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Research Note

PESTICIDE DEMAND AMONG HYBRID VEGETABLE AND CEREAL SEED PRODUCERS IN BANGLADESH: A SIMULTANEOUS EQUATION ANALYSIS

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ABSTRACT

Demand for pesticides, inorganic and organic fertilizers were jointly estimated using survey data from a randomly selected 81 BRAC `contract hybrid vegetables and cereal seed growers' in northwestern Bangladesh applying a simultaneous equation framework. Pesticide cost accounts for 6.9% of the gross value of output in hybrid seeds of vegetables and 3.2% in cereals. About 87% of farmers used pesticides at least once with mean number of application of 4.4 times. Twenty-seven brands of pesticides were used including a substantial number of banned pesticides. Price elasticity of demand for pesticides, fertilizers and biofertilizers were estimated at -0.83, -0.21 and -1.13, respectively. Farmers treat chemical fertilizers and pesticides as complements. Increase in prices of both vegetable and cereal seeds significantly increases pesticide demand. Farmers who use mask as a precaution during pesticide application apply significantly higher amount of all three inputs. Farmers' level of education and experience significantly reduce pesticide use. Major thrust for pesticides regulation and effective implementation, promotion of education and increasing farmers' awareness on effects of pesticide use were suggested to safeguard the farmers.

1. INTRODUCTION

The economy of Bangladesh is largely dependent on its agriculture. As the population of the country is fast increasing and the land area is finite, the only way to increase food production is to raise productivity of land through use of chemical, biophysical and technological inputs including diffusion of high yielding varieties (HYV), better innovations and efficient management practices to fulfill the increasing food demand. Consequently, the major thrust of the national policies over the past four decades concentrated on promoting the `Green Revolution' technology, which lead to significant increase in rice production through intensive rice monoculture. However, such increased adoption of HYV technology led to displacement of land under low productive non-rice crops such as pulses, oilseeds, spices and vegetables, leading to erosion of crop diversity, thereby, endangering the sustainability of crop-based agricultural production system (Husain et al., 2001). Therefore, in recent years, focus is gradually shifting to the feasibility of introducing hybrid crops, yet another chemical

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input intensive technology, to combat the battle of food shortage. The thrust again is in diffusing hybrid rice followed by wheat, vegetables, and maize as a complement towards crop diversification on one hand and to raise productivity of the land with similar amount of inputs (?) and farm incomes on the other. In this drive for diffusing hybrid crop production technology, the Government of Bangladesh envisaged to involve the private sector, mainly seed companies and selective non-governmental organizations (NGOs), to participate in the process of importing hybrid seeds and assist in disseminating the technology to the farmers (Husain et al., 2001).

In Bangladesh, pesticides are widely used by rice and vegetable growers and its use rate is increasing sharply (Hossain et al., 1999). Pesticide consumption doubled in six years from 2510 MT in 1982 to 5150 MT in 1988 with insecticides covering 96.6% of total consumption. And in terms of chemical composition, organophosphorus compounds constitute 60.4% of total followed by carbamates (28.6%), organochlorines (7.6%) and others (3.4%) (Rahman et al., 1995). The average annual compound growth rate of pesticide use in Bangladesh for the period 1976/77 - 1993/94 is estimated at 8.6 percent per annum'.

Since the beginning of 1990, the non-governmental organizations (NGOs), such as BRAC, Proshika, and ASA, undertook vegetable production as a strategy to alleviate poverty of the landless poor, particularly women, with limited national coverage. However, from 1996, BRAC launched a nationwide comprehensive agricultural development program for its landless beneficiaries and extended to cover the large pool of marginal and small farmers who were traditionally not included in its target beneficiaries. In this program, BRAC started to diffuse an estimated 81 types of hybrid and/or modern varieties of field crops (rice, wheat, maize, vegetables, spices and oilseeds) to its newly defined target beneficiaries. Between 1996 and 2000 approximately 100,000 women were trained as vegetable growers and at present BRAC produces about 90% of the maize seeds and 35% of the vegetable seeds in Bangladesh. The program covers some 25,000 villages in its vegetable extension network out of a national total of approximately 68,000 villages (BRAC, 2000).

Also, among the exportable items, historically vegetable export constitutes roughly 1% of total (BBS, 2000) and its potential for improvement is under scrutiny, which is another motive of the Government behind promoting hybrid technology. As one of the forerunner in promoting hybrid technology in Bangladesh, BRAC's vegetable export started in 1997 and is currently exporting more than 100 tons of beans to markets in Europe, Dubai and Singapore. By the end of December 2000, there were 1097 contract farmers engaged in vegetable cultivation solely for export (BRAC, 2000).

Since hybrid technologies that the Government as well as BRAC is promoting are highly chemical input intensive, including pesticide use, analysis of farmers' responses to changes in prices of three essential inputs (pesticides, chemical fertilizers and biofertilizers) and outputs (hybrid vegetable and cereal seeds) as well as fixed factor endowments can provide valuable information for the policy makers in devising appropriate pesticide policies. Also, little is known about the pesticide use and pest management practices of farmers in Bangladesh in general. Indiscriminate use of pesticide poses a risk of pesticide pollution in food supply chain, which has widespread implication on population health as well as export pōtential of vegetables, as some recipient countries may be sensitive to the quality of the product coming from Bangladesh. It is also expected that such study would help devise more environment friendly rural development interventions for NGOs, including BRAC.

II. RESEARCH DESIGN

The data

The research was based on a survey conducted among the BRAC supported contract hybrid vegetable and cereal[2] seed producers[3]. A pre-tested structured questionnaire was utilized. Although BRAC operates its various programs throughout Bangladesh, the hybrid vegetable and cereal seed production program is concentrated in specific regions of the country where it is supported by its seed production farm in Dinajpur as well as its seed-processing center in Bogra. Therefore, information on chemical use and handling practices was collected at random from a total of 81 contract hybrid vegetable and/or cereal (maize, rice and wheat) seed growers from 29 villages of 6 upazilas (sub-districts) of Dinajpur and Bogra. Data collection was conducted for a period of two weeks during March 27–April 10, 2000.

Theoretical framework

To examine farmers' resource allocation decisions adopting hybrid seed production technologies, a set of reduced-from variable input demand functions was postulated using a standard simultaneous equations framework. The input demand functions were derived based on the assumption of profit maximization[4].

Assume for simplicity that there is variable input matrix: Q, and one fixed input, L that is allocated between various crops (L_i being the allocation to the ith crop). These are used to produce n number of crops ($i = 1 \dots n$).

Producer j maximizes total profits:

$$\sum_{i=1}^{n} p_i Y_{ij} - w^Q Q_j$$

$$\text{s.t. } Y_{ij} = f(Q_{ij}, L_{ij}, E_j),\ \forall\, i = 1, \dots, n \qquad (3)$$

$$\text{and } \sum_{i=1}^{n} L_{ij} \le L_j \qquad (4)$$

where $Q_j = Q_{1j} + \dots + Q_{nj}$

$L_j = L_{1j} + \dots + L_{nj}$

Equation (3) is an individual production function for each crop i. It depends on the variable inputs applied to that crop, land allocated to that crop, and a set of exogenous variables, E_j that shift the production function and/or affects producers' resource allocation decisions. Y's are output quantities; p's and w's are output prices and input prices. Equation (4) simply states that land allocated to various crops must be less than the total land cultivated by the producer.

The first order conditions will lead to the corresponding demand functions for each of the variable inputs for individual crops:

$$Q_j = Q_j\,(w^Q, p_1 \ldots p_n, L_{1j} \ldots, L_{nj}, E_j) \qquad (5)$$

We can express the respective input demand functions for the jth farm as a whole by aggregating the input demand functions of individual crops as follows:

$$Q'_j = Q'_j\,(w^Q, p_1 \ldots p_n, L_j, E_j) \qquad (6)$$

where, L_j is the aggregate amount of land cultivated by the farmer.

Equation 6 forms a system of demand equations for the inputs used for crop production. Observe that the arguments appearing in the input demand functions are the vector of input prices, output prices, land cultivated and a set of socio-economic characteristics.

Econometric Model

The specification of input demand functions postulated above already reflects that the system of equation needs to be estimated simultaneously to get efficient estimates[5]. The full model containing all the system of equations, dropping the jth subscript for the farm was written as:

$$\ln Q_I = \alpha_I + \sum_{K=1}^{3} \beta_K \ln w_K + \sum_{M=1}^{2} \gamma_M \ln P_M + \delta_I \ln L + \eta_I\, MASK + \tau_I\, EDUC + \lambda_I\, AGE + \varepsilon_I \quad (7)$$

$$\ln Q_F = \alpha_F + \sum_{K=1}^{3} \beta_K \ln w_K + \sum_{M=1}^{2} \gamma_M \ln P_M + \delta_F \ln L + \eta_F\, MASK + \tau_F\, EDUC + \lambda_F\, AGE + \varepsilon_F \quad (8)$$

$$\ln Q_B = \alpha_B + \sum_{K=1}^{3} \beta_K \ln w_K + \sum_{M=1}^{2} \gamma_M \ln P_M + \delta_B \ln L + \eta_B\, MASK + \tau_B\, EDUC + \lambda_B\, AGE + \varepsilon_B \quad (9)$$

where, the subscripts I, F and B stands for pesticides[6], fertilizers, and biofertilizers, respectively.

The list of variables included in the input demand functions were: (a) input prices (w) – includes price of pesticides (taka/100 ml or gm), price of fertilizers (taka/kg), price of biofertilizers (taka/kg); (b) output prices (P) in taka/kg – includes prices of hybrid vegetable seeds and cereals (c) amount of land cultivated in hectares (L); (d) a set of socio-economic characteristics which include age of the farmer in years (proxy for measuring farming experience) and level of education of the farmer (completed years of schooling), and (e) technical knowledge on the precautionary measures need to be taken by the farmer and includes use of masks while spraying (1 if yes, 0 otherwise).

Fertilizers and biofertilizers are the two major inputs that are essential in producing any crop and contribute significantly to the total cost of production, particularly in producing hybrid vegetables. Profit maximizing farmers are expected to respond and/or adjust their input use levels to changes in the prices of these two major inputs and hence included in the demand function. Prices of outputs have direct bearing on the gross revenue earned from producing individual crops. Therefore, farmers are expected to respond to changes in the output prices.

Incorporation of total cultivated land is obvious as it is expected to have significant positive association with quantities of input demanded. Also, most of the studies in Bangladesh found land as the most important input in crop production with a very high level of output elasticity (see, Wadud and White, 2000; Ahmed and Hossain, 1990, and Hossain, 1989).

Two variables, age and education, together as a group or in isolation should have an influence on resource allocation decisions. The education variable was used as a surrogate for a number of factors. At the technical level, access to information (in this case, adoption of hybrid technology) may influence type of hybrid crops to produce as well as resultant input allocation decisions. Age (measured as a proxy for farming experience) may also assist the farmer in making decision regarding wise use of scarce resources.

Table 1. List of pesticides used by hybrid vegetables and cereal seed farmers.

Brand name of pesticides	Ban status	Percent of pesticide using farmers (%)
Basudin	Banned	1.2
Benicron	Banned	1.2
Cap	-	6.2
Cymbush	-	22.2
Darsban	Banned	65.4
Diathene	-	2.5
Diazinon	Banned	9.9
Dimecron	Banned	9.9
Ezodrin	Banned	19.7
Furadan	-	44.4
Megaphos	-	1.2
Maltheon	Banned	9.9
Nogos	Banned	2.5
Okosam	-	1.2
Ostad	-	4.9
Redomyl	-	2.5
Regent	Banned	2.5
Relithion	-	4.9
Rezonil	-	1.2
Ripcord	-	22.2
Secufon	-	1.2
Sifanan	-	4.9
Sumithion	Banned	9.9
Symbar	-	1.2
Takgar	Banned	3.7
Tilt	-	1.2
Xolon	-	1.2

Note: Total exceeds 100 because farmers use more than one type of pesticides.
Information on ban status is taken from Motin (2000) and Daily Star (2001).

Source: Field Survey, 2000.

Finally, a dummy variable representing farmers' technical knowledge was incorporated to examine its influence. Dependent variables in the demand functions for pesticides, fertilizers and biofertilizers were: amount of pesticide used per farm in 100 ml or gm of active ingredients, amount of fertilizers used per farm in kg, and amount of biofertilizers used per farm in kg, respectively.

III. EMPIRICAL RESULTS

Types of pesticides used

Table 1 lists the various types of pesticides used by BRAC contract farmers. A total of 27 brands of pesticides were used. Among these 27 brands, 11 were from the "dirty dozen" pesticides that are banned worldwide including Bangladesh (Motin, 2000). An alarming 65.4% of farmers used Darsban, a banned pesticide. Though no information on human health component was collected in this study, one can get an indication of potential human health hazard by observing the type and level of pesticides used.

Use level and factor share of pesticides

As pesticides are used with greater frequency, that is, as and when required, even the minimal doses eventually add up to a large rate of application. Although the standard recommended rate by BRAC staff (in verbis) is 4 ml and/or gm per decimal of land for each application, the average level of pesticide application by farmers seems alarming estimated at 2.2 kg of active ingredients per ha (Table 2). The application rate was highest for vegetables (2.6 kg of active ingredients per ha). Farmers also use high level of chemical fertilizers and biofertilizers to boost yield levels and quality of seed output (Table 2).

Cost of pesticide use is estimated at Tk. 1,197 per ha and the highest cost is in vegetables (Tk. 1,333 per ha). The overall factor share of pesticides is estimated at 5.8% of gross value of output and is highest in vegetables (6.9% of gross value of output) (Table 2). Factor shares of other two inputs are also substantially higher for hybrid vegetables.

Table 2. Pesticide use rates, cost per hectare and share in gross value of output.

Crops	Mean input use rates (kg/ha)			Average cost per ha (taka/ha)			Factor share (% of gross value of output)		
	Pest-icides	Ferti-lizers	Bioferti-lizers	Pest-icides	Ferti-lizers	Bioferti-lizers	Pest-icides	Ferti-lizers	Bioferti-lizers
Vegetables	2.59 (5.30)	551.47 (313.57)	8654.59 (7032.59)	1333.27 (1365.48)	5091.23 (2994.08)	1615.97 (1518.29)	0.069 (0.146)	0.281 (0.314)	0.101 (0.236)
Cereals	1.47 (1.75)	639.41 (426.83)	9572.85 (8100.14)	907.14 (1015.59)	5640.40 (3825.95)	1582.44 (1333.06)	0.032 (0.074)	0.161 (0.210)	0.042 (0.036)
All crops	2.23 (4.49)	594.14 (360.46)	9227.74 (7468.33)	1197.31 (1269.55)	5387.14 (3331.72)	1652.72 (1464.32)	0.058 (0.129)	0.247 (0.243)	0.083 (0.178)

Note: Figures in parentheses are standard deviations
Source: Field Survey, 2000.

The frequency of application varies widely ranging from 1 to 10 times in a single seed production cycle. Also, frequency of pesticide use is highest in vegetables with a mean number of applications of 6.2 times (Table 3). Overall, 87% of all farmers used pesticides at least once in a crop season, while the remaining 13% did not use any pesticides. In case of vegetables, 92.7% of farmers applied pesticides at least once and a substantial 47.5% of the farmers applied pesticides more than five times.

Table 3. Number of applications of pesticides in a crop season.

Number of applications of pesticides	Farmers (%)		
	Vegetables	Cereals	All crops
Farmers applying pesticides	**92.7**	**70.0**	**87.0**
One time	3.6	50.0	21.0
Two times	12.7	6.7	11.1
Three times	7.3	0.0	4.9
Four times	16.4	0.0	11.1
Five times	5.5	3.3	3.7
More than five	47.5	10.0	32.1
Farmers not applying pesticides	7.3	30.0	13.0
Total	100.0	100.0	100.0
Mean number of application	**6.15**	**2.03**	**4.41**
Standard deviation	5.19	3.86	4.98
Total farmers	55	30	81

Note: Four farmers were involved in producing both vegetables and cereals and hence are counted only once when overall applications were considered, thereby arriving at a total number of 81 farmers instead of 85.
Source: Field Survey, 2000.

Pesticide use in BRAC 'foundation seed' production farm

The BRAC 'foundation seed' production farm, located at Dinajur city, is the main source of hybrid technology diffusion and therefore its chemical use intensity was also investigated. Results show that the frequency and cumulative use of pesticides of various categories is alarmingly high in BRAC 'foundation seed' production farm. The net sown area of the seed farm is approximately 2 ha where 'foundation seeds' of a large variety of hybrid vegetables for both summer (kharif) and winter (rabi) seasons are produced. Consequently, the total amount of active ingredients of pesticides going to a limited soil area of only 2 ha reaches an alarming level. Table 4 clearly reveals that this small plot ultimately received an estimated total of 29.2 kg of active ingredients in a one-year crop cycle. Among the individual crops, the highest amount pesticides were applied to okra, tomato and bottle gourd seeds. Specifically, a total of 14 brands of pesticides were used in this seed farm of which 7 are banned pesticides (Table 4).

Farmers' perception on effects of pesticide use

When farmers were asked to opine on the harmful effects of pesticide use, 37% of them provided a long list, which is elaborated in Table 5. Of the farmers, 49% considered that there were no harmful effects of pesticide use. About 9% did not give any comment on whether or not pesticides had harmful effects, implying 58% being naive about any harmful effects of pesticides. Among the harmful effects, 10% of farmers thought that pesticides kill useful

Table 4. Amount of pesticides used in BRAC 'foundation seed' production farm, Dinajpur.

		Amount of pesticides used (active ingredients)													
		Mega-phos	Rip-cord	Cym-bush	Takgar	Rido-mil	Dithane M-45	Ezo-drine	Nogos	Mal-theon	Bavis-tine	Dime-cron	Dars-ban	Tilt	Rovral
Ban status		-	-	-	B	-	-	B	B	B	-	B	B	-	B
Unit of doses		ml	ml	ml	ml	Gm	gm	ml	ml	ml	gm	ml	ml	ml	gm
Name of vegetables	Area (ha)														
Bean	0.14	420	420	420	0	0	0	0	0	0	0	0	0	0	0
Yardlong bean	0.08	0	0	0	0	0	0	0	160	0	0	160	0	0	0
Mungbean	0.10	0	0	0	0	0	0	0	0	200	0	200	0	0	0
Bottle gourd	0.20	0	0	0	1,600	200	200	0	0	0	0	0	0	0	0
Bitter gourd	0.12	0	0	0	960	0	0	0	240	0	0	0	0	0	0
Ridge gourd	0.12	0	0	0	120	0	120	0	0	0	0	240	240	0	0
Pumpkin	0.08	0	0	0	80	0	80	0	0	0	0	160	160	0	0
Chalkumra	0.10	0	0	0	100	0	100	0	0	0	0	200	200	0	0
Cucumber	0.05	0	0	0	40	0	40	80	160	0	20	80	0	0	0
Kangkong	0.02	0	0	0	40	0	0	0	0	80	0	0	0	0	0
Vatishak	0.10	400	0	0	0	0	0	0	0	0	0	0	0	0	200
Red amaranth	0.16	0	0	0	0	320	320	0	0	0	0	0	320	320	0
Amaranth	0.06	0	0	0	0	120	180	0	0	0	0	0	120	120	0
Tomato	1.34	0	0	0	0	2,640	1,320	0	1,320	0	0	0	0	0	0
Radish	0.16	0	0	0	0	0	160	480	0	0	0	320	0	0	160
Eggplant	0.30	1,200	0	0	0	0	300	0	1,200	0	0	1,200	0	0	0
Okra	1.48	0	0	0	0	0	0	2,928	0	0	2,928	2,928	0	0	0
Cauliflower	0.02	0	0	0	0	40	20	40	0	0	40	40	0	0	0
All crops	**2.00**	**2,020**	**420**	**420**	**2,940**	**3,320**	**2,840**	**3,528**	**3,080**	**280**	**2,948**	**5,528**	**1,040**	**440**	**400**

Note: Information on ban status is taken from Motin (2000) and Daily Star (2001).
Source: Field Survey, 2000.

insects and animals, such as, earthworm, honeybees and frogs that are good for crop production. Adverse effect on human health (9%) emerged as the second important harmful effect of pesticide use. Damages to crop (8%) as well as the reduction of soil fertility (7%) also appeared among the adverse effects. About 5% opined that pesticides also kill birds that come into contact with the crops.

Demand for pesticides: a simultaneous equation analysis

The system of three reduced form input demand functions for pesticides, chemical fertilizers and biofertilizers was estimated simultaneously using Three Stage Least Squares Estimation (3SLS) procedure[7] and the parameter estimates[8] are presented in Table 6. The fit is satisfactory for all the demand functions as indicated by values of adjusted R^2.

The input demand functions were specified in double-log form except for the three variables, the use of mask, education and age, thereby enabling us to read the remaining parameter estimates directly as demand elasticities. All own-price elasticities have consistent negative signs and two were significantly different from zero at 1 percent level (p<0.01), except fertilizer price. Price elasticity of demand for pesticides, fertilizers and biofertilizers

Table 5. Harmful effects of pesticide use as opined by the farmers.

Harmful effects of pesticides used as opined by the farmers	Responses (%)
Has harmful effects	**37.3**
Kills useful insects and animals (e.g., honey-bees, frogs, earthworms)	9.9
Affects human health	8.6
Damages crop and flowering if used in excess	7.8
Damages soil fertility and/or leading to increase in fertilizer doses	7.4
Kills birds	4.9
Affects the environment and/or damages environmental balance	3.7
Poisons food	1.2
Reduces fish catch	1.2
Increases crop pest attacks	1.2
Causes stomach pain if inhaled	1.2
No harmful effects	49.4
Did not examine whether have any harmful effects	8.6
Non-response	3.7

Source: Field Survey, 2000.

were estimated at –0.83, –0.21 and –1.13, respectively. All three inputs are complements to each other and the complementarity is significant between fertilizers and pesticides (p<0.10). Own-price elasticities of pesticides and manures, the conventionally omitted variables in most

Table 6. Demand for pesticides among hybrid vegetable and cereal seed producers.

Variables	Joint determination of demand for pesticides, fertilizers and biofertilizers		
	Pesticide demand	**Fertilizer demand**	**Biofertilizer demand**
Constant	-1.0163 (-1.203)	-1.6139 (-1.300)	0.3892 (0.072)
ln Pesticide price	-0.8308 (-2.041)***	-0.1704 (-1.685)*	-0.5699 (-1.286)
ln Fertilizer price	-2.0729 (-1.715)*	-0.2140 (-0.713)	-1.0977 (-0.834)
ln Biofertilizer price	-0.1867 (-0.620)	0.0540 (0.722)	-1.1264 (-3.434)***
ln Vegetable price	1.2961 (1.992)**	0.2795 (1.729)*	1.1609 (1.649)*
ln Cereal price	3.4009 (3.680)***	0.8905 (3.878)***	-0.0716 (-0.071)
ln Land cultivated	0.1689 (0.774)	0.9697 (17.884)***	0.9807 (4.128)***
Use mask while spraying	1.5849 (3.319)***	0.3319 (2.798)***	1.4458 (2.202)**
Education of farmer	-0.1091 (-2.519)***	-0.0022 (-0.200)	-0.0627 (-1.330)
Age of farmer	-0.0324 (-1.738)*	0.0015 (0.333)	0.0154 (0.4465)
Adjusted R^2	0.40	0.84	0.31
F value	7.01***	46.12***	5.07***
Degree of freedom	71	71	71

Note: Figures in parentheses are t-ratios.
*** Significant at 1 percent level (p<0.01)
** Significant at 5 percent level (p<0.05)
* Significant at 10 percent level (p<0.10)

studies, are quite high, the latter being in the elastic range, thereby indicating their importance for inclusion rather than omission. A fall in the price of biofertilizers will significantly increase its use and is therefore expected to contribute to enhancing soil fertility.

Response of input demands to output price change is consistent with a positive sign in cases where it is significantly different from zero. Demand for pesticides increase significantly with a rise in prices of vegetables and cereals and the values and are in the elastic range. Accept for the demand for biofertilizers in cereals, the response is significantly positive for all three inputs, consistent with the expectation and establishes the input intensity argument of hybrid crop production technology raised at the beginning of the paper.

Increase in land area under cultivation will significantly increase input use as expected although the incremental effect is not significantly higher in pesticide demand function.

Farmers equipped with technical know-how on precautionary measures needed while spraying pesticides seem to use significantly higher amount of all three inputs, which is a source of concern. Although they reported use of mask while spraying, the quality of this precautionary measure is not conducive to required safety standard and pose serious health hazard potential.

It is encouraging to note that the educated farmers as well as those who are more experienced in farming use significantly less amount of pesticides.

IV. CONCLUSION

The present study revealed that pesticide use is quite high in producing hybrid crops. Also, frequency of pesticide use is alarming. Results reveal that lowering of prices of pesticides as well as biofertilizers will significantly increase their use. Although increase in use of biofertilizers will enhance soil fertility, the increased use of pesticides in response to a fall in price raises concern on the potential environmental and health hazards of the farming population. Furthermore, a rise in vegetable and cereal prices would induce significant increases in use of pesticides and chemical fertilizers to boost yield levels and profitability. All these response patterns have profound implications for agricultural sustainability.

Although farmers seemed to be aware of hazards associated with chemicals, they used banned pesticides as these are the only ones available in the market and are probably cheaper and show visible results. On the other hand, farmers, who has some knowledge on the protective measure to be taken during pesticide application also uses significantly more pesticides. Result also revealed that educated and experienced farmers use significantly less amount of pesticides. However, it is worth noting that farmers selected by BRAC as 'contract seed producers' are relatively better-off, generally falling within the 'large farmer' category and are relatively educated above primary level (see Table A1 in the appendix) compared to the general farming population of Bangladesh who are largely landless and/or marginal farmers with no formal education. Therefore, the level of awareness of these 'contract seed' farmers is expected to be higher which is probably the case manifested above. Even this relatively higher level of awareness of farmers adopting these chemical input intensive hybrid crop production technologies is not sufficient in clearly safeguarding them from potential health and other environmental hazards.

In the drive for crop diversification through hybrid technology promotion, there remains a danger of losing biodiversity and the richness of traditional varieties, which are not always necessarily associated with low productivity. Particularly, the sustainability of these hybrid technologies are uncertain and they largely depend on modern inputs that are imported and quite demanding on natural resources such as minerals and fossil fuels. Also, potential health hazard associated with the handling of these harmful chemicals without proper precaution raises concern about the safety of the farming population.

Therefore, a combination of pesticide regulatory policies and effective implementation, thrust in promoting education among farmers, and programs to raise farmers' awareness of the harmful effects of pesticides, may safeguard the poor farmers in their pursuit of increasing income and better livelihood.

NOTES

1. Growth rate is estimated using semi-log trend function: $\ln Y = \alpha + \beta t$ where t is time. Data were from Hamid (1991) and BBS (various issues).
2. Cereals include hybrid varieties of maize, wheat and rice.
3. BRAC receives 'parent seeds' from Bangladesh Agricultural Development Corporation (BADC). After receiving the 'parent seeds' BRAC produces 'foundation seeds' in its seed production farm located at Dinajpur. Once the 'foundation seeds' are produced, BRAC distributes these to 'contract seed farmers' who in turn produces 'certified seeds' with technical support from BRAC Agricultural Extension program. These 'certified seeds' were again purchased by BRAC at a pre-set guaranteed price that in turn sells the seeds in the market. General farmers, therefore, purchase these 'certified seeds' to produce hybrid vegetables and cereal crops in their field.
4. Evidence of profit maximizing behavior of Bangladeshi farmers is well established (e.g., Hossain, 1989, Hossain et al., 1990, and Ahmed and Hossain, 1990).
5. One can also estimate demand for individual inputs after testing for input separability assumption. However, our interest is to estimate the set of input demands simultaneously in order to examine substitutability and/or complementarity among inputs, as it will provide us with more information for making policy decisions.
6. Pesticide in this study is treated as a normal variable input used in hybrid crop production technologies although its use rate actually varies with frequency of pest infestation. Nevertheless, farmers do use at least one dose of pesticide at the beginning of the crop cycle irrespective of whether pest infestation will occur or not. The reasoning is particularly true for hybrid crop technologies.
7. LIMDEP Software Version 7 (1997) was used for the analysis.
8. The summary statistics of the variables are presented in Appendix A.

REFERENCES

Ahmed, R., and Hossain, M. 1990. *Developmental Impact of Rural Infrastructure in Bangladesh*. Research Report. No.83. International Food Policy Research Institute, Washington, D.C.

BBS, (various issues). *Statistical Yearbook of Bangladesh, (various issues)*. Dhaka: Bangladesh Bureau of Statistics.

BRAC, (2000), BRAC Annual Report 2000. Dhaka.

Daily Star, 2001. "Selling of substandard pesticides continues in northern district". Daily Star (National Newspaper). October 4, 2001.

Hamid, M.A., 1991. *A Database on Agriculture and Foodgrains in Bangladesh (1947/48 – 1989/90)*. Dhaka: Bangladesh Agricultural Research Council/ Winrock International.

Hossain, M., 1989. *Green Revolution in Bangladesh: Impact on Growth and Distribution of Income*. University Press Limited, Dhaka.

Hossain, M., Quasem, M.A., Akash, M.M., Jabber, M.A., 1990. Differential Impact of Modern Rice Technology: The Bangladesh Case. Bangladesh Institute of Development Studies, Dhaka.

Hossain, M.I., Shively, G., and Mahmoud, C., 1999. "Factors influencing pesticide use in a rice vegetable farming system in Bangladesh". *Bangladesh Journal of Agricultural Economics*. **22**: 87 – 98.

Husain, A.M.M., Hossain, M., and Janaiah, A., 2001. *Hybrid Rice Adoption in Bangladesh: A Socioeconomic Assessment of Farmers' Experiences*. BRAC/IRRI, Dhaka.

Motin, R., 2000. "Stark realities of pesticide use". *Dhaka Courier*. **16**: 18 – 19.

Rahman, M.S., Malek, M.A., and Matin, M.A. 1995. "Trend of pesticide usage in Bangladesh". *The Science of the Total Environment*. **159**: 33 – 39.

Wadud, A. and White, B. 2000. "Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods". *Applied Economics*, **32**: 1665 – 1673.

APPENDIX

Table A1. Summary statistics of the variables used in the analysis.

Variables	Mean	Standard Deviation
Dependent variables		
Pesticide quantity (100 gm or ml)	7.18	9.99
Fertilizer quantity (kg)	350.72	567.57
Biofertilizer quantity (kg)	4602.88	5551.63
Explanatory variables		
Pesticide price (taka/100 gm or ml)	93.43	43.73
Fertilizer price (taka/kg)	9.21	1.48
Biofertilizer price (taka/kg)	0.25	0.21
Vegetable price (taka/kg of seed)	83.05	32.00
Cereal price (taka/kg of seed)	14.66	4.02
Land cultivated (ha)	0.59	0.74
Use mask while spraying (%)	0.44	0.50
Education of farmer (completed years of schooling)	7.12	5.09
Age of the farmer (years)	37.56	11.87

Source: Field Survey, 2000.