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Research Note

FACTORS INFLUENCING PESTICIDE USE IN A RICE-VEGETABLE FARMING SYSTEM IN BANGLADESH

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ABSTRACT

This paper studies factors associated with pesticide use in a rice-vegetable farming system in Bangladesh. Data came from a 1998/99 survey of 400 farm households. Regressions were used to examine factors that helped explain variation in patterns of pesticide expenditure. Controlling for farmer characteristics, results revealed positive and significant correlation between pesticide expenditures and farm size, non-agricultural income and degree of vegetable commercialization. Access to credit was found to have no explanatory power in the regressions. Farmers' estimates of pest infestation and damage were weakly correlated with pesticide expenditures.

I. INTRODUCTION

Since independence Bangladesh has achieved considerable growth in food production. A shift toward irrigation, modern seed varieties, and inorganic fertilizers, together with government investments in infrastructure have helped move the country towards food sufficiency (Ahmed and Haggblade, 2000). But given that the entire *boro* rice harvest and most of the *aman* rice harvest made possible using modern seed varieties, the prospects for further yield improvements in rice via a shift from local to modern varieties seem somewhat limited. As a result, efforts to achieve food security in Bangladesh-as opposed to the more narrowly defined goal of self-sufficiencynow must emphasize ways to facilitate a shift from food grain production to the production of high-valued crops such as vegetables. Studies show that revenue per hectare can increase dramatically when land is converted to vegetable production. Some vegetables, among them brinjal (eggplant), radish, cucumber, tomato, yardlong

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bean, and cabbage, rank among the highest valued crops grown in Bangladesh (Mahmud, Rahman, and Zohir 1994).

Table 1. Growth of crop area and production, 1979-1990

(Fig in percent)

Crop	Area	Production
Food grains	0.13	2.33
Paddy	0.05	2.42
Wheat	1.77	0.19
Non food grains	-1.73	-.28
Jute	-1.51	-0.44
Oilseeds	-1.55	-0.57
Pulses	-2.84	-1.82
Spices	-0.51	1.32
Fruits	1.30	-0.04
Vegetables	2.85	1.99
Tubers	-0.39	-0.15
Sugarcane	1.85	0.54
Tea	0.71	0.61
Minor cereals	-12.03	-11.42
All Crops	-0.28	1.62

Source : Faruquee (2000)

In the case of vegetables, data show that output growth in Bangladesh is taking place mainly through area expansion, without much improvement in yield (Table 1). Scope for yield improvement through development of better seeds, better methods of pest and disease control, and better harvest and post-harvest handling be there. However, one potential drawback associated with a shift toward more intensive vegetable production is the common reliance of most vegetable producers on heavy application of pesticides, and the externalities that they introduce (Pimentel and Levitan, 1986; Antle and Pingali, 1994; Rola and Pingali, 1993). Damage caused due to pest is particularly acute in the Asian region, as the data in Table 2 illustrate. Faced with high potential crop losses, the application of pesticides (insecticides, herbicides, fungicides, molluskacides, and rodentacides) would appear to be a rational response to pest outbreaks, given the absence of other options. Yudelman, Ratta, and Nygaard (1998) provide a very complete survey of trends in pesticide use.

Table 2. Estimates of crop loss due to pests in Asia

Pest	Country	Estimated Losses
Stem borers	Bangladesh (outbreak)	30-70%
	Bangladesh (no outbreak)	3-20%
	India	3-95%
	Malaysia	33%
	Philippines	6.6%
Leafhoppers and planthoppers	Bangladesh	50-80%
	India	1.1-32.5%
Rice bugs and gall midge larvae	India	10-35%
	Vietnam	50-100%
Blast	India	1% loss
	Japan	3%
	China	8-14%
	Philippines	50-85%
Tungro	Bangladesh	40-60%
	Philippines	30%
	Thailand	50%
Bacterial blight	Japan	20-30%
	India	6-60%
	China	5-6%
Sheath blight	Japan	20-25%
	Philippines	7.5-22.7%
	Sri Lanka	10%
	Mainland China	9-12%

Source: Based on various studies cited by Teng et al. (1990); reference years vary.

In Bangladesh, pesticides are widely used by rice and vegetable growers. Although pesticide use is low compared with other countries, use is rapidly increasing. A study undertaken by the Ministry of Agriculture in the early 1990s concluded that 1.8 million hectares were treated with pesticides in 1992, and that between 1982 and 1992 the total amount of active ingredient used in the country increased by 66% (for insecticides), 260% (for herbicides), and 1467% (for fungicides) (GOB/MOA 1995a). Several observers have noted that, due to lack of knowledge, some farmers may be using the wrong pesticides, or using the right pesticides at either sub-optimal or excessive rates (Ramaswamy 1992; Jackson 1991). A study indicated that while most water samples showed low concentrations of pesticide residues, approximately 11% of samples indicated pesticide residues that exceeded WHO-guidelines (GOB,1995b). A different study indicated slight organochloride pesticide pollution in floodplain ecosystems in the early 1990s, and some degree of bioaccumulation of pesticides in fish muscle tissue (GOB 1993). In addition to the risks that pesticides pose to the domestic food supply in Bangladesh, some export markets may be sensitive to the presence of pesticide residues on fresh vegetables, and future growth in export markets may depend upon proper control and application of pesticides. Misconceptions among farmers regarding pest behavior, coupled with lack of accurate information regarding pests, pest damage, and appropriate intervention means that farmers often incur unnecessary production costs. Some studies suggest that lack of education and training contribute to sub-optimal use of inputs in the face of technological change (Ramaswamy 1992). The research and policy-making communities in Bangladesh could benefit from a better understanding of factors influencing pesticide use, especially as a foundation for developing appropriate pesticide policies and alternative pest management practices, such as Integrated Pest Management (IPM).

II. MODEL

The empirical results of the paper were based on regressions derived from the following formal model of agricultural production under pest pressure (Feder, 1979). For convenience, it can be assumed that damage is due to a single pest. This pest causes damage to the crop in an amount related to its number N. Denote the cost of damage by $D(N)$:

$$D(N) = \delta N \tag{1}$$

where δ denotes the damage caused by a single pest. By assumption, this level of damage is independent of the total number of pests. Using x to denote the level of pesticide use, profit from agricultural production π can be expressed as:

$$\pi = \pi_0 - \delta N[1 - k(x)] - cx \tag{2}$$

where, π_0 denotes profits that would be realized if no pest were present (i.e. if $N = 0$). The number of pests surviving after pesticide application is N (1 - $k(x)$), where $k(x)$

(the so-called "kill rate") denotes the proportion of the target pest population killed. The unit cost of pesticide application is c, so that total expenditure on pesticide is simply the product of this unit cost and the level of application, i.e. cx. The farmer's objective is to choose the appropriate level of pesticide application in order to maximize expected utility of profit, defined as:

$$EU(\pi) = EU(\pi_0 - \delta N[1 - k(x)] - cx). \qquad (3)$$

First order conditions for equation (3) imply that the optimal level of pesticide application is that for which the expected marginal benefit (in utility terms) of additional pesticide application equals the marginal cost of additional pesticide use. Given uncertain damage due to pests, three points regarding (3) are worth noting. One, the model implies the level of pesticide application is increasing in the level of infestation, i.e. $\partial x/\partial N > 0$. This pattern reflects the fact that the expected marginal benefit of pesticide use increases with the level of infestation (since the expected level of damage increases with infestation) while the marginal cost is constant.[1] Two, other things equal, an increase in the expected mean level of damage δ will increase the level of pesticide application. And three, using a model based on (3), Feder (1979) argues that, for a given N and c, increases in the level of uncertainty regarding pest damages will elicit an increase in the amount of pesticide applied. This is because an increase in pesticide application reduces risk.

In the absence of constraints on operations, one would generally expect to observe levels of pesticide expenditure that maximize the expected net benefit of pesticide application, i.e. the difference between expected profits with and without pesticide application. This level of application should reflect actual levels of pest infestation. But in practice, information regarding pests and pesticides play a key role in pesticide application decisions. Information regarding pest infestation is nearly always imperfect. Furthermore, the quality of information may be influenced by farmer experience, training, or level of agricultural activity. Farmers who heavily rely on agricultural income in general, and vegetable income in particular, may have greater incentives to apply pesticides as part of income-maintenance and risk-reduction strategies. Section 4 explores the implications of this framework by examining per-hectare levels of pesticide expenditure, while specifically accounting for farm characteristics, farmer characteristics, and estimates of pest damage.The next section reviews data used in the analysis.

III. SOURCES OF DATA

Data used in this study came from a 1998-99 survey of 400 vegetable producers in four villages of Bangladesh. Two villages were selected from each of two Union Parishads (Kahsimpur and Konabari) under Joydebpur Thana in the district of Gazipur. The Kashimpur Union Parishad was within the Bangladesh Agricultural Development Corporation (BADC) pilot area and the Konabari Union Parishad was outside the BADC pilot area.[2] All the villages are located within the urban belt and have good communication linkages with markets at Dhaka. Prior to the survey, lists of farmers were collected from the respective Union Parishad offices and from the respective study villages. A total of 1300 vegetables growers were listed from the study villages. One hundred farmers were randomly chosen in each village. Among the 100 respondents in each village, 25 female respondents were chosen at random. Among remaining respondents, most were males.[3]

Characteristics of the farm households are reported in Table 3. Four sampled villages were located within the urban belt and all grew vegetables. For sake of comparison, data in Table 3 are presented for two non-overlapping subsets of the sample: those farms that planted vegetables only (n=178) and those that planted both rice and vegetables (n=222). Looking to the final column of Table 3, one can see that the average age of the respondents was 40 years. Nearly 20 percent of the respondents received some sort of general training in agriculture (not necessarily vegetable production or IPM), although the average level of education was reported to be only 3.5 years. Average experience in agriculture was 19 years.

Data indicated that, with the exception of the share of agricultural income in total income, average values for parameters reported in Table 3 differed significantly between vegetable growers and rice-vegetable growers. Expenditures on pesticides by vegetable growers (mean = Tk 507/ hectare) were significantly greater than expenditures incurred by those who grew both rice and vegetables (mean = Tk 356/hectare). Income of vegetable growers (mean = Tk 26,264) were significantly lower than income of those who grew both rice and vegetables (mean = Tk 51,604). Similarly, the average area cultivated by vegetable growers (mean = 0.45 ha) was significantly lower than for farms that grew both rice and vegetables (mean = 0.69 ha), as was total farm size. Data also show that, on average, farmers who grew both rice and vegetable received higher income outside of agriculture (Tk 9,958 vs. Tk 5,392).

Table 3. Characteristics of sample data for vegetable growers, 1998/99 sample means (standard deviations)

Parameter	Vegetable Farms only		Vegetable & Rice Farms		All farms	
Expenditures on pesticides (TK/ha)	507	(310)*	356	(520)*	440	(423)
Farm size (ha)	0.61	(0.81)	0.73	(0.61)*	0.69	(0.85)
Area cultivated (ha)	0.45	(0.65)*	0.69	(0.61)*	0.57	(0.65)
Income (Tk)	26,264	(34,497)*	51,604	(46,969)*	40,327	(43,690)
Non-ag income (Tk)	5,392	(11,620)*	9,958	(15,887)*	7,926	(14,313)
Ag income/Total income (%)	0.84	(0.30)	0.83	(0.22)	0.83	(0.26)
Education of respondent (yrs)	2.2	(3.1)	4.6	(4.3)	3.5	(4.0)
Age of respondent (yrs)	36.8	(10.8)	41.8	(14.4)	39.6	(13.5)
Experience in agriculture (yrs)	16.2	(8.9)	22.0	(12.3)	19.4	(11.3)
Training (0=no;1=yes)	0.12	(0.32)*	0.26	(0.44)*	0.20	(0.40)
BADC pilot area (0=no; 1=yes)	0.53	(0.50)	0.47	(0.50)	0.50	(0.50)
Gender of respondent (0=female; 1=r	0.42	(0.49)	0.95	(0.21)*	0.72	(0.45)
Veg sales/Total agri. production (%)	0.67	(0.38)*	0.43	(0.25)*	0.54	(0.34)
Utilized credit (0=no;1=yes)	0.09	(0.29)*	0.20	(0.13)*	0.05	(0.22)
Rice damaged by diseases (%)	-	-	4.37	(6.55)	-	-
Veg. damaged by diseases (%)	16.52	(20.99)	7.94	(12.15)*	11.76	(17.19)
Rice damaged by insects (%)	-	-	10.43	(10.55)	-	-
Veg. damaged by insects (%)	19.76	(22.19)*	7.53	(8.54)*	12.97	(17.20)
Number of households	178		222		400	

Source: Survey data . Note * indicates means are significantly different at 95% confidence level.

Education and experience among vegetable growers were lower than among the farmers producing both rice and vegetables. More than twice as many rice-vegetable growers had received training (of any kind) as compared with people growing vegetables only (26% vs. 12%). For farmers producing only vegetables, reported crop damage by diseases and pest attacks combined was on average lower than for those planting both rice and vegetables (7.6% vs. 18.1%). In terms of access to and use of credit, vegetable producers were more likely to use credit than those who grew rice and vegetables (9% vs. 2%).

In most cases the characteristics of and information reported by female respondents differed from those of male respondents at statistically significant levels. As expected, females were younger, less educated, less experienced in agriculture, and had received less formal training. They reported lower levels of household income and lower levels of non-agricultural household income. Female-reported cultivated area and share of vegetable income to total agricultural income did not differ from male-reported figures, but a significantly higher proportion of female respondents reported use of credit. They also reported higher level of insect and disease damage in vegetables. Whether this damage reflected true differences or different levels of awareness on the part of men and women is not known.

Finally, comparing among the respondents within the BADC pilot area and those outside the BADC pilot area, one finds statistically significant differences. Respondents within the BADC pilot area were younger, less educated, and had less farming experience than those outside the BADC pilot area. Farm size as well as and cultivated area in the BADC area were significantly smaller than those outside the BADC area and also income was lower. The importance of agriculture in general, and of vegetable sales in particular was greater inside the BADC pilot area.

IV. RESULTS AND DISCUSSION

Table 4 presents results from three farm-level regressions. All regressions were estimated by ordinary least squares, using per-hectare expenditure on pesticides (in Tk) as the dependent variable. The total variation in pesticide expenditure explained by the regressions was found relatively low, as reflected by R^2 values ranging from 0.21 (Model 1) to 0.24 (Model 2).

Model 1 used a set of basic farm-level variables as regressors. These included area cultivated, a BADC pilot area indicator, non-agricultural income, proportion of agricultural income to total income, degree of vegetable commercialization (as measured by the share of vegetable sales in the total value of agricultural production), access to credit, and gender of the respondents. With the exception of credit received (0/1), all the regressors were individually significant at 95% confidence level. Per-hectare pesticide expenditures were positively correlated with area cultivated, level of non-agricultural income, share of agricultural income, and degree of vegetable commercialization. Controlling for these factors, male respondents reported significantly higher level of pesticide expenditure than female respondents. Utilization of credit was not correlated with pesticide expenditures. In terms of elasticities, at the sample mean the share of agricultural income and the degree of vegetable commercialization showed the largest strength of association. One percent increase in the degree of vegetable commercialization was associated with a 0.45 percent increase in pesticide expenditure per hectare. One percent increase in the share of agricultural income in total income was associated with a 1.08 percent increase in pesticide expenditure per hectare.

Table 4. Regression results; dependent variable is expenditures on pesticides (Tk/ha)

Variable	Model 1	Model 2	Model 3
Constant	-359.13* (139.12)	-368.94* (143.50)	-409.72* (147.46)
Area cultivated (ha)	134.95* (35.81)	123.37* (36.30)	112.64* (36.31)
BADC pilot area (0=no; 1=yes)	-249.48* (42.84)	-272.49* (45.67)	-285.00* (48.43)
Non-ag income (Tk)	0.010* (0.002)	0.010* (0.002)	0.010* (0.002)
Ag income/Total income (%)	573.87* (138.94)	557.24* (139.32)	572.19* (141.22)
Veg sales/ Value of total agr.	364.54* (66.16)	379.45* (67.13)	375.75* (68.84)
Credit (0=no; 1=yes)	-20.55 (93.48)	-3.18 (93.84)	-34.70 (96.54)
Gender of respondent (0=female; 1=male)	128.88* (45.77)	84.33 (53.51)	126.18 (66.55)
Education (yrs)	—	3.41 (5.70)	2.00 (5.71)
Experience in agriculture (yrs)	—	2.04 (1.99)	1.49 (1.99)
Training (0=no;1=yes)	—	79.48 (54.92)	76.19 (54.84)
Rice damaged by disease (%)	—	—	9.65* (3.95)
Veg. damaged by disease (%)	—	—	1.57 (1.38)
Rice damaged by insects (%)	—	—	-3.49 (2.49)
Veg. damaged by insects (%)	—	—	0.67 (1.57)
R^2	0.21	0.22	0.24
N	400	400	400

Source: survey data

Note: * indicates significance at the 95% confidence level; standard errors are in parentheses.

Model 2 added to Model 1 three farmer-specific variables as explanatory factors. These variables—education, experience in agriculture, and training—were individually insignificant at a standard test level. Furthermore, the null hypothesis that the three farmer-specific variables were jointly insignificant could not be rejected using a F-test (the test value is 1.55, which falls below the critical value of 2.6). Adding these variables did not generally diminish the explanatory importance of the variables from Model 1, although the addition of education, experience, and training did reduce the statistical significance of the gender variable below standard significance level. In other words, large part of the difference in pesticide expenditure observed for male respondents in Model 1 was likely due to underlying differences between men and women with regard to education, experience and training.

Model 3 added to Model 2 four variables measuring farmers' subjective estimates of disease and insect damage to rice and vegetables. Damages were measured as a percentage of total crop lost. The value of these variables—and the degree of accuracy with which they measure actual disease and pest damage—must be viewed with caution since other information from the survey indicates that many farmers in the sample were unable to accurately identify common diseases and pests. Of the four variables, only the reported disease damage in rice helped to explain variation in pesticide expenditures. Higher perceived levels of disease in rice were positively correlated with pesticide expenditures. The null hypothesis that the three remaining damage variables were jointly insignificant could not be rejected using a F-test (the test value is 1.14, which falls below the critical value of 2.6). The addition of the four damage variables improved the overall fit of the model somewhat, and did not greatly alter the interpretation of the remaining variables. In elasticity terms, however, the importance of damage appears extremely small: one percent increase in level of disease damage in rice was associated with only 0.05 percent increase in pesticide expenditure at sample means.

V. CONCLUSIONS

This study examined the factors influencing levels of pesticide expenditure on low-income vegetable farms in Bangladesh. Least-square regressions were used to study patterns of pesticide expenditure on 400 farms from four villages. Positive and significant correlation was found between pesticide expenditures per hectare and area cultivated, level of non-agricultural income, agricultural income shares, and degree of vegetable commercialization. Pesticide use was significantly lower inside a BADC pilot area. With the exception of gender, the characteristics of farmer-respondents were not significantly correlated with pesticide expenditures. Farmers' perceived levels of disease and insect damage were only weakly correlated with pesticide expenditures. one clear pattern emerged with respect to intensive use of pesticides wherein farms focussing on agriculture as the main activity and production of vegetables for markets as a focus were more likely to be applying large amount of pesticides. Results suggest that use of pesticides was somewhat indiscriminate, and weakly related to experience, education, or training. The primary factors explaining levels of pesticide use were those related to farmer's ability or capacity to use them. Results suggest that efforts to reduce pesticide use and promote technologies such as Integrated Pest Management (IPM) should be targeted at larger farms and those farms where a greater priority is being placed on agricultural activities, especially vegetable production and sales.

REFERENCES

Ahmed, R. and S. Haggblade (2000). "Introduction." In Ahmed, R., S. Haggblade, and T. E. Chowdhury (eds.) *Out of the Shadow of Famine: Evolving Food Markets and Food Policy in Bangladesh.* Washington, D.C.: International Food Policy Research Institute.

Antle, J. M. and P. L. Pingali (1994). "Pesticides, Productivity, and Farmer Health: A Philippine Case Study." *American Journal of Agricultural Economics* 76:418-430.

BBS (1995). *Yearbook of Agricultural Statistics of Bangladesh.* Dhaka: Ministry of Planning, Govt. of Bangladesh.

Faruquee, R. (2000). *Bangladesh Agriculture in the 21st Century.* Dhaka: The University Press Ltd.

Feder, G. (1979). "Pesticides, Information, and Pest Management under Uncertainty." *American Journal of Agricultural Economics* 61:97-103.

Government of Bangladesh (1993). "Investigation of Pesticide Residue Levels in Floodplain Fish in Bangladesh." Interim Report Annex B, Fisheries Studies and Pilot Project FAP 17 (July).

Government of Bangladesh (1994). "Topic Report on Water Quality Aspects." Ministry of Agriculture, National Minor Irrigation Development Project. Consultant report prepared by William Halcrow & Partners Ltd. (April).

Government of Bangladesh (1995a). "Topic Report on Pesticide and Fertilizer Use in Bangladesh." Ministry of Agriculture, National Minor Irrigation Development Project. Consultant report prepared by William Halcrow & Partners Ltd. (February).

Government of Bangladesh (1995b). "Baseline Survey Water Quality." Ministry of Agriculture, National Minor Irrigation Development Project. Consultant report prepared by William Halcrow & Partners Ltd. (February).

Hossain, Md. I., G. Shively and C. Mahmoud (2001). "Crop Production and Pest Management Practices on Rice and Vegetable Fields." IPM CRSP Working Paper 2001-01.

Jackson, G. J. (1991). "Agrochemical Usage in Asia Region: A Reference Compendium." Mimeo.

Mahmud, W., S. H. Rahman, and S. Zohir (1994). "Agricultural Growth Through Crop Diversification in Bangladesh," Working Paper No. 7. Washington D C: International Food Policy Research Institute.

Pimentel, D. and L. Levitan (1986). "Pesticide amounts applied and amounts reaching pests. *BioScience* 36:86-91.

Ramaswamy, S. (1992). "Pest Control and Environment." Paper presented at the Bangladesh Research Council Seminar on Environment & Agriculture in Bangladesh, September 11, 1992.

Rola, A.C. and P.L. Pingali (1993). *Pesticides, rice productivity, and farmers' health: an economic assessment.* Manila: International Rice Research Institute.

Teng, P. S. (1990). "Crop loss assessment: a review of representative approaches and current technology." In *Crop Loss Assessment in Rice.* Los Baños: International Rice Research Institute.

Yudelman M., A. Ratta, and D. Nygaard (1998). "Pest Management and Food Production, Looking to the Future." Food, Agriculture, and the Environment Discussion Paper 25. Washington, DC: International Food Policy Research Institute.

Notes

[1] The critical pest population level $\tilde{N}$ at which the decision maker will be indifferent between applying and not applying pesticide is referred to as the "economic threshold population," and is defined by:

$$EU'\left[\delta\tilde{N}k'(0)-c\right]=0.$$

[2] The BADC pilot area is a location in which farmers were receiving, on an ongoing basis, a range of agricultural training and technical support. The name of the villages under Kashimpur were Enayetpur and Barenda-Noyaparea. Those under Konabari were Aahaki and Joyertek.

[3] The reader should not conclude that these households are female-headed. Instead, the sampling method merely aimed to ensure a high degree of reporting by females. Whether reported behavior in these households with respect to pesticide use differed from behavior reported by male respondents is examined below.