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Farmers' Perception of Integrated Pest Management and its Impact on Cucumber Production in Bangladesh

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ABSTRACT

IPM is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Farmers' perception of integrated pest management (IPM) and its impact on cucumber (*Cucumis sativus L.*) production were assessed in Bangladesh using few econometric models. A total of 119 cucumber farmers were interviewed in 2015 to achieve the objectives. Most of farmers perceived that IPM was beneficial for farmers' health, water bodies. IPM adoption significantly reduced the pesticide applications cost per hectare ($P<0.01$), while increasing the net return ($P<0.10$) from cucumber cultivation. The adoption of IPM also had a significant and positive impact ($P<0.01$) on the level of technical efficiency of the adopters. The production of cucumber could be increased to a larger extent by improving technical efficiency of the growers. Trainings and demonstration programmes to improve the knowledge and technical skills of farmers are essential. However, findings of this study cannot be generalized, as this was administered on a small number of cucumber farmers. A large-scale survey may be useful in developing a complete scenario for the adoption of IPM in Bangladesh.

Introduction

The use of synthetic pesticides in Bangladesh started from mid-fifties and increased in the early 1970's, partly as a result of government support for chemical control measures to avoid crop losses (Rahman *et al*., 1995; Matin, 2003; Aziz, 2005). Excessive use of pesticides has had adverse effects on the environment and on the farmers' health (Dasgupta *et al*., 2005; Muriithi *et al*., 2016). Inappropriate use of pesticides often raises production costs and reduces net returns from vegetable cultivation. In order to minimize the negative impacts of pesticides, the Government of Bangladesh emphasized the use of integrated pest management (IPM) with the goal of enabling farmers to grow healthy crops, minimize production costs, and increase their incomes on a sustainable basis (GoB, 2002).

IPM is a management approach that involves the enhancement of natural enemy population, the planting of pest resistant crops, adaptation to cultural management practices, and use of pesticides judicially (USDA, 1993). The vegetables IPM in Bangladesh has gained momentum with the introduction of the Integrated Pest Management Innovation Lab (IPM IL), a global research support programme funded by the United States Agency for International Development (USAID), which started operating in Bangladesh in 1998. The present study used data from a sub-project of the IPM IL that involved the transfer of IPM practices to various locations in Bangladesh for a number of vegetables. Among the vegetables, this study focuses on cucumber due to the high adoption of IPM practices in that crop.

Cucumber is one of the important summer season vegetables in Bangladesh. A total of 65,499 metric tons of cucumber was produced at 9,593 ha during the 2017-18 growing season (BBS, 2018). For the control of cucumber pests, the IPM package includes the use of yellow sticky traps for aphids, sex pheromone traps, tricho-compost, and the release of natural pest enemies including ladybird beetles (McCarthy, 2015). Several technology transfer methods, including trainings, small group discussions, and field days, has been used by IPM IL to disseminate the IPM practices and to increase

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knowledge, adoption, and production efficiency of growers (McCarthy, 2015).

Adoption of cucumber IPM is expected to reduce pesticide costs, increase incomes and efficiency of growers. While there is considerable literature addressing the impacts of IPM on eggplant, tomato, and bitter gourd (Rahman *et al*., 2018; Rahman and Norton, 2019), studies on farmers perception and impacts concerning IPM implementation in cucumber are limited in Bangladesh. Exploring farmers' perception of IPM can play a crucial role to increase adoption level of IPM (Rahman, 2020). Certain studies (Karim *et al*., 2013; Akter *et al*. 2016) found that IPM adopters received higher return compared to non-adopters, without considering the selection bias arising when the sample of farmers is non-random. Past studies suggested that excessive pesticide use can have negative effects on farmers' health (Chitra *et al*., 2006; Dey, 2010; Bhattacharjee *et al*., 2013; Khan and Damalas, 2015; Nicolopoulou *et al*., 2016), while farmers' good health has a positive effect on production efficiency (Ajani and Ugwu, 2008; Ulimwengu, 2009; Yamou and Molua, 2018). A few studies (Karim et at., 2013; Islam, 2014; Rahman and Norton, 2019) compared technical efficiency (TE) differences between IPM adopters and non-adopters but, failed to estimate the effect of IPM adoption on TE. Thus, reduction in pesticide use through adopting IPM can reduce pesticide cost, increase income and efficiency of cucumber growers which need to be evaluated for future policy implementation. In the light of the above-mentioned facts, this study was undertaken to know the farmers perception of IPM and its farm-level impacts on cucumber production.

Materials and Methods

Data sources

The present study was conducted in four districts: Jashore, Magura, Barisal, and Jhalokati. These districts were selected by the IPM IL project to correspond with USAID Feed-the-Future (FtF) programme districts. From these four districts, a total of 104 villages were randomly selected. A complete list of vegetables growers was prepared and a total of 838 vegetable farmers were selected randomly for interview. Out of 838 farmers, a total of 751 farmers were interviewed in 2015 (some farmers of the original sample of the 838 farmers had migrated to other villages, while others were not interested in being interviewed). Out of the 751 farmers, all of them, who cultivated cucumber during 2015, were selected as the sample for the present study. Farmers who adopted any of the several IPM practices: use of yellow sticky traps, pheromone traps, tricho-compost, soil amendment with poultry refuse, release of predatory ladybird beetles, grafting, and pest resistant varieties, were considered to be IPM adopters, while the remaining farmers were considered to be non-adopters. A total of 119 cucumber farmers were included, of which 38 farmers were IPM adopters and 81 were non-adopters. Cross-section data on socio-economic characteristics, IPM practices, farmers perception, pesticide applications, labour use, and productivity of cucumber were collected through face-to-face interview. In addition, after data collection, farmers were contacted by mobile phone to cross-check the responses and ask for few new information, such as use of seedling and fertilizer, required for the analysis.

Analytical techniques

Descriptive statistics along with a set of econometric models were used to address the objectives of the study. Following Rahman (2020) farmers' perception of the benefits of IPM was assessed using six-point scale: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree, and 0 = do not know.

Measuring the impacts of IPM

Measuring the impact of a technology adoption based on cross sectional data is always challenging due to potential selection bias. To deal with the selection bias problem, the present study employed propensity score matching (PSM), regularly used in drawing causal inferences (Khan *et al*., 2012; Schreinemachers *et al*., 2016; Gautam *et al*., 2017). PSM helps in creating a counterfactual from control group (in this study non-adopters) based on two conditions; a conditional independence assumption (CIA) and overlap in propensity scores across the adopters and non-adopters. Failing to achieve CIA would mean that there are unobserved factors that affect the outcome and lead to a hidden bias (Caliendo and Kopeinig, 2008). Under the CIA, the average treatment effect on the treated (ATT) was computed as below (Khan *et al*., 2012):

$$ATT = E(Y1 - Y0 \mid X, T=1) = E(Y1 \mid X, T=1) - E(Y0 \mid X, T=0)$$

To estimate the ATT, we first estimated a binary probit model (adopters =1, otherwise =0) to calculate the propensity scores. Finally, using the estimated propensity scores, adopters and non-adopters of IPM were matched and the mean difference of outcome was considered as the impact of adoption. The explanatory variables used in the probit model were selected based on expectation and previous adoption related literatures. Description of the explanatory variables is given in Table 1.

Table 1. Description of the explanatory variables

Variable	Notation	Description
Distance to highway (km)	z_1	Distance in kilometers of highway from the primary farmer's field.
Active member (No.)	z_2	The total number of people in a family. between the ages of 15 to 65 years.
Experience (yrs)	z_3	Vegetable cultivation experience in years of the primary farmer.
Education (yrs)	z_4	Total years of schooling, representing the level of knowledge of the primary farmer.
Farm size (ha)	z_5	Total amount of cultivable land owned by the primary farmer, calculated as: Farm size = own land + rented in + sharecropped in – rented out – sharecropped out
Access to credit (yes/no)	z_6	One (1) if the farmer received loan from any formal source, otherwise 0.
Extension contact (yes/no)	z_7	One (1) if the farmer obtained agricultural information from an agricultural officer or SAAO in the last year, otherwise 0.
Contact with neighbours (yes/no)	z_8	One (1) if the farmer discussed about cucumber cultivation with neighbours in last year, otherwise 0.
IPM training (yes/no)	z_{89}	One (1) if the farmer received training on IPM in the last year, otherwise 0.
Farmers adopting IPM (No.)	z_{10}	Total number of farmers who adopted IPM near the primary farmer's field.

Table 2. Definition of the variables used in stochastic frontier model

Variable	Notation	Description
Seedling	β_1	Farmers were asked about the number of seedlings used in the cucumber plot and later it was converted on per hectare basis.
Human labour	β_2	Human labour was calculated on man-day per hectare basis and eight adult male hours were considered equivalent to one man-day.
Chemical fertilizers	β_3	Total amount (kg) of fertilizers (NPK) used in per hectare of land.
Organic fertilizers	β_4	Total amount (kg) of organic fertilizers (cow dung, tricho-compost) used in per hectare of land.
Material cost	β_5	Per hectare cost of irrigation, pest management, trellis and land preparation were taken together to form the variable material cost.
Yield	Y	Yield was estimated on kg per hectare.

IPM practices were introduced with a view to reduce production cost, increase income and efficiency of the farmers. Based on these criteria, the impacts of cucumber IPM adoption was assessed for the following outcome indicators: Productivity (Kg/ha): Total production of cucumber per season per hectare. Pesticide cost (Tk/ha): Total cost of pesticide spray per season per hectare (Tk is Bangladeshi currency, 1 USD = Tk. 80). Production cost (Tk/ha): Total cost of production was estimated by adding different variable and fixed cost of production. Net return (Tk/ha): Per hectare gross return was subtracted from the variable and fixed cost of production. Technical efficiency (TE) score: TE score of the individual farmers was calculated using Cobb-Douglas type production function.

Measuring technical efficiency

A farm is considered technically efficient if it produces the maximum output from the minimum quantity of inputs. Frontier techniques have been widely used in determining the farm-level TE (Coelli *et al.* 1998; Alam *et al*. 2012). To calculate TE, Cobb-Douglas type stochastic frontier production function (SFPF) was specified as follows:

$$Ln\, Y = b_0 + \sum_{i=1}^{5} b_i LnX_i + vi - ui$$

Where, Y is per hectare yield of cucumber in kg on farm i, X_j is explanatory variables included in the stochastic frontier function, β_j is a vector of parameters to be estimated, v_i is the two sided random error, independent of the u, that allows for random variations in output due to factors, such as omitted explanatory variables, measurement error in y and other exogenous shocks, and u_i is the one sided non-negative error term accounting for farm specific TE. A description of the explanatory variables included in the model is shown in Table 2.

Results and Discussion

Descriptive statistics

Descriptive statistics of the variables used in the PSM and SFPF models are presented in Table 3. Findings indicate that some differences in selected characteristics (distance to highway, training, contact with neighbours, chemical fertilizer, and material cost) were significant between adopters and non-adopters, while other characteristics were almost identical. Significant differences between adopters and non-adopters in terms of training and contact with neighbouring farmers suggest that the farmers-to-farmers extension approach may play an important role in the adoption process.

Farmers' perception of IPM

A large number of farmers (34%) have no idea that whether or not IPM is more effective than synthetic pesticides, while only 16% agree that IPM is more effective than synthetic pesticides for pest control. More than 60% of the farmers agreed that IPM provides health benefits to them and also is beneficial for water bodies, which confirms findings of Roy *et al*. (2009). This may be due to the fact that IPM is a holistic approach and discourages excess use of harmful chemicals that can cause health problems. More than 45% of the farmers agreed that IPM can easily be integrated with traditional pesticide-based pest control technologies for better results (Table 4). It is also evident from Table 5 that a large proportion of the farmers did not know anything about the beneficial effects of IPM, which indicates that the IPM concept is still not clearly understood by farmers. More awareness building programmes should be arranged in the study areas to encourage farmers to reduce harmful pesticide applications. Previous studies have also shown that improving farmers' technical knowledge of IPM by extension services can minimize excessive insecticide spraying (Allahyari *et al*. 2016; Allahyari *et al*. 2017).

Adoption of IPM practices

Table 5 presents the percentage of farmers adopting various IPM practices in the study areas. It reveals that 32% of farmers used sex pheromone traps in their cucumber fields followed by poultry refuse for soil amendment. Kabir and Rainis (2015) also stated that among different IPM practices most farmers in Bangladesh adopted sex pheromone traps and soil amendment methods. These two technologies are available, cheap, and effective in controlling insects and soil borne diseases compared with pesticides. Only a few farmers used yellow sticky traps and tricho-compost. The findings also indicate that farmers in the study areas hardly used any complex IPM practices, such as biological control measures, which is similar to the findings of other studies (Singh *et al*. 2014; Materu *et al*. 2016).

Impacts of IPM

The results in Table 6 indicate that adoption of IPM had significant effects on all outcome variables except productivity and production cost. IPM adopters had significantly lower pesticide applications cost compared to non-adopters. It may indicate that IPM adoption reduced reliance on chemical pesticides, which may positively affect human health and the environment. Due to lower pesticide costs, on average, IPM adopters received higher net returns which may have a positive effect on the well-being of cucumber growers. Overall, IPM adopters maximized their profit by reducing cost, which is consistent with findings of some other studies (Karim *et al*., 2013; Gautam *et al*., 2017). The adoption of IPM also had a significant effect on farmers TE level. Higher TE indicates improvement in extension services, such as training and demonstrations, are warranted as these factors have had a significant impact on adoption (Rahman *et al*., 2018; Rahman and Norton, 2019).

Constraints of IPM adoption in the study areas

IPM is farmers' friendly and profitable, but it has some constraints that need to be addressed. Among them, the lack of appropriate information on IPM was a major barrier to adoption. The lack of technical expertise and the unavailability of few IPM products at the farm-level adversely affected the decision to adopt IPM (Table 7). The adoption of IPM as a package needs to be encouraged through proper training (Allahyari *et al*., 2016).

Table 3. Descriptive statistics of the variables

Variable	Adopters		Non-adopters		Mean difference
	Mean	SD	Mean	SD	
Distance to highway	1.18	1.17	1.63	1.47	-0.45**
Active member	3.55	1.45	3.27	1.30	0.28
Education	5.63	3.33	5.23	4.11	0.40
Experience	13.10	10	12.00	9	1.1
Farm size	1.09	0.96	0.98	0.69	0.11
Extension contact	0.71	0.37	0.72	0.51	-0.01
Access to credit	0.55	0.45	0.58	0.47	-0.03
Contact with neighbours	0.72	0.42	0.55	0.34	0.17**
Training on IPM	0.44	0.43	0.17	0.36	0.27***
Farmers adopting IPM	1.08	1.51	0.98	1.07	0.10
Human labour	193	68	183	87	10
Seedling	14344	1883	14655	1688	-311
Chemical fertilizers	675	332	938	344	-263***
Organic fertilizers	5388	3093	4522	2004	866
Material cost	94871	28584	104337	22294	-10466*

Note: *,** and *** indicates significant at 10%, 5% and 1% level; t-test was used to calculate the mean difference

Table 4. Farmers' perception of the benefits of IPM

Item	Farmers' perception (%)					
	SA	A	N	D	SD	DN
IPM is more effective than synthetic pesticides	00	16.0	25.0	25.0	--	34.0
IPM is beneficial for farmers health	17.8	45.2	2.3	1.7	--	32.7
IPM is beneficial for water bodies	15.4	44.0	4.7	1.7	--	33.9
IPM is more costly than synthetic pesticides	4.1	23.2	3.5	25.0	6.5	37.5
IPM practices can be integrated with traditional pesticide-based technologies	2.9	45.8	10.1	7.7	0.6	32.7

SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree, DN = do not know.

Table 5. Percentage of farmers adopting different IPM practices

IPM practices	Percent of farmers
Sex pheromone trap	32
Yellow sticky trap	7
Poultry refuse for soil amendment	21
Tricho-compost	4

Table 6. Impact of IPM adoption on various outcome indicators

Variables	Mean		ATT	SE	t-ratio
	Adopters	Non-adopters			
Productivity (Kg/ha)	17245	16985	87	85	1.05
Pesticide cost (Tk/ha)	18213	22493	-5780***	1783	-3.16
Production cost (Tk/ha)	195884	215760	-1366	1336	-1.08
Net return (Tk/ha)	62791	35618	11408*	6050	1.89
TE score	0.70	0.63	0.07***	0.03	3.19
Model diagnostic					
Section of common support	Yes (0.133 to 0.989)				
Balancing property satisfied	Yes				
Number of optimal blocks	5				

Radius matching was used to measure the ATT; * and *** indicate significant differences at 10% and 1% level, respectively; PSM produce a sub-sample of 71 match farmers. Tk indicates Bangladeshi currency. 1 USD = Approximately Tk 80 at the time of the analysis.

Table 7. Constraints to IPM adoption in the study areas

Factor	Percent of farmers	Rank
Unavailability of IPM products	51	2
Lack of technical skill	43	3
Lack of appropriate information about IPM	56	1
Labour intensive	11	4

Conclusion and Recommendations

This study explored farmers' perception of IPM and its impacts on cucumber production using cross sectional data associated with the IPM IL sub-project. Farmers perceived IPM to be healthy and reduces cost of production. Findings have showed that IPM adopters have cost advantages over non-adopters. Higher net return can have a positive effect on poverty reduction in Bangladesh. The TE level of IPM adopters was significantly higher than that of non-adopters in the study areas. Production of cucumber can be increased to a significant amount by improving the TE of growers. The availability of IPM practices, such as beneficial insects, tricho-compost, and sticky traps at a reasonable price need to be ensured at farm level, if high adoption of those IPM practices is to occur. There is a need to develop an effective framework for the diffusion of IPM practices all over the country. Mass media can also play a vital role in resolving this constraint. An appropriate IPM programme, with emphasis on biological pest control techniques, need to developed and disseminated. It is also important to improve the TE level of adopters in the study areas by providing additional training and improving the knowledge of farmers about IPM practices. However, findings of this study cannot be generalized, as this was administered on a small number of cucumber farmers. A large-scale survey may be useful in developing a complete scenario for the adoption of IPM in Bangladesh.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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