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PESTICIDE USE, ITS IMPACT ON CROP PRODUCTION AND EVALUATION OF IPM TECHNOLOGIES IN BANGLADESH

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ABSTRACT

Pesticides are generally sold at a price lower than MRP, but in some cases during peak period they are sold higher than MRP. More than one-half of farmers use recommended quantity of pesticides. Almost all farmers use pesticides after seeing pest/disease in the field. Majority of them cover their face during pesticide application. Among all crops, comparatively more pesticides are applied for vegetables crops. Majority of farmers believe that pesticide application pollute water & air and they are harmful to farm labour. The study shows that farmers use excess pesticides for all crops except Banana (sagar) and Mango. Non-IPM farmers apply much higher amount of pesticides than IPM farmers. Only IPM trained farmers know and use IPM technologies. Apart from pesticide application, majority of trained farmers are aware and use crop rotation and control by hand methods. In contrast, a few of them use cultural and biological methods. Although they are interested to use pest resistance seeds, they cannot use those because of non-availability of seeds. In case of using recommended doses of pesticides, IPM and nonIPM farmers differ significantly. Comparatively more IPM farmers express their view that pesticide application pollutes air as well as crop. Finally, this study reveals that training on IPM encouraged farmers to adopt non-traditional pest control methods.

I. INTRODUCTION

The role of pesticides has become critically important with modernization of agriculture. Modernization of agriculture implies increased use of modem inputs such as chemical fertilizer, irrigation and modern seeds, which provide a favourable climate for rapid growth of pests. Moreover, modern seeds are more susceptible to insect pests and diseases.

The use of pesticides, however, carries several dangers. Non-optimal and non judicious use of pesticides may result in a series of problems related to both loss of their effectiveness in the long run and certain externalities like pollution and health hazards. It is argued that increase in production cost, when associated health costs are counted due to use of pesticides, exceeds the improvement in crop productivity. Prophylactic chemical control (i.e. calendarbased pesticide application) recommendations for rice were set in the early 70s when modern varieties were introduced. Since then, despite improved varietal resistance and management practices, these recommendations have hardly changed. Prophylactic chemical control has

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been associated with destruction of other beneficial (predator) species, resurgence of the treated pest populations, outbreaks of secondary pests, residues in food, feed and the environment, and farmer illness from prolonged exposure to pesticides. Since pesticides having some undesirable effect on environment and human health, several countries including Bangladesh are introducing integrated pest management (IPM) technologies which are based on the natural balancing forces in ecological • system. An economic evaluation of these technologies is urgently needed.

In Bangladesh, several studies have been conducted on marketing and economic use of different agricultural inputs. But the studies on pesticides are scantly. Rahman (1978) emphasized on the study concerning correct application and economic viability of insecticides. Prabhu (1985) showed that pesticides use by farmers was excessive and their pesticides use decisions were based on their expectations regarding the timing and intensity of pest attack, the pest damage function and the effectiveness of pesticides. Rola and Pingali (1993) candidly recognized that frequency application and use of very toxic chemicals increased risk of farmer health damage due to chemical exposure and indiscriminate pesticide use leads to larger pest related yield losses than not applying pesticides at all. They warned that poorly implemented IPM programs could increase the amount of insecticides applied where insecticide use is low. They concluded that under normal circumstances, the natural control option is often the economically dominant pest management strategies.

Sabur and Akter (1997) showed that total as well as per hectare use of all types of pesticides were found to increase since 1982/83, but this upward growth had been checked in the recent past of Bangladesh. Their study result showed that pesticides influenced value of production positively up to certain level, after that they affected negatively. In a study Chand and Birthal (1997) showed that pesticide use was positively and significantly influenced by irrigation coverage, percent of rice area irrigated, share of cotton in the gross cropped area and percent area under HYVs of cereals.

Gandhi and Patel (1997) found that farmer perception of the significant impact of pesticides on the environment seemed to exist but was limited to their immediate surroundings of labour, other human beings and animal. It did not go beyond this to the effect on water, air and residues in the produce. Further their awareness about environment friendly alternative such as biological control, integrated pest management and homemade formulations was almost nil. On the other hand, awareness about pesticides was about 100 per cent and used by 90 per cent farmers. It was found that pesticides use levels were determined significantly by the extent of irrigation, presence of cotton and wheat, and location. The intensity of use was higher on small farms. Education and age of the farmers seemed to affect pesticide use negatively.

None of the earlier studies provided detail information regarding economic use of pesticides, its impact on crop production and evaluation of IPM technologies. This study is expected to fill this information gap concerning pesticides in Bangladesh.

The objectives of this study are to observe the pesticides use pattern by the farmers, to examine the storage and safety practice of the farmers, to find out the relationship between pesticides use and crop productivity and to evaluate the integrated pest management technologies in Bangladesh.

II. METHODOLOGY

On the basis of highest pesticide use per hectare for Boro paddy, four greater districts from four divisions namely Comilla from Chittagong division, Mymensingh from Dhaka division, Jessore from Khulna division and Bogra from Rajshahi division were selected for this study. One or two thanas from each district was chosen based on highest pesticide used as well as IPM technology used areas. If a thana where higher pesticide as well as IPM used was not found, two thanas, one as higher pesticides use area and another as IPM use area, were selected. Accordingly, Ishwargonj thana from Mymensingh, Sadar and Jhikargacha thanas from Jessore, Sadar and Sariakandi from Bogra and Burirchong and Laksham thanas from Comilla were selected.

In case of fruits and vegetables, six greater districts such as Mymensingh, Jessore, Bogra, Chittagong, Dhaka and Rajshahi were chosen for this study.

Selection of Farmers

Ninety farmers from each district totaling 360 farmers were selected for this study. Of the 90 farmers selected from each district, 30 were IPM trained farmer (henceforth IPM farmer) and the rest 60 were non-trained farmers (henceforth non-IPM farmer). For non-IPM farmers, two or three higher pesticides used villages were chosen after consulting with Agricultural Officer. All Boro farmers were listed with the help of Block Supervisors of the respective villages. Farmers were classified into three groups such as small (< 2.51 acres), medium (2.51-5.00 acres) and large (> 5.00 acres). Sample was drawn in such a way that all groups of farmers might be included into the sample. In case of selecting IPM farmers, more than one farmer's field schools (FFS) were chosen. In farmers field school farmers were trained on IPM technologies. Thirty farmers were selected from the list of trained farmers in such a way that all groups of farmers might be included into the sample.

On the basis of higher pesticides use, four vegetables namely Brinjal, Cabbage, Bean and Potato and four types of fruits namely Banana (Sagar), Banana (Sabri), Guava and Mango were selected. Areas where these selected vegetable and fruits are grown intensively were chosen for this study.

For Boro paddy, data related to 1997-98 crop season were collected during May to October 1998. For vegetables and fruits, data related to 1998-99 crop season were collected during April to July 1999. (Detail methodology is shown in Sabur & Molla, 2000)

III. PURCHASE OF PESTICIDES

Pricing System

Some big companies such as Noverties, Rhone Polenec, Padma follow fixed price system throughout the year. In some cases, during peak demand period traders raise the price and sell at price higher than MRP. But, during lean period, they sell at a price lower than price fixed by the company by forgoing some portion of commission/profit. About 41% farmers stated that pesticides are purchased at price fixed by the companies. On the other hand, in some cases prices are fixed by traders, as mentioned by about 60% of farmers. Finally, more than one-half informed that prices are determined by open bargaining.

For the pesticides of well-known company like Novertice, Boro paddy farmers pay higher than the maximum retail price (MRP) of the company. The variation of price across the

Table 1. Average price of pesticides paid by the Boro paddy farmers during 1998-99.

Name of Pesticides	Company	Average price paid	MRP	Difference between Av. Price & MRP	Coefficient of price variation
Basudin (Tk./kg.)	Novertice	91.34	97.00	-5.66	8.32
Diazinon (Tk./liter)	Novertice	791.30	600.00	191.30	30.70
′ Dimecron (Tk./liter)	Novertice	941.82	904.00	37.82	9.09
Azodrin (Tk./liter)	Padma	833.33	705.80	127.53	17.32
Furadan (Tk./kg.)	Padma	86.16	87.60	-1.44	9.36
Marshall (Tk./liter)	Jamuna	535.00	605.00	-70.00	3.97
Miral (Tk./liter)	Novertice	130.00	129.00	1.00	13.14
Nogos (Tk./liter)	Novertice	654.00	580.00	74.00	23.50
Pillarcorn (Tk./liter)	Shetu Corp.	648.50	780.00	-131.50	27.13
Sunfuran (Tk./kg.)	Shetu Pest.	85.44	86.50	-1.06	0.62
Thiovit (Tk./kg.)	Rhone-Poulenc	108.33	125.00	-16.67	18.65

farmers is significant. The coefficient of price variation ranges from 31% for Diazinon to 0.62% for Sunfuran (Table 1). With few exceptions, price variation is found lower for wellknown and well-used pesticides like Basudin, Furadan, Marshall, Dimecron etc.

On the other hand, vegetable farmers generally purchase pesticides at a price lower than the maximum retail prices. This indicates that during vegetable season market is very much competitive and traders are compelled to sell pesticides at a price lower than MRP by giving up some percentage of their commission

Problems in Purchasing Pesticides

Some low quality and less effective pesticides are sold at higher price as complained by more than two-thirds of the farmers in the study area. It is reported that some traders sell low quality and date expired pesticides after pasting new label of well-known reputed company. One-half of the farmers remarked on the higher prices of pesticides. During peak period, traders raise the price of pesticide by creating artificial shortage of supply.

Subject Matter officer, Block Supervisor and traders suggest different company's pesticides for a particular pest or diseases. As a result farmers face problem of selecting pesticides during pest attack and disease infestation.

Farmers cannot purchase required quantity of pesticides due to scarcity of cash money in the peak period of Boro season. Sometimes necessary pesticides are not available in the market at the time of severe pest attack.

Although MRP is fixed by the company for each pesticides, but pesticides are not sold on that price. Farmers have to haggle with traders for purchasing pesticides. As a result, more time is wasted in case of purchasing pesticides.

The different traders even in a same market sell same pesticides of a company at different prices. As a result, farmers often pay higher price of pesticides due to lack of market knowledge.

IV. PESTICIDES USE

Use of Recommended Quantity

More than one-half of the farmers use recommended quantity of pesticides in their crops (Table 2). On the other hand, each one-fifth of them either uses more or less than the required quantity. The study shows interesting result that more proportion of small and medium farmers use excess quantity compared with large farmers. However, this is reverse in the case of using less quantity. This indicates that there is no relation between the financial solvency and use of pesticides in the study area.

Table 2. **Using recommended quantity of pesticides** (% of farmer)

Type of farmer _	Recommended quantity	More than recommended quantity	Less than recommended quantity
Small	62.11	19.82	18.06
Medium	52.78	27.78	19.44
Large	65.52	3.45	31.03
All	60.37	20.12	19.51

Nine-tenth of the farmers reported to have information regarding recommended quantity of pesticides from Block Supervisor. One-fourth of them received knowledge from retailer

and over one-half from other farmers. Thus, it is found that concerning recommended doses the Block Supervisor's role is very prominent.

Farmers use higher amounts of pesticides than recommended doses because of ignorance, lack of training, experience, awareness etc. Farmers believe that production will be more if they apply more of pesticides. For that reason they use excess pesticides. For selling more pesticides the traders advise farmers to pse more pesticides. As Block Supervisors do not meet farmers regularly, the farmers remain unaware about the recommended doses of pesticides. As a result they fail to use proper doses. Sometimes pesticides are applied according to the advice of neighbouring farmers who do not know the proper doses. Generally the traders sell pesticides on credit, which results in using more amounts of pesticides. The estimated maximum likelihood logit function shows that excess use of pesticides and IPM training are negatively related (Appendix table Al). That means training on IPM has a negative impact on excess use of pesticides. In other word, imparting training on IPM induces the farmers not to use excess pesticides.

Time of Use

Most of the farmers (95%) use pesticides on crop after seeing pest/disease in their field. About 19% and 12% farmers use pesticides after applying fertilizers and after ploughing land respectively. Although few farmers apply pesticides at prefixed time, none of the large farmers found using pesticides at prefixed time. That means large farmers seem to be more conscious about time of using pesticides. One-tenth of the farmers use pesticides on their crops by seeing use of neighbouring farmers. Proportionately more large farmers use pesticides after fertilizer application but it is reverse in case of applying pesticides after ploughing land.

Majority of farmers (80%) reported to use pesticides during initial attack. About twofifths of them apply during severe attack. Hundred percent of large farmers reported using during initial attack. However, only a few of them apply during severe attack. Thus, in terms of condition of pesticide used, large farmers seem to be more efficient compared with other farmers. Only few farmers use pesticides without seeing any pest or disease.

Security measures

All farmers do not adopt security measure during pesticide application; 12% do not take any measure. Majority (88%) of them cover their face with cloth during application. In addition to covering face, nearly one-half cover their head and two-fifths wear shirt at the time of pesticides application. Only 16.55% reportedly use socks to cover their hands and legs and 4.48% use glasses to protect their eyes.

Pesticides applied area

Farmers apply pesticides in all types of crops but the pesticides applied area varies from crop to crop in accordance with the importance of crop, severity of pest and disease attack etc.

More pesticides are applied for vegetable crops like potato, brinjal etc. Pesticides are applied in 85% of total potato area and 83% brinjal area (Table 3). Among different types of paddy, pesticides are used comparatively more on Boro area. Pesticides area comprises about two-third of total Boro area against 54% for Aus and 45% for Aman paddy. Besides, pesticides are applied in the significant portion of sugarcane (44%) and oilseed (43%) area. Pesticides are used only in a small portion of pulse (19%) and jute (11%) areas.

Table 3. Crop area applied by pesticides.

Crops	Boro	Aman	Aus	Jute	Pulse	O'I seed	Sugar cane	Potato	Brinjal	Other Veg	Other crop
% of total area	62.89	45.70	51.46	11.11	23 00	42.57	44.31	90.41	83.05	61.53	49.22

Types of pesticides applied for Boro paddy

Farmers use different types of pesticides for the production of Boro paddy. The highest 26% of farmers use Basudin, about 17% use Furadan and 12% Dimecron in the study area. As these pesticides are very popular to the farmers from long back and as they are sure about the quality of these products, they prefer to use these pesticides even at higher price. They do not take risk to use new pesticides. Besides a significant portion (10%) of farmers use Diazinon in the study area.

V. FARMERS' OPINIONS ON DIFFERENT ASPECTS OF PESTICIDES

Approximately all farmers express their view that applying pesticides pollute water (Table 4). Eighty six percent of them believe that pesticide application is harmful to farm labour. More than three-fourths opined that using pesticides might pollute air. "Pesticide application is injurious to the health of other persons and animal" is expressed by over one-half of the respondents. Lastly 41 % viewed that crop might be polluted after using pesticides. Regarding water pollution and harmful to farm labour, majority of farmers believe that the effect of pesticides application is more serious compared with other effect.

Due to lack of training nearly one-half of the farmers believe that all insects are harmful to crops. About 90% of farmers opined that there is positive relationship between pesticides use and crop production. That means they believe that production will be higher if they use more pesticides and vice versa. On the other hand, 87% respondent think that pesticides application is profitable. A large portion of large farmers are convinced of the profitability of pesticides use.

Theoretically, price of pesticides should remain the same all the year round as mentioned by the government and pesticides companies' association. But in practice this does not happen. Only 21.61% farmers reported that price remained the same in all the seasons in a year. That means about 80% farmers informed that price changes due to change in demand. This has happened due to the fact that during peak demand season, especially during Boro

Table 4. Farmers' opinion about the effect of pesticides (% of farmer)

Particulars	Severity rate	Small Farmer	Medium farmer	Large farmer	All farmer
Water pollution	More	79.60	77.92	79.31	79.21
	Less	19.60	19.48	20.69	19.66
	All	99.20	97.40	100.00	98.87
Harmful to farm labour	More	36.07	48.68	21.43	37.64
	Less	50.41	39.47	57.74	48.56
	All	86.48	88.15	78.57	86.20
Air pollution	More	37.20	48.05	17.24	37.92
	Less	40.40	28.57	58.62	39.33
	All	77.60	76.62	75.86	77.25
Harmful to other person	More	17.84	22.06	0.00	17.21
	Less	39.91	39.71	59.26	41.56
	All	57.75	61.77	59.26	58.77
Harmful to Animal	More	14.16	23.19	7.14	15.51
	Less	41.10	36.23	46.43	40.51
	All	55.26	59.42	53.57	56.02
Crop pollution	More	14.46	18.42	3.45	14.41
	Less	26.10	30.26	31.03	27.40
	All	40.56	48.68	34.48	41.81

season, dishonest traders with the help of regional office of companies artificially elevate the price in order to earn excess profit. As pesticides are essential at the time of pest attack, most of the farmers, particularly the large farmers, try to use required quantity even at the time of financial hardship. Only one-third of farmers informed that they use fewer amounts if price is higher.

VI. EFFECT OF PESTICIDES ON CROP PRODUCTION

Effect of different inputs including pesticides:

In order to determine the effect of different inputs including pesticides on crop production, the following production function was estimated.

$$GI = \alpha + \beta_1 HL + \beta_2 IC + \beta_3 FC + \beta_4 MC + \beta_5 AM + \beta_6 PC + \beta_7 SC + \beta_8 D_1 + \beta_9 D_2$$

Where,

GI = Gross income per hectare

HL = Human labour cost per hectare

IC = Irrigation cost per hectare

FC = Fertilizer cost per hectare

MC = Manure cost per hectare

AM = Animal & Machine cost per hectare

PC = Pesticide cost per hectare

SC = Seed cost per hectare

D_1 = Dummy variable for Comilla district i.e. for Comilla district it is 1 and 0 for other districts.

D_2 = Dummy variable for Jessore district i.e. for Jessore district it is 1 and 0 for other districts.

The function was fitted for different groups of farmers (small, medium & large) and for different types of farmers (IPM & Non-IPM). Dummy variables were used only in the case of different groups of farmers for Boro paddy. The multicollinearity problem was tested through estimating correlation matrix of independent variables. The multicollinearity problem was considered harmful if $r^2 \geq R^2$, where, r is the simple correlation coefficient between two explanatory variables and R^2 is the multiple correlation coefficient. The multicollinearity problem was solved either by excluding one variable or by converting two variables into one.

Effect of Pesticides on Boro Paddy Production

Quantity and cost of pesticide used: Farmers use on an average 5.85 kg. of solid pesticides and 339.70 m. liter of liquid pesticides in case of Boro paddy cultivation. (Table 5). Large variation in pesticide use is also found in the study area. This implies that farmers are not using pesticides at the optimal level; more or less use prevails in the study area. Between IPM and non-IPM farmers, the variation in pesticide use is remarkable. Non-IPM farmers apply much higher amount of pesticides than IPM farmers. It is two and a half time higher in case of solid pesticides and about three times in case of liquid pesticides. Pesticides cost accounts for about 3% of total cost of production. On an average, farmers obtain gross income of Tk. 41830 per hectare from Boro cultivation. Average net income, which is Tk. 15308, is found the highest for large farmers followed by small and medium farmers. Benefit-cost ratio is also the highest for large farmers. Thus with respect to net income and benefit–cost ratio large farmers seem to be more efficient than other groups of farmers. Farm to farm variation in net income is found very high.

Table 5. Quantity of pesticides used, cost and return per hectare for producing Boro paddy

(Per Hectare)

Particulars	IPM farmer	Non-IPM Farmer	All Farmers	
	Average	Average	Average	Coefficient of Variation
Solid Pesticides (kg.)	2.92	7.31	5.85	121.20
Liquid Pesticides (m. liter)	152.13	433.49	339.70	210.27
Total Pesticides cost (Tk.)	382.50	950.15	760.93	107.89
Total Production Cost (Tk.)	24278.76	27642.54	26524.30	46.49
Gross Income (Tk.)	39089.56	43199.82	41829.80	43.87
Net Income (Tk.)	14810.80	15557.29	15308.50	89.31
Benefit-Cost Ratio (Tk.)	1.61	1.56	1.58	-

Effect of Pesticides: Table 6 presents the estimated production functions for Boro Paddy. All functions are fitted well, as R^2 are above 0.6. That means over 60% variation of gross income is explained by the variables included in these functions. Since all the variables are in value

term, the coefficients of the functions indicate the marginal value products (MVP) of respective inputs.

Except IPM farmers, no pesticides coefficient is significant in the study area. That means excess pesticides are used and income of the farmers can be increased by reducing the cost of pesticides. Only in case of IPM farmers, pesticides affect the income positively and significantly. Additional one taka investment in pesticide yields Tk. 2.83 to the IPM farmers. The irrationality of the non-IPM farmers, as reflected in their tendency to use more than optimal quantities of pesticides may be explained if consideration such as complimentary of input use and uncertainty are brought into the picture. The pesticides use decision of cultivators is based on their expectations regarding the timing and intensity of pest attack, the pest damage function and the effectiveness of pesticides. The expectation of the cultivators tends to be wrong in the absence of perfect information regarding the above factors. In the

Table 6. Estimated production functions for different groups of farmers.

Type of farmers	Constant	Human labour cost	Irrigation cost	Fertilizer cost	Manure cost	Animal & Machine power cost	Pesticide cost	Seed cost	Comilla dummy	Jessore dummy	R^2
Small	9044.65	0.60[a] (2.94)	0.69[a] (4.73)	4.73[a] (10.22)	0.30[b] (2.05)	4.03[a] (4.67)	-0.98 (-1.11)	0.51[b] (2.38)	-11885.3[a] (-5.68)	-10972.3[a] (-4.65)	0.66
Medium	8120.35	-0.036 (-0.12)	2.09[a] (3.59)	2.64[a] (2.65)	0.22 (1.18)	1.77 (1.25)	2.15 (1.27)	14.74[b] (2.47)	-4526.56 (-1.34)	-15396.2[a] (-4.64)	0.60
Large	3860 4.60	-0.34 (-0.56)	1.09 (0.74)	5.74[a] (3.09)	-9.60[b] (-2.12)	-5.36[c] (-1.90)	-2.53 (-0.90)	-1.20 (-.11)	7652.43 (0.95)	-14858.1 (-1.66)	0.62
IPM	1289 7.5	-1.24 (-1.21)	2.45[a] (7.80)	0.86 (1.50)	-0.15 (-0.13)	1.59[c] (1.73)	2.83[c] (1.79)	0.66[a] (3.63)	-	-	0.61
Non-IPM	1516.68	-5.49[a] (-5.09)	0.10 (0.62)	2.63[a] (5.60)	0.30[b] (2.49)	5.91[a] (6.20)	0.28 (0.30)	15.88[a] (6.22)	-	-	0.64
All	1132 9.54	0.40[b] (2.37)	0.85[a] (6.26)	4.65[a] (11.52)	0.35[a] (3.09)	3.50[a] (4.83)	-0.25 (-0.33)	0.58[a] (2.79)	-10469.2[a] (-6.02)	-12534.8[a] (-6.91)	0.61

Dependent variable: Gross income per hectare

Figures in the parentheses indicate 't' values.

[a], [b] & [c] indicate significant at 1%, 5% & 10% levels respectively.

context of uncertainty, the pesticides use behaviour of cultivators depends on their attitude to risk taking. Prabhu (1985) explained that the risk aversion on the part of cultivators, and uncertainty regarding the intensity of pest attack and effectiveness of pesticides caused the cultivators to use excess amount of pesticides.

Effect of Pesticides on Vegetable Production

Quantity and cost of pesticides used: Average 2783.57 gram of solid and 2838.83 milliliter of liquid pesticides are used per hectare for selected vegetables.(Table 7). The highest 5080 ml. of liquid pesticides are applied for bean followed by 4212 ml. for cabbage and 1800 ml. for potato. The lowest amount of liquid pesticides is used for brinjal. In case of solid pesticides, farmers use highest amount (4214 gm.) for cabbage followed by potato. On an average, the highest amount of pesticides (both liquid & solid) is applied for cabbage and the lowest amount for brinjal.

Farmers spend on an average Tk.3,213 per hectare for pesticides for vegetable production (Table 7). Average pesticide cost which is equally shared by solid and liquid comprises around 6% of total cost of production. This percentage is the highest for cabbage followed by potato and bean. The lowest cost percentage is found for brinjal in the study area. The highest total cost of production is found for potato and the smallest for brinjal. However, in the case of net return it is reverse because of higher gross return of brinjal and lower for potato.

Table 7. Quantity of pesticides used, cost and return per hectare for producing different types of vegetables.

Particulars	Potato	Bean	Cabbage	Brinjal	Average
Solid pesticides quantity (gm)	3445.94	0.00	6722.95	634.21	2783.57
Liquid pesticides quantity (ml)	1799.83	5079.93	4214.37	780.67	2838.83
Solid pesticides cost (Tk.)	3542.71 (5.81)	0.00 (0.00)	2504.83 (4.80)	151.81 (0.34)	1549.84 (3.01)
Liquid pesticides cost (Tk.)	1130.75 (1.85)	3199.47 (6.75)	1950.81 (3.74)	371.91 (0.82)	1663.23 (3.23)
Total pesticide cost (Tk.)	4673.46 (7.67)	3199.47 (6.75)	4455.64 (8.54)	523.72 (1.16)	3213.07 (6.25)
Total cost of production (Tk.)	60958.51	47367.23	52150.21	45190.47	39682.86
Gross margin (Tk.)	96414.48	137282.76	131300.25	182079.29	136769.2
Net margin (Tk.)	35455.97	89915.53	79150.04	136888.81	85352.59

Figures in the parentheses indicate percentage of total cost of production.

Effect of pesticides: Estimated production functions of different vegetables are presented in Table 8 Pesticides cost affects the production of vegetables negatively, as all the pesticides coefficients excepting one are negative. In the case of cabbage, although the coefficient is positive, it is not significant. That means for vegetable production excessive pesticides are used and production can be increased by decreasing the amount of pesticides used. This

problem is more serious in case of bean as the pesticides coefficient is negative and highly significant. The result indicates that farmers are not using pesticides economically and judiciously.

Table 8. Estimated Production functions of vegetables

Name of [illegible]	Constant	Land	Human labour cost	Animal labour & power cost	Urea cost	TSP cost	Pesticides cost	Irrigation cost	Seed cost	R^2
Potato	-7068.69	-	-	15.94** (2.62)	-	-	-0.11 (-0.12)	-	2.58** (2.74)	0.46
Cabbage	31361.07	-	0.62** (2.53)	-	-18.43 (-5.05)	7.87*** (3.04)	1.05 (0.42)	-31.56** (-2.97)	17.81 (5.72)	0.80
Bean	-36.68	77106.44 (12.93)	-	-	1.40 (0.081)	-	-25.57*** (-3.49)	-	4.76* (1.79)	0.93
Brinjal	-113922.4	-	8.96** (2.76)	-	32.08* (1.86)	-13.96 (-0.83)	-33.73 (-0.73)	11.41 (0.83)	-6.13 (-0.61)	0.43

Figures in the parentheses indicate 't' values
***Significant at 1% level
** Significant at 5% level
*Significant at 10% level

Effect of pesticides on Fruits Production

Quantity and cost of pesticides used: The quantity of solid and liquid pesticides used for fruits averaged 3610 gm. and 1483 ml. per hectare respectively (Table 9). The highest quantity of solid pesticides of 8780 gm. is used for banana (Sabri) whereas for mango the highest amount of liquid pesticides is used. The quantity of liquid pesticide used for mango is 22 times higher than that of Guava and about 8 times higher than that used for Banana (Sabri). Overall the least amount of pesticides is used for Guava in the study area.

On average Tk. 2,689 comprising about 3% of total cost of production is spent for purchasing pesticides in the case of fruits in the study area (Table 9). The cost of liquid pesticide is double the cost of solid pesticides. The absolute as well as percentage cost of pesticides are the highest for banana (Sabri) and the lowest for guava. The total production cost is the highest for Mango and the lowest for Banana (Sabri). However, net margin is found highest for guava because of comparatively higher gross margin and lower production cost. Net margin of guava is nearly two and a half time higher than that of Banana (Sagar).

Table 9. Cost and return for different types of fruits production

Cost item	Banana (sagar)	Banana (sabri)	Guava	Mango	Average
Solid pesticides (kg./hectare)	4.02	8.78	0.005	1.65	3.61
Liquid pesticides (ml/hectare)	1532.95	487.50	167.50	3742.92	1482.72
Solid pesticides cost	330.73 (0.38)	2466.36 (3.32)	62.28 (0.07)	646.49 (0.51)	876.47 (0.92)
Liquid pesticides cost	1217.05 (1.39)	2339.82 (3.15)	562.01 (0.61)	3129.97 (2.47)	1812.21 (1.90)
Total pesticide cost	1547.78 (1.77)	4806.18 (6.46)	624.30 (0.68)	3776.46 (2.98)	2688.68 (2.82)
Total cost of production	87384.49	74368.10	92112.86	126857.79	95180.81
Gross margin	194115.53	231911.69	356336.08	285740.60	267026.0
Net margin	106731.04	155034.28	264223.22	158882.80	171217.8

Figures in the parentheses indicate percentage of total cost of production.

Effect of pesticides: The estimated production functions show that pesticides affect the production of Banana (sagar) and Mango significantly (Table 10). An additional one taka spent on pesticides raises the gross return as obtained from Banana (Sagar) and mango by Tk

Table 10. Estimated Production functions of Fruits

Name of Fruits	Constant	Land	Manure cost	Urea cost	Total Fertilizer cost	Pesticides cost	Irrigation cost	Seed cost	R^2
Banana (Sagar)	-2877.72	83324.99	-4.71** (-2.78)	-	-0.41 (-0.15)	54.59** (2.30)	-2.89 (-0.41)	-	0.94
Banana (Sabri)	-11239.56	134274.10	5.18** (2.82)	-	6.61** (2.16)	0.07 (0.03)	-	-22.70*** (-4.55)	0.95
Guava	-33153.30	-	121.18** (2.66)	140.08* (1.87)	-	83.47 (1.15)	-87.67** (-2.40)	50.63*** (3.16)	0.94
Mango	103591.21	-	5.31 (0.56)	-	-	20.67** (2.46)	8.65** (2.26)	1.03** (2.34)	0.54

Figures in the parentheses indicate 't' values
***Significant at 1% level
** Significant at 5% level
*Significant at 10% level

55 and Tk. 83 respectively. This indicates that in the case of these two fruits, pesticides are used at sub optimal level. In case of Banana (sabri) and Guava, the pesticide cost coefficients are positive but non-significant. That means use of pesticides has little effect on the return of these two types of fruits.

VII. INTEGRATED PEST MANAGEMENT METHODS

Practice of IPM methods

There are two constraints in implementing IPM methods in Bangladesh. These are non-availability of training facilities and lack of awareness about IPM methods among the farmers. Majority (about 68%) of farmers do not know and practice IPM methods in order to protect crops from pests and diseases. About only one-third knows and applies these methods. That means only the farmers who have training on IPM know and use these methods. Proportionately, more small and medium farmers know and use these methods compared with large farmers. Interestingly, some of the small farmers who do not receive training know about IPM methods. Excepting small farmers, all farmers who know about IPM methods practice these methods. All farmers know IPM methods either from Thana Agricultural Officer (TAO) or from Block Supervisor (BS). A few of them came to know from other farmers, NGOs, etc.

Training on IPM methods

IPM methods include different methods such as cultural method, biological method, crop rotation, control by hand, use of pest resistance seed, pesticides application, etc. Eighty percent farmers received training on all methods of IPM. In some cases, trainers avoid to provide training on some difficult methods to the farmers. That is why, one-fifth of the farmers reported that they were trained up on some methods only.
Although most of the farmers received training on all methods, few of them use all. Only 23% farmers use all methods of IPM.. Two-fifth farmers use two to five methods and onethird practice six to seven methods.

Awareness, use and effectiveness of different pest control methods

Table 11 presents the finding on the awareness, use and opinion on effectiveness about different major methods of pest control. Among all methods, the awareness on pesticides application is the highest. All farmers know this method, of which 87% use this. But only 62% of them feel that this method is effective. With respect to crop rotation, the awareness and use are also very high; 79% and 71% farmers know and use this method respectively. Majority (64%) of farmers opine that this method is effective. On control by hand, the awareness and use are high. Seventy one percent of farmers know this method and of which 61% use it. Fifty seven percent of them consider this method to be effective.

Majority of farmers (about 60%) aware and use cultural methods. But not all of them think it to be effective. The awareness about cultural method is higher for large farmers compared with other groups of farmers. Although the awareness about use of pest resistance seed is high (56%), the use of this method is very low (29%) may be due to the non-availability and doubtful on the effectiveness of this kind of seed. The awareness about

biological methods is very low as only 36% of farmers know this method. Only 15% of farmers use this method and 17% feel this to be effective.

Table 11. Awareness, use and effectiveness of different pest control methods. (% of farmer)

Methods	Aware/Use/ Effectiveness	Small farmer	Medium farmer	Large farmer	All farmer
Pesticide application	Aware	100.00	100.00	100.00	100.00
	Use	87.10	85.50	85.20	86.60
	Effective	63.60	61.90	48.20	61.90
Cultural method	Aware	59.10	62.00	82.80	61.70
	Use	55.90	58.20	75.90	58.10
	Effective	41.20	44.30	41.40	42.00
Biological method	Aware	33.70	39.20	41.40	35.60
	Use	16.20	13.90	10.30	15.30
	Effective	17.40	16.40	10.30	16.70
Crop rotation	Aware	80.20	70.90	85.20	78.60
	Use	72.20	64.60	75.90	70.90
	Effective	65.90	58.20	62.10	63.90
Control by hand	Aware	71.00	67.10	79.30	70.80
	Use	61.10	59.50	69.00	61.40
	Effective	56.80	57.00	58.70	56.90
Use pest resistance seed	Aware	55.20	58.20	58.60	56.10
	Use	31.40	25.30	17.20	28.90
	Effective	31.00	25.30	17.20	28.60

Evaluation of IPM technology

In order to examine the effectiveness of IPM technologies, the activities, opinions, awareness etc. of IPM farmers are compared with that of non-IPM farmers.

Activities regarding pesticides use: Regarding informing family members about the poisonousness of pesticides, the IPM and non-IPM farmers differ slightly. Ninety two percent of IPM farmers and 88% of non-IPM farmers informed their family members of this matter. But in case of using recommended doses of pesticides, they differ significantly. Eighty four percent IPM farmers and 51% non-IPM farmers use recommended doses of pesticides.

Relatively more IPM farmers use pesticides at prefixed time whereas it is reverse in case of applying pesticides after fertilizer application. Only 3% IPM farmers use pesticides as a routine work after fertilizer application. Non-IPM farmers appear to be more conscious on pest attack as 84% of them use pesticides during initial attack. In case of IPM farmers the corresponding percentage is 68.

Regarding covering face and body during pesticides application, the difference between two groups of farmers is found less. But in case of covering other parts of the body, the difference is very significant. That means IPM farmers take more safety measures during pesticide application.

Relatively more IPM farmers apply pesticides in the windward direction, the best direction to apply. Because of ignorance nearly one-half of the non-IPM farmers wash their cloths in the pond whereas one-quarter of IPM farmers do this practice.

Opinion on pesticides application: Ninety eight percent, 80%, and 74% of IPM farmers believe that pesticides use is harmful to farm labour, other persons and animal respectively. The corresponding percentages of non-IPM farmers are 79%, 47% and 46%. Comparatively more IPM farmers express their view that pesticides application pollutes air as well as crop. On the other hand, nearly all farmers of both groups think that water become polluted because of pesticide use.

Nearly all non-IPM farmers believe that there exists positive relationship between pesticide use and crop production. They also believe that pesticides application is profitable. But all IPM farmers do not believe these.

Awareness and use of different pest control methods: Although all farmers know the use of pesticides, but 67.50% of IPM and 88.75% of non-IPM farmers use these. In case of all other methods, comparatively low percentage of non-IPM farmers aware and use those methods. Very few (8%) non-IPM farmers use biological methods. This indicates that training on IPM encouraged the farmers to adopt non-traditional pest control methods that do not pollute environment.

Table 12. Awareness and use of different pest control methods. (% of farmer)

Methods	Aware/Use/ Effectiveness	IPM farmer	Non-IPM Farmer
Pesticide application	Aware	100.00	100.00
	Use	67.50	88.75
Cultural method	Aware	84.17	50.42
	Use	84.17	45.00
Biological method	Aware	76.67	15.00
	Use	34.17	7.92
Crop rotation	Aware	91.67	60.42
	Use	85.00	50.83
Control by hand	Aware	88.33	73.75
	Use	84.17	64.17
Use pest resistance seed	Aware	76.67	45.83
	Use	31.67	27.50

VIII. CONCLUSION AND RECOMMENDATION

Government monitoring system should be strengthened so that persons producing and selling any adulterated and low quality pesticides may be punished. For that purpose, government vigilance team may make surprise visit at regular interval of time.

Maximum retail price (MRP) must be fixed by government after assessing the production and marketing cost. Steps to be taken so that no company or traders can raise prices of pesticides, particularly during peak period, without any reasonable cause.

The study reveals that only the farmers who have training on IPM use IPM technology. Moreover, the trained farmers do not apply all IPM methods. Majorities of the farmers do not use biological and cultural methods. Although they are interested to use pest resistance seed, they cannot use it because of non-availability of this type of seed. Therefore, arrangement should be made so that all farmers may receive training on IPM within short period of time. In this process, trained farmers may be employed as trainer to provide training to other farmers. In this respect the NGOs may come forward to provide IPM training to the farmers. The trained farmers should be motivated to adopt all methods, especially the biological and cultural methods. Furthermore, pest resistance seeds for all types of crops should be developed and make available to the farmers.

Farmers as well as block supervisors should be trained up on the recommended doses of each pesticide. The farmers may be advised to consult block supervisors instead of traders for knowing recommended doses of pesticides. Each company should supply price list and recommended doses of their pesticides to the block supervisors. Besides, the company must print the MRP, recommended doses and harmful effect on the label of each pesticide.

The farmers, especially the non-IPM farmers, do not have sufficient knowledge about safe handling and use of pesticides. They should not only be taught about the harmful effect of pesticides but also about safe handling and judicious use of pesticides.

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APPENDIX

Table A1. Maximum Likelihood Estimate of Logit Function for Excess Use of Pesticides.

Explanatory Variable	Coefficient	S.E.	Wald Chi-Square	Odd Ratio	Probability
Constant	-0.542	0.740	0.537		
IPM Training	-2.367**	0.553	18.302	10.661	0.91
Education	0.509	0.228	5.014	0.601	0.38
Age	-0.322	0.311	1.073	1.379	0.58
Income	-0.007*	0.003	5.394	1.007	0.50
Pesticide Training	-1.649*	0.755	4.770	5.204	0.84

** Significant at 1% level. * Significant at 5% level.
Log likelihood -279.217
Variables included in the Logit Model.
Dependent Variable: Use of excess quantity = 1
Use of not excess quantity = 0
Explanatory Variable:
1. IPM Training: Binary, 1 = Received IPM Training
0 = Otherwise
2. Education: 0 = Illiterate
1 = Primary Level
2 = Above Primary level
3. Age: 0 = Upto 30 Years
1 = 31 to 50 Years
2 = Above 50 Years
4. Income: Yearly Income in Thousand Taka.
5. Pesticide Training: 1= Received Training on Pesticide use other than IPM.
0 = Otherwise.