method rather than to rely solely on pesticides. Integrated Pest Management (IPM) has now been considered as the most appropriate one in this respect. The present study is designed to assess the effect of IPM on rice production.

2.0 Literature Review

The findings of Santha (1992) revealed that a majority of farmers (48 per cent) was under high awareness category on cultural methods of IPM, while 22.5 and 20 per cent belonged to low and medium level categories respectively. In general, most of the IPM respondents belonged to high awareness category, while only one-fourth of the non-IPM farmers were in the high awareness category. According to Sorensen (1993) most farmers were using some IPM tactics, but were not incorporating a total systems approach in their farming operations.

According to Sujatha (1995) adoption is the acceptance and application of some or all the recommendation practices by the respondents in crop husbandry.

Giriram and Sawarkar (1996) defined awareness as the type of social component which increases the consciousness among the people and generate confidence in the individual to face the problems contemplatively. Thanulingam (1996) defined awareness as the ability of consumer to recall more or less currently the various aspects of consumer movement and consumer rights and the respondents' clarity of understanding of the selected aspects. Sri Ram (1997) in his study meant adoption as following the eco-friendly agricultural practices in cotton cultivation as recommended by the extension agency. According to Arul Murugan (2000) awareness is the pre - requisite for how to do knowledge and adoption. Priya (2006) defined awareness as the things known to an individual presented as cognitive domain. It is a pre-requisite for adoption of innovation, as this would enable the farmers to completely understand the aspects behind IPM technology for vegetable crops and also its relative advantage. She also defined adoption as a decision to use the practices on continued basis.

During the past three decades, indiscriminate use of chemical pesticides in agriculture has created serious health and environmental problems in many developing countries (World Resources, 1998-99). The World Health Organization (WHO) and United Nations Environment Program estimate pesticide poisoning rates as 2-3 per minute, with approximately 20,000 workers dying from exposure every year, the majority in developing countries.

A FAO 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 (Zahm, Ward and Blair, 1997). Most of these impacts are a direct result of the usage of imbalanced pesticides. Several recent studies have found that inadequate product labeling and farmers' lack of information often lead to widespread use of dangerous pesticides in developing countries. These problems will undoubtedly increase if Bangladeshi farmers' respond to rapidly-rising food demand by intensifying their use of chemicals for pest control.

3.0 Objective of the Study

Considering the importance of agriculture in the socio-economic development of Bangladesh, our objective is to compare the outcomes of farming with IPM and conventional techniques, to determine the environmental effect before and after using pesticides and IPM. The ultimate objective of the study is to draw the attention of the authorities of the existing service and of the Government to take necessary initiatives to grow awareness about IPM farming to minimize the health and also environmental hazards.

4.0 Methods and Materials

This study is based on a field level survey of 405 Bangladeshi farmers from five districts: Dhaka, Chittagong, Barisal, Rangpur and Sylhet of Bangladesh collected in the year of 2019. A convenient sampling method was used, but districts were selected from different regions of the country and farmers were selected randomly to ensure proper representation of the sample. Data were collected using structured questionnaires to collect information on conventional and IPM farming techniques, pesticide use and practices, applications precautions and damage-averting behavior, health effects and environmental impacts. To provide greater depth, 108 randomly selected rice farmers who currently use IPM were interviewed. Also 297 farmers who use chemical pest controls were interviewed. The sample size was determined using the following formula:

$$n = \frac{pqz^2}{d^2}$$

Where,

p=assumed proportion in the target population estimated to have a particular characteristic = 0.5 (assumed for this study)

q=1-p = 1-0.5 = 0.5

z= standard normal deviate = 1.96 at 5% level

d=the degree of dispersion = 4.87% = 0.0487

Thus, $$n = \frac{pqz^2}{d^2} = \frac{0.05\times0.05\times(1.96)^2}{(0.0487)^2} = 404.94 \approx 405$$

So, 405 primary data on farmers were collected for the above study.

Though convenient sampling method is used, to ensure the proper representation of farmers, data were collected from all types of IPM users and conventional farmers. Among the surveyed IPM farmers, reported techniques include manual removal of pests (70% of the sample), use of natural parasites and predators (65%), light trap(20%),crop rotation (10%) and smoke (5%). More than 90% of the surveyed IPM farmers received formal training from Agriculture Ministry officials as the providers.

After collecting data from the field, they were entered into computer using statistical software SPSS and then they were analyzed using statistical software STATA. Cobb-Doulas Production Function was fitted to the data to estimate the effect of IPM on rice production. Also Propensity Score Matching was conducted to identify the factors for adoption of IPM.

5.0 Findings and Discussion

A. Fitting Cobb-Douglas production function

We have estimated a standard Cobb-Douglas production function with factor and material inputs: land, family labor, hired labor, capital, irrigation, seed and fertilizer. We include pesticide inputs and a dummy variable for IPM use in alternative specifications, since IPM explicitly minimizes pesticide use. In addition, we allow for Hicks-neutral efficiency differences across farms that are attributable to age, education, ownership, pesticide application training, farming experience, poor health, and production scale. The production function is as follows:

$$\ln Y_i = \beta_0 + \sum \beta_n x_i + \sum \alpha_i \ln z_i + u_i$$

where,

Y_i = rice output (in kg)

x_i= land (acres), labor (man-days), capital (in Taka), irrigation cost (Taka), fertilizer (kg), IPM (dummy variable: 1 if IPM; 0 otherwise) or pesticide (kg)

z_i= age (years), education (categorical: 0-5 (No schooling, Primary, Secondary, Higher school, other), ownership (1 if owner of farm; 0 otherwise), training (1 if prior training in pesticide applications; 0 otherwise), farming experience (years), poor health (1 if significant self-reported health problems; 0 otherwise), farm scale (log of total farm size in acres)

u_i= stochastic error term

Table 1: Cobb-Douglas Production Function Result

	(1)	(2)	(3)	(4)	(5)	(6)
C	6.661 (20.32)**	6.670 (25.55)**	6.550 (28.33)**	6.855 (27.55)**	6.421 (29.38)**	6.884 (24.58)**
LAND	0.595 (20.32)**	0.621 (14.52)**	0.645 (15.66)**	0.650 (17.52)**	0.596 (14.66)**	0.642 (21.50)**
FAMILY_LABOR	-0.035 (1.18)	-0.036 (1.22)	-0.062 (0.97)	-0.063 (0.58)	-0.050 (0.25)	-0.051 (0.17)
HIRED_LABOR	0.147 (1.59)	0.146 (1.89)	0.131 (1.56)	0.131 (1.62)	0.095 (1.46)	0.094 (1.23)

CAPITAL	0.091 (2.58)**	0.087 (3.01)**	0.071 (2.58)**	0.068 (3.33)**	0.058 (4.25)**	0.064 (3.95)**
IRRIGATION	0.881 (6.25)**	0.845 (5.66)**	0.991 (6.26)**	0.951 (5.98)**	0.772 (4.25)**	0.825 (4.98)**
SEED	0.048 (2.85)	0.059 (1.98)	0.049 (1.58)	0.036 (1.79)	0.055 (2.55)	0.069 (2.59)
FERTILIZER	0.075 (3.56)**	0.082 (3.26)**	0.091 (4.21)**	0.094 (4.23)**	0.100 (3.98)**	0.998 (3.78)**
PESTICIDE	-0.006 (0.86)		0.007 (0.25)		-0.032 (0.75)	
IPM		-0.032 (0.88)		-0.025 (0.75)		0.025 (0.80)
REGIONS						
BARISAL			-0.153 (2.52)**	0.157 (2.58)**	-0.198 (3.29)**	-0.198 (3.50)**
CHITTAGONG			-0.162 (1.09)	-0.161 (1.15)	-0.110 (2.04)	-0.113 (1.12)
DHAKA			-0.149 (3.50)**	-0.191 (3.22)**	-0.151 (2.95)**	-0.123 (2.84)**
RANGPUR			0.171 (2.87)	0.154 (3.25)	0.164 (3.95)	0.541 (3.25)
SYLHET			-0.199 (3.98)*	-0.221 (4.02)*	-0.151 (3.56)*	-0.166 (4.25)*
EFFICIENCY FACTOR						
AGE					-0.001 (0.15)	-0.001 (0.22)
EDUCATION					-0.032 (1.52)	-0.033 (1.62)
OWNERSHIP					0.035 (1.55)	0.036 (1.25)
TRAINING					-0.023 (0.75)	-0.013 (0.86)
EXPERIENCE					-0.004 (0.88)	-0.004 (0.75)
POORHEALTH					0.002 (0.25)	0.005 (0.49)
OBSERVATIONS	405	405	405	405	405	405
R-squared	.68	.65	.62	.70	.69	.60

Absolute value of t statistics in parenthesis *Significant at 5% **Significant at 1%

Table 1 presents estimates for equations that include IPM and pesticide use, with and without regional dummies and efficiency variables. All inputs except labor and pesticides are significant in all or most of the models. Our results suggest that the survey farmers are operating under surplus labor (zero marginal productivity) conditions for both family and hired labor. We also find no evidence of positive productivity for pesticide use, possibly because direct benefits of pesticides are counteracted by their toxic impact on beneficial soil organisms and insects that prey on pests. We obtain functionally equivalent results for the IPM dummy: Farmers who reduce pesticide use by adopting IPM are neither more nor less productive than conventional farmers. This result is not affected by the inclusion of regional dummies and efficiency-related variables. Many of the farmers are highly significant, suggesting important roles for local soil and weather conditions, while we find no significance for any of the variables that were hypothesized to affect efficiency as well as IPM adoption.

B. Propensity Score Matching

We want to know the effect of IPM on production. But IPM itself depends on several factors such as age of the farmers, their education level, training experience etc. So we need to control these factors. This task is achieved by propensity score matching. First we need to estimate PROPENSITY SCORE model. The algorithm to estimate Propensity Score is given in Table 2; the result given in Table 2 shows that AGE, EDUCATION, OWNERSHIP and TRAINING has positive effect for adopting IPM and FARM & EXPERIENCE has negative effect for adopting IPM. In the common support region STATA provides estimated Propensity Score by percentile which is given in Table 3. STATA provides estimate that is common support which is [0.1262, 0.5221] representing the range of Propensity Score that we need to adjust for.

ISSN: 2958-2776

Table 2: Algorithm to Estimate the Propensity score

The treatment is IPM

IPM	Freq.	Percent	Cum.
0	297	73.33	73.33
1	108	26.67	100.00
Total	405	100.00	

Estimation of the propensity score

```
Iteration 0:   log likelihood = -234.86564
Iteration 1:   log likelihood = -222.83049
Iteration 2:   log likelihood = -222.75397
Iteration 3:   log likelihood = -222.75395

Probit regression                               Number of obs   =        405
                                                LR chi2(6)      =      24.22
                                                Prob > chi2     =     0.0005
Log likelihood = -222.75395                     Pseudo R2       =     0.0516
```

IPM	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
AGE	.0068398	.0101678	0.67	0.501	-.0130887	.0267682
EDUCATION	.1445483	.0683039	2.12	0.034	.0106751	.2784215
OWNERSHIP	.2226171	.1844239	1.21	0.227	-.1388471	.5840813
TRAINING	.552021	.1399704	3.94	0.000	.277684	.8263579
FARM	-.0768475	.0546055	-1.41	0.159	-.1838723	.0301774
EXPERIENCE	-.0068521	.0113141	-0.61	0.545	-.0290273	.0153232
_cons	-1.422087	.3877366	-3.67	0.000	-2.182037	-.6621377

Note: the common support option has been selected
The region of common support is [.12623767, .52219148]

Table 3: Estimated Propensity Score by Percentile

	Percentiles	Smallest		
1%	.1303591	.1262377		
5%	.1433725	.1280285		
10%	.1634847	.1295894	Obs	372
25%	.1940981	.1303591	Sum of Wgt.	372
50%	.2501538		Mean	.2768353
		Largest	Std. Dev.	.1007276
75%	.3517729	.5152608		
90%	.4264128	.5171755	Variance	.010146
95%	.4581767	.517692	Skewness	.5213541
99%	.5152608	.5221915	Kurtosis	2.202151

Next thing STATA shows that the optimum number of blocks which is 3. This number of blocks ensures that the mean Propensity Score is not different for treatment and control in each block. Then it was tested for balancing property and it is found that the balancing property is satisfied which means that in each of these blocks we have not only the Propensity Score similar but also the X characteristic that we matched is also similar. Then we conducted analysis to match the Propensity Score. The result is given in Table 4.

Table 4: Matching of treated and controls (Actual nearest neighbor matches)

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
108	84	0.446	0.130	3.420

Note: the numbers of treated and controls refer to actual nearest neighbour matches

ISSN: 2958-2776

From Table 4, we have ATT estimate with nearest neighbor matching. Here number of treatment is 108 and for them number of control with nearest neighbor is 84. Also ATT estimate is 0.446. Thus, after propensity score matching we see that the ATT estimate is 0.446; which is the difference between production of the farmers who adopted IPM and who didn't adopt IPM after matching. This is the effect that, if some of the farmers adopt IPM their production will increase on an average 0.446 ton per acre. So we can conclude that average production for IPM farmers is higher compared to that of conventional farmers. From the Propensity Score analysis we see that after controlling the effect of AGE, EDUCATION, OWNERSHIP and TRAINING the average production is higher for the farmers who take IPM. So we can conclude that IPM provides higher production compared to the conventional farmers.

6.0 Conclusion and Recommendations

In this paper, new survey data on rice production was used to assess the net economic, health and environmental benefits of switching to Integrated Pest Management in Bangladesh. Our evidence suggests that IPM adoption increases profits for rice farmers, since pesticide costs are reduced with no countervailing reduction in output. Also it was found that IPM can change the production. Also it may reduce production cost. And most important fact is that, IPM has a positive effect on the farmer's health. 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. Again, local adoption of IPM is a collective decision because farmers' pesticide applications affect their neighbors' fields as well. The following recommendations for policy implication were made in view of the overall findings of the study:

i. Farmers training and motivation should be required for IPM adoption.
ii. IPM should be applied at a time when it will be most effective against the crop pest.
iii. Regular monitoring and IPM related research are needed for maintaining the awareness among the farmers.
iv. Effective promotion strategies should introduce to emphasize on training of individual farmers in the relevant skills.
v. Government should play role to enhance IPM program.

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