# An Analysis of Pesticide Use for Rice Pest Management in Bangladesh

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## Abstract

The so-called Green Revolution package was introduced into Bangladesh agriculture system in mid 1960s. It promised to increase production of cereal crops, particularly rice by the introduction of HYV seeds, application of chemical fertilizer and pesticide, and irrigation. HYVs rice has contributed significantly to the progress towards the food self sufficiency in Bangladesh on the contrary increased to the environmental degradation due to the intensive use of agrochemical and other modern technology. The use of pesticide has been increased 400% per acre and its cost increased 600% during the last couple of decades. Between 1985 and 1990 the sales of pesticide became double. At present, 84 pesticides active ingredients belonging to 242 trade names have been registered in Bangladesh. Out of the total pesticide use, over 80% are used in rice fields. The rapid increase of pesticide use is causing detrimental effect on environment and health of farm workers and consumers. Pesticides are contaminating ground and surface water, which is causing depletion of inland fishing resources and ecosystem. Therefore, the present study evaluates the level of farmers' pesticide use practiced to rice pest control, their knowledge and perception of the impact of pesticides on environment. A questionnaire survey has been conducted to collect the data from the farmers. Data have been collected from 86 rice farmers of Bangladesh. The study revealed that the respondent farmers used mostly insecticides at the rate of 1 to 10 kg active ingredients per hectare of cropland and the time of application varied from 1 to 4 sprays per crops. The richer farmers used pesticide more frequently as compared to small and medium farmers. But most of the pesticides belong to extremely and highly hazardous category as classified by WHO. Considering the cropping intensity and toxicity of the pesticide, the environment and farmers health are at high risk under the pesticides contamination. The average level of knowledge and perception of the respondents was found poor to moderate. In general the respondents showed favorable attitude towards the pesticide use. Among the insecticides used by the farmers, Bashudin 10 G, Diazinon 60 EC, Sumithion 60 EC and Padan 50 SP have already been banned for use on rice in other developing countries. The use and availability of Bashudin, an obsolete pesticides indicates that existing pesticide laws and regulations are not strictly enforced in relation to import, formulation, repackaging, distribution, advertising and use of pesticides. Therefore, in Bangladesh the laws and regulations of pesticide should be enforced more strictly

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and a new policy should be enacted to educate the farmers regarding the harmful impacts of pesticides. There is an urgent need to assess the impact of pesticides on human health and pollution level of pesticides in soil, water, and air in Bangladesh.

Key words: Environment, impact, pesticide, perception, rice farmers.

## 1. Introduction

Pesticide use in crop production has been suspected of being a major contribution to environmental pollution. There are widespread and growing concerns of pesticide over-use, relating to a number of dimensions such as contamination of ground water, surface water, soils and food, and the consequent impacts on wildlife and human health (McLaughlin and Mineau, 1996). Farmers often spray hazardous insecticides like organophosphates and organochlorine up to five to six times in one cropping season while only two applications may be sufficient. The usual practice of draining paddy water into irrigation canals may cause river and lake contamination. Residues carried by the water can be taken up by non-target flora and fauna, leach in to soil, and possibly contaminate groundwater or potable water. A greater problem lies in the bioaccumulation of pesticides in beneficial organisms like fish. Residues in food pose to consumers if the maximum residue limit set by Food and Agriculture Organization (FAO) and World Health Organization (WHO) is exceeded (Pingali and Roger, 1995).

To reduce crop losses due to pest attack, farmers in parts of Asia are spraying as much as 800 times the original recommended dosage of pesticides (Farah, 1994). The use and abuse of pesticides has disturbed the ecological balance between pests and their predators in developed and developing countries (Dahal, 1995). The lesser-developed countries still don't use as much pesticide as does the industrialized world. A study of Food and Agriculture Organization apprehended that in 21st century the pesticides use would increase in the developing countries (FAO, 1995).

Pest control becomes a social need in countries where the food supply is short and there is an urgent necessity to increase rice production. Before the green revolution pesticide use was largely confined to the industrialized nations. Today, pesticides are produced and used globally. The third world's use of pesticides increased greatly during the Green Revolution in the 1960`s and beyond, and it is related to the changed growing conditions which was brought about by the use of green revolution varieties and technologies. Monocultures coupled with increases in irrigation and fertilization often improve conditions for pests, necessitating more control efforts (Yudelman et al. 1998).

Insecticide choice in the developing world is often older, broad-spectrum compounds belonging to the organophosphate and carbamate classes chemical families noted for their acute toxicity. These products are popular partly because they are no longer under patent protection thus are considerably cheaper than the newer, still-proprietary pesticides increasingly used in more developed countries. Organochlorine insecticides such as DDT, lindane, and toxaphene are still widely used in the developing world, although their danger to humans and animals is well known. In fact, about 1/2 of the pesticides used in the lesser-developed countries are persistent Organo chlorine, such as DDT. They are used because they are cheaper and are considered safer for farmers to apply because of their relatively low short-term toxicity to mammals (including farmers).

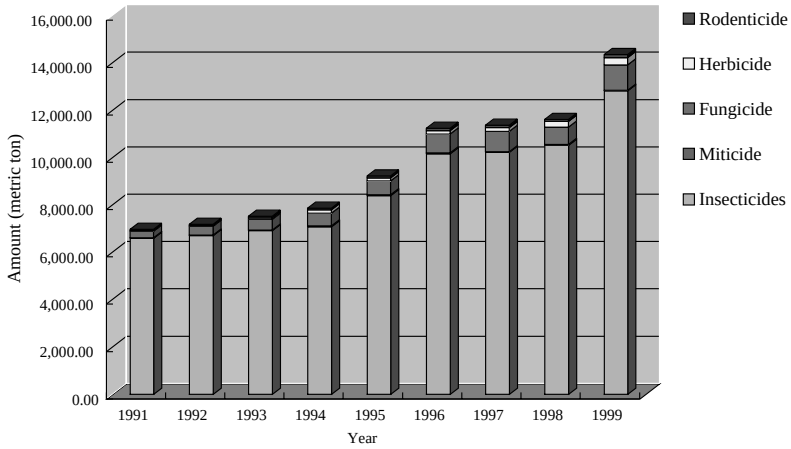


**Figure 1.** Trend in Pesticides consumption in Bangladesh

**Pesticides Use in Bangladesh**

Pesticide as agricultural input was introduced in Bangladesh in 1957 and mainly DDT and BHC was distributed by the Government to the farmers free of cost until 1973. The pesticides become very popular to the farmers for two reasons; firstly quick and visible effect on pest and secondly, no cost involvement. In 1974, the subsidy was reduced to 50% and in 1979 it was withdrawn completely (Islam, 2000). As a result at first pesticide use declined and again gradually increased and in 1999 the amount reached 15000 metric tons (**Figure 1**). At present 84 pesticides with 242 trade names have been registered in Bangladesh (PAB, 2000).

The use of pesticides in Bangladesh is less in comparison to other developing countries. It is 0.03 kg/ha compared to 0.3 kg/ha in India, 0.4 kg/ha in Sri Lanka and 0.8 kg/ha in Indonesia (Karim, 1998). Currently, 14,340.40 metric tons of commercial pesticides are used annually, primarily in the cultivation of rice, tea, jute, sugarcane and vegetables. About 70% of pesticides are used on rice. Pesticides used on rice consist almost exclusively of insecticides, but fungicides are used occasionally. In 1989-90 almost 90% of pesticides were used on rice. In Bangladesh, insect pests' outbreak is frequent in rice and crop losses occurred due to rice insect pest attack up to 80% (Kalam, 1998).

The intensification of agriculture has been accompanied by the rapid increase of insecticide use. Increased use of pesticides leads to two primary concerns (Kalam, 1998):

1) Adverse effects on the health of farm workers as well as others exposed to the pesticides
2) Polluted ground water and surface water, causing harm to the water users as well as inland fisheries and other aquatic animals.

Biodiversity is declining due to the effect of pesticide and fertilizer use. Population of native fish species (Channa spp., Heteropneustes clarias, and Anabas testudineus) is now endangered and the traditional rice-fish systems have disappeared. The bird and other small wild animals are in threat of wide spread because of the use of pesticides in rice and vegetables. The rice-based agroecosystem is showing signs of unsustainability. Most of the rice farmers are dependent on insecticides for pest control. A survey conducted by the Non Government Organization Community of American Relief Everywhere (CARE) of rice farmers in Comilla district, a high-input use area showed that 96% used insecticides dur-

ing the dry season. But despite of or due to the prevalence of insecticide use, old farmers reported that insect pests are now more difficult to control than in their youth (Barzman and Das, 2000).

Most of the farmers of Bangladesh are not capable of taking decisions on pest management and pesticide application. Often they apply pesticides when there is no real need or they use wrong chemicals at wrong doses, methods and times. As a result they kill the beneficial organisms easily and create pest resistance causing the greater problems and crop losses. The Brown Plant Hopper (BHP) outbreak in 1991 in Nilphamari and Rangpur districts of Bangladesh has been attributed to the excessive use of pesticides. Aerial application of pesticides on rice has been abandoned in India as early as in 1976 and in Indonesia in 1985 because of its serious harmful effects on environment. A survey conducted by the department of environment indicated that, following the aerial spraying in 1999, cows, calves, goats, fish, honey bees, dragon flies, lady beetles, birds and many other useful insects and animals had been seriously affected by the aerial spraying of pesticides.

There is a suspicion that pesticide residues are common in surface water system, especially in irrigation drains, which ultimately pollute the pond and river water. There are many undocumented cases of chronic health effect of pesticides on farmers and other people. Several factors are supposed to be responsible for chronic health effect such as; improper handling, lack of protective measure, improper storage, use of obsolete pesticides, etc.

The knowledge, attitude and perception of the farmers reflect their practice of pesticide use and decision making process regarding the pest management strategy (Carlson and Mueller, 1987). Therefore, this study was formulated to know the pesticide use practice as well as to evaluate the farmer's knowledge, attitude and perceptions regarding the impact of pesticides on environment.

## 2. Study Area and methods

**Study area:** The study area comprised of three districts such as, Kushtia, Comilla and Manikgonj (**Fig. 2**). Comilla is located in the 120-kilometer southeast of Dhaka, the capital of Bangladesh. In terms of Agro-Ecological Zone (AEZ) Comilla belongs to AEZ 19: Meghna Estuarine Floodplain Zone. Kushtia is located 257-kilometer northwest of Dhaka and belongs to AEZ 11: High Ganges river Floodplain area. Manikgonj is in the 50-kilometer northwest of Dhaka and belongs to AEZ 8: Jamuna Floodplain Zone. The typical soil type of these three regions is loamy to clayey, which is suitable for the rice production. The area under rice cultivation of Comilla district in 1995 was 2,53,885 hectare, 3% of national average and rice production share was 4% of national average. Whereas, the area of rice production in Kushtia and Manikgonj accounts for


**Figure 2.** Bangladesh map showing the study area

2% of national average as of 1995.i The cropping intensity of Comilla is 194.90 %, Kushtia 195.77% and in Manikgonj is 175.59% (BBS, 1995). Besides rice as the major crop, the important farm products are vegetables in Comilla, tabacco in Kushtia and potatoes in Manikgonj. These three regions have good communication and marketing facilities. The farmers of these regions managed to produce three crops per year, with at least two rice crop. More than 90% of the farmers are producing rice as the main crop. Among the rice farmers about 70% are small farmers (0.02 to 1.00 hectare of land holdings) 25% are medium farmers (1.01 to 3.03 ha of land holdings) and only 5% are large farmers (above 3.03 ha of land holdings). Therefore, majority of farmers are in the subsistence level, produce food crops mainly for the family consumption. Only a small proportion of farmers (medium and large) is producing rice for commercial purpose and most of them try to use high input of High Yielding Varieties (HYVs), fertilizer, pesticide and irrigation for more profit. Whereas, the majority of small farmers are not able to use high level of input.

**Data collection:** The rice farmers who were using chemical pesticide as a pest control measure, were purposively selected as the respondent of the study. Three villages were selected from the three locations such as, village Khoshbash, thana Barura of district Comilla, village Bramanpara, thana Bheramara of District Kushtia and Chandirchar village of Manikgonj Sadar Thana. A total of 86 farmers, 40 from Comilla, 25 from Kushtia and 21 from Manikgonj were selected randomly on the basis of the total number of farmers of the specific area. The face to face interview of the farmers was taken using a structured and pretested questionnaire on the following aspects.

**Pesticide use profile:** The respondents have been asked to mention the name (trade name) and amount of pesticide used for a unit area, the common name was collected from the list of pesticide provided by the Pesticide Association of Bangladesh. From the quantity of used per unit of area, the amount was calculated for a hectare.

For other information the probable items were given with the assigned number and farmers have been asked to put the appropriate number against the each parameter for each pesticide, the parameter and probable answer are as follows;

| **Crop stage:** | **Basis:** | **Effectiveness** |
|---|---|---|
| Nursery -1 | Presence of pest-1 | Veryeffective:75-100% insects killed-1 |
| Early tillering-2 | Action thresholds-2 | Effective:50-75% insects killed-2 |
| Late tillering-3 | Calendar spray-3 | Small effect only:<50% insects killed-3 |
| Booting-4 | Crop phenology-4 | No effect-4 |
| Flowering-5 | Per consultant-5 | Makes the insect problemworse-5 |
| Milky-6 | | Weather-6 |
| Soft Dough-7 | Neighbor's farm-7 | |
| Before harvest | | |

| **Formulation:** | **Application method:** |
|---|---|
| Granular-1 | Hand sprayer-1 |
| Powder-2 | Knapsack sprayer-2 |
| Liquid-3 | Broad cast - 3 |
| Wettable powder-4 | Others traditional methods-4 |
| Others-5 | |

**Use of other control methods;** the respondents were asked to check the methods they used among the following,

- Use of resistant varieties
- Use of IPM
- Timely planting
- Improve drainage
- Biocontrols(use of predators/parasites)
- Crop rotation
- Use of low-toxicity pesticides such as oils, soaps, biopesticides and sulfur
- Others(if any please mention)

The knowledge of the respondent farmers was measured by using 10 question providing 3 probable answers, the respondents were asked to check the appropriate answer, score 5 or 0 were assigned respectively for the right and the wrong answer. On the basis of the mean score of the questions the knowledge level of the respondent farmers was measured.

To measure the attitude of the respondent farmers, 10 statements were selected and they were asked to check their opinions in a 5 point's scale. The numeric values for the opinions were assigned as 5 for strongly agree 4 for agree, 3 for undecided, 2 for disagree and 1 for strongly disagree. The statement was positive as well as negative in nature. On the basis of the obtained scale value the attitude of the respondents were categorized as favorable (value 4 & 5), neutral (value 3) and unfavorable (value 1 & 2).

To assess the perception of the respondents towards the environmental impact of the pesticide, the environmental aspects were divided into four issues or elements of issue such as, I) ecological impact, ii) impact on soil, iii) impact on water and iv) impact on air and health hazard. Five statements for each of the issues were selected on the basis of extensive literature search. The statements were put on a five-point scale to measure the degree of their opinion as strongly agree, agree, undecided, disagree and strongly disagree and numeric value of 5,4,3,2 and 1 were assigned respectively. On the basis of the scale value of each of the statement the perception of the respondents have been categorized as strong perception (score 4 and 5), weak perception (score 1 and 2), no perception (score 3) and no response (didn't respond).

The technical aspects and classification of the pesticides were collected from the Pesticide Association of Bangladesh as well as the list of pesticide sales in the regions was collected from the pesticide dealers.

## 3. Results

### 3.1 Pesticide use profile

A total of 15 active ingredients with 21 trade name were used by the respondent farmers of Bangladesh in their winter rice crop of the year 2000 (**table 1**). Among the 15 ingredients 3 were fungicides and 12 were insecticides. Most of the insecticides were used to kill the stem borer, green leafhopper and some of grasshopper and gall midge. The fungicide used to control the sheath blight and blast diseases. The frequency of pesticide use was varied from 1 to 4 sprays per crop season. The rate of

**Table 1** Chemical pesticides used in 2000 winter rice by the respondents farmers in Bangladesh

| Common name | Trade name | WHO category | Type | % of farmers used | kg or L/ha used | Targetted pests |
|---|---|---|---|---|---|---|
| *Insecticide* | | | | | | |
| Carbofuran | Agrifuran 5G | Class Ib | C | 1 | 3.8 kg | Stem borer |
| | Biesterin 5G | Class Ib | C | 16 | 7.04 kg | Leaf hopper |
| | Sunfuran 5G | Class Ib | C | 9 | 6.89 kg | Stem borer, Defoliator |
| | Furadan 5G | Class Ib | C | 9 | 4.89 kg | Stem borer, Grass hopper |
| | Carabofuran | Class Ib | C | 2 | 0.93 kg | Rice bug |
| Dioxathion | Bashudin 10G | O | OP | 44 | 8.27 kg | Stem borer, Gall midge |
| Cyhalothrin | Karate 2.5 EC | Class II | PY | 3 | 5.00 litre | Plant hopper, Green leaf hopper |
| Cypermethrin | Cymbush 10 Ec | Class II | PY | 3 | 3.74 litre | Defoliators, Green leaf hopper |
| | Ripcord 10 EC | Class II | PY | 2 | 0.96 litre | Rice hispa |
| Diazinon | Diazinon 60 EC | Class II | OP | 3 | 5.97 litre | Green leaf hopper, stem borer |
| DDVP | Nogoz 100 EC | Class Ib | OP | 3 | 9.23 litre | Thrips |
| Fenitrothion | Sumithion 50 EC | Class II | OP | 15 | 5.83 litre | Leaf roller, rice hispa |
| Monocrotophos | Monotaf 40 WSC | Class Ib | OP | 14 | 8.76 litre | Stem borer |
| Malathion | Malathion 57 EC | Class III | OP | 2 | 4.38 litre | Green leaf hoppers, Thrips, Rice bug |
| | Faifanon 57 EC | Class III | OP | 24 | 2.69 litre | Stem borer, Brown grass hopper |
| Phosphamidon | Dimecron 100 SCW | Class Ia | C | 34 | 4.23 litre | Rice hispa |
| Cartap | Padan 50 SP | Class II | C | 2 | 0.86 kg | Plant hopper, Green leaf hopper |
| BPMC | Baycarb 500EC | Class II | C | 26 | 5.24 litre | Defoliators; Green leaf hoppers; Thrips |
| *Fungicide* | | | | | | |
| Edifenfos | Hinosan 50EC | Class Ib | OP | 7 | 3.8 litre | Blast |
| Carbendazim | Knowin 50 WP | Class U | C | 44 | 5.48 kg | Sheath blight |
| Propiconazole | Tilt 250 EC | Class II | OP | 9 | 7.96 litre | Blast |

Frequency of application in a crop season by the respondents: 1=11%, 2=11%, 3=59% and 4=19%
Note: Ia = Extremely hazardous, Ib = Highly Hazardous, II = moderately hazardous;
III = Slightly hazardous; U = Unlikely to present acute hazard in normal use;
O = Obsolete as pesticide, not classified. OP = Organophosphorus compound
C = Carbamate; PY = Pyrethroid

application was not so high. The rate varied from about 1 kg/liter to 10 kg or liter per hectare of land They had the knowledge about rate and frequency of pesticide application from the dealer and also they had considered the cost of the pesticides.

The farmers have used an equal number of 8 Organophosphates and Carbamates pesticides and 3 pyrethroid. Fortunately no organochlorines have been found to be used by the respondents farmers. Bangladeshi rice farmers used mostly category Ia, Ib and II pesticides that the WHO classifies, respectively extremely, highly and moderately hazardous. Almost all of the carbamate insecticides they used are of extremely or highly hazardous category having wide spectrum toxicity to the environment. The

pyrithroids they used were moderately hazardous.

The insecticide Bashudin 10G and Organophosphates was used by the largest proportion of the farmers (44%) followed by the Dimecron (34%) and Baycarb 500 EC (26%). Fungicide Knowin was used by 44% of farmers. Bashudin 10G is an obsolete insecticide which had been used by the largest number of farmers of Bangladesh and the average application rate was also maximum among the pesticides used. Monocrotophos and DDVP are also known as their wide spectrum toxicity. The mostly used fungicide Knowin 50 WP is a carbamate type and it is categorized as unlikely to present acute hazard in normal use.

### 3.2 Crop stage of pesticide used

Largest number of farmers used pesticides in the early tillering stage (30%) followed by the late tillering and booting stages (**Figure 3**). Vegetative growth stage is the most susceptible to the pest attack, that's why farmers applied mostly in early and late tillering stages than the booting, flowering and milky stages. Major insect pests such as stem borer, leaf hopper and plant hopper attacks are prevalent in these stages. Rice hispa is one of the major insect pests of rice attacks in the mature stage like soft dough (Shepard et al 1995). In Bangladesh, rice hispa infestation is common and more than 12% of farmers applied insecticides in the soft dough stage. Ten percent farmers applied insecticides at the nursery stage which is susceptible to thrip, defoliator, stem borer, green leaf hopper and plant hopper (Mueller, 1980).

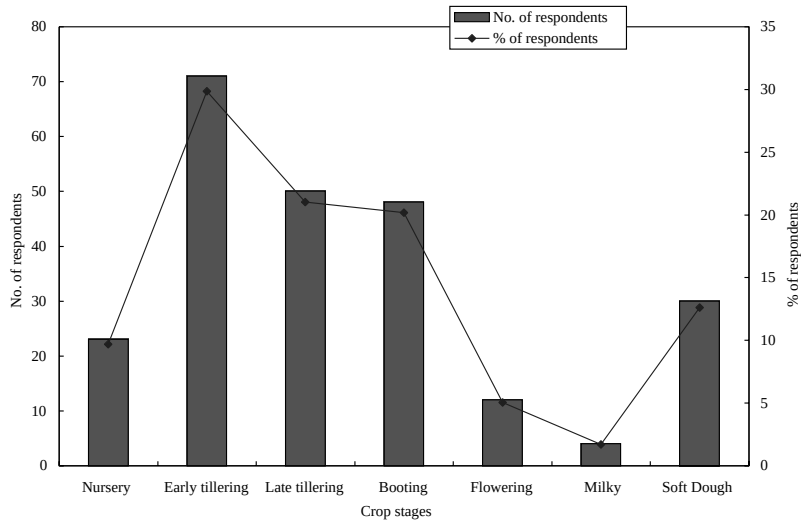


**Figure 3.** Stages of pesticide used to control rice pest by the selected farmers

### 3.3 Basis of application

Almost an equal proportion of farmers used pesticides on the basis of presence of pest and action threshold (**Figure 4**). Twenty three percent of the farmers used pesticide after consultation with the personnel of the Department of Agricultural Extension and 4% used as calendar spray for preventive measure. As reported by the Pesticide Association of Bangladesh many farmers apply pesticide mixed with basal dose of fertilizer as preventive measure, without any basis.

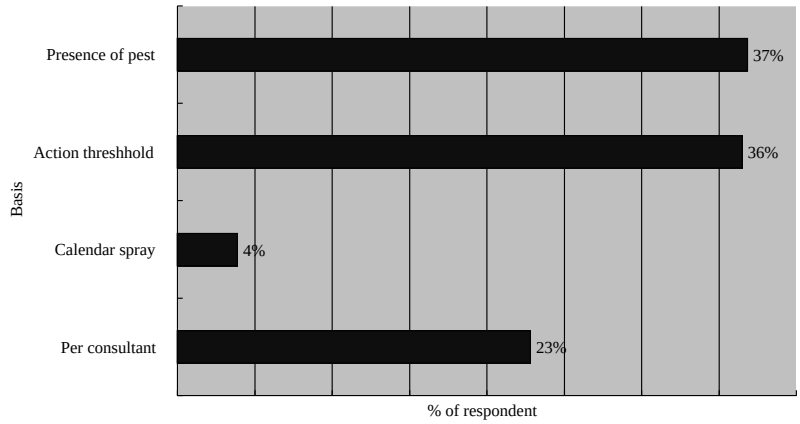


**Figure 4.** Basis of pesticide application by the selected rice farmers.

### 3.4 Application methods

Among the surveyed farmers of Bangladesh 57% used hand sprayer and 8% used Knapsack sprayer to apply the pesticides on the crop field (**Figure 5**). Remaining 18% farmers used broadcast methods and 16% used other traditional methods. The sprayers they used were not in a good condition. The hand sprayer they used includes a container with broom and sprinkled the pesticide with broom. Most of the farmers don't have any sprayer of their own; they borrowed it from relatively richer farmers. They didn't have any training about the sprayer use and precaution. Therefore, the spray was always associated with high risk of exposure. The farmers broadcast the granular insecticide keeping in an open bowl or basket and broadcast by bare hands and feet. The traditional methods they used are very unscientific. For example they brush the crop field. In this method, usually the insecticide is mixed with water in an open bowl or a big can then date palm leaf is soaked in it and the standing crop plant is brushed. During the mixing and brushing the farmers as well as the environment are exposed to pollution. No farmers have used any protective measure such as musk or gloves. According to the pesticide agent and leaflet provided by the

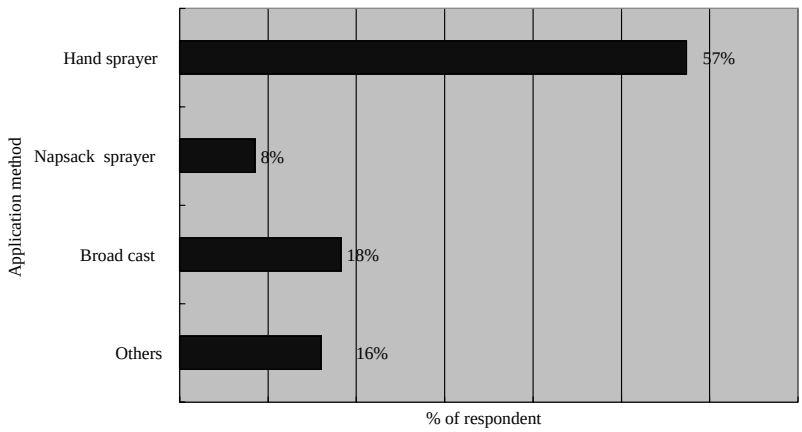


**Figure 5.** Pesticide application methods used by the selected rice farmers

Department of Agricultural Extension, the measuring unit is being used as spoonful, handful or lidful.

### 3.5 Effectiveness of pesticide

An equal proportion of 48% of farmers said that the pesticide used to control pest was very effective (75 to 100% pests were killed) and effective (50 to 75% pests were killed). Only 4% farmers said the pesticides had small effect (less than 50% pests were killed (**Figure 6**). Barely no respondent perceives an insecticide or fungicide they used were ineffective or as causing more pest problems. These results indicate that the respondent farmers are not aware of the concept of pest resurgence and natural enemies. To them, insecticides are always a solution to, never a cause of, insect pest problem.

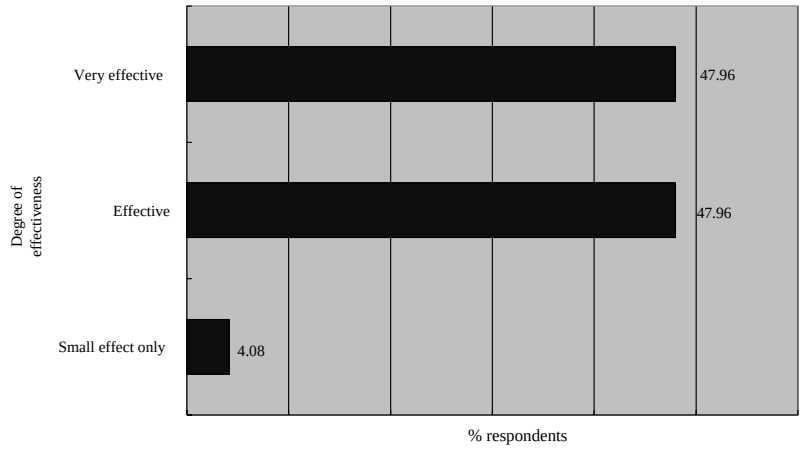


**Figure 6.** Effectiveness of the pesticides as perceived by the respondents

### 3.6 Alternative methods used for pest control

Because of late introduction of pesticide in Bangladesh agriculture the farmers are used to control pest using other traditional methods besides insecticide. In these cases they used indigenous knowledge to control pest not to avoid the hazard of pesticide, mainly to minimize the production cost. Among the other methods, 40% of the farmers used crop rotation as an alternative to chemical pesticides use, 19% used timely planting and 15 % used resistant varieties. Only 2% of the farmers used Integrated Pest Management (IPM) technique to control pest of rice (**Figure 7**). Biocontrols means that they use bird to feed the insect. Remaining 12% farmers used other methods such as, soap, karosene oil, light and net trap to control insect. In certain extent they pull the insect larvae by hand also.

### 3.7 Knowledge about the pesticide use

On the basis of the average score of the questions the knowledge level has been categorized as poor (the average score up to 1.5), moderate (the average score from 1.6 to 3.0) and good (average score above 3.0). The study shows that the farmers possessed moderate level of knowledge in the most of the aspects of pesticide use. Out of 5.0 average knowledge score varied from 0.5 to 3.7 for different questions (**Figure 8**). They have poor knowledge regarding the effect of excessive use of pesticide in the crop field (Q9), the direction of pesticide spray (Q4) and the worst impact of improper handling of pesticide (Q10). On the other hand, the respondents have good knowledge regarding the purpose of Diazinon

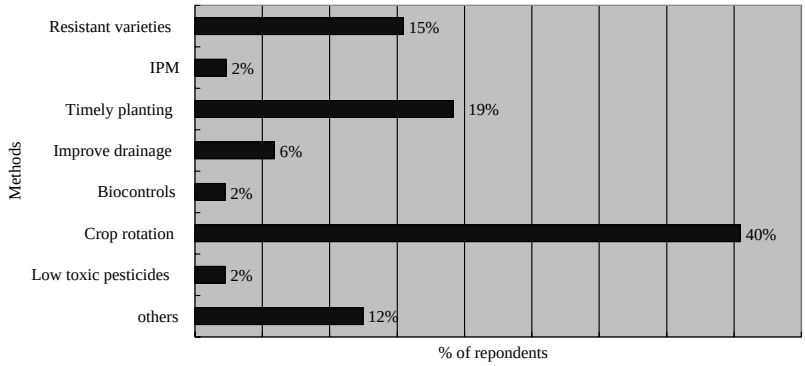


**Figure 7.** Alternative methods of chemical pesticides to pest control by the selected rice farmers

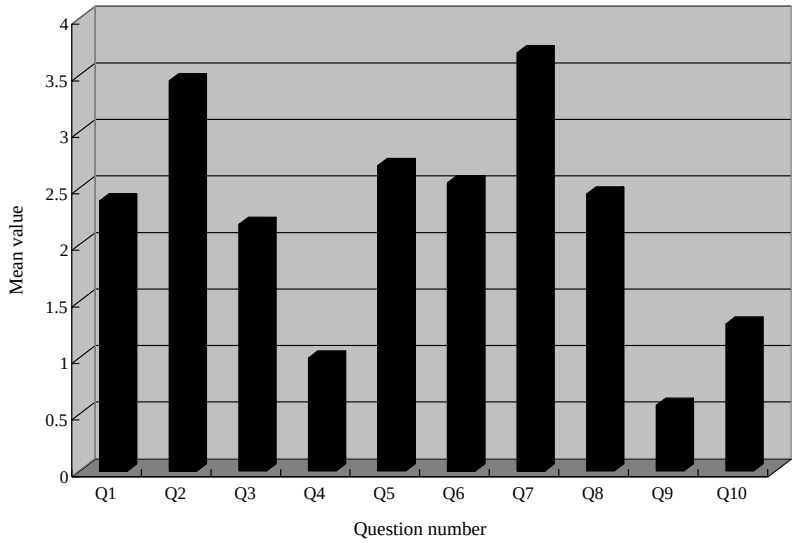


**Figure 8.** Average knowledge level of the respondent farmers about the chemical pesticide use

use (Q2, the average score being 3.5) and the cause of the harmfulness of the pesticide (Q7, the average score is 3.7). Thirty seven percent farmers said that using traditional hand spray with broom is the appropriate method for pesticide application, whereas, 41% said the sprayer is more appropriate. Most of the farmers know that pesticide is a poisonous chemical, but they don't have knowledge that the excessive use may create pest resistant and improper handling may cause health hazard (**Table 2**). Forty six per cent farmers said that pesticide should not be used just at scorching noon. Farmers have confusion regarding the direction of pesticide spray, as 45 % said opposite to the wind and 40% said towards the wind direction. Because of the risk of exposure to the applicator, pesticide should be sprayed on the wind direction and only 15% farmers knew this. Forty four per cent respondents have knowledge that the pesticide application in mature stage of crop is the most harmful for the consumer, therefore they do not spray. It is noteworthy to mention that among the respondent farmers nobody has ever had training regarding the pesticide handling and precaution.

**Table 2** The knowledge of the respondents farmers of Bangladesh regading the different aspects of pesticide use

| Index | Questions | % of respondents answered | | |
|---|---|---|---|---|
| Q1 | Appropriate way of pesticides application of the field with brooms | i) Using sprayer | ii) Realesing one corner | iii) Traditional hand spray |
| | | 41 | 22 | 37 |
| Q2 | Purpose of Diazinon use | i) to control harmful insect/disease* | ii) To control disease | iii) to control weed |
| | | 59 | 30 | 11 |
| Q3 | Time when pesticide should not be applied | i) Just at scorsching noon* | ii) From 10-11 at morning | iii) Afternoon |
| | | 38 | 42 | 20 |
| Q4 | Direction of pesticide spray | i) Towards the wind direction | ii) Opposite the wind | iii) both the direction |
| | | 15 | 45 | 40 |
| Q5 | Appropriate depth of stagnant water to use granular pesticides | i) 5-10 cm* | ii) 0 cm (surface) | iii) 25-100 cm |
| | | 46 | 40 | 14 |
| Q6 | Most harmful stage of pesticide use for the consumer | i) Mature stage* | ii) seedling stage | iii) tillering stage |
| | | 44 | 30 | 26 |
| Q7 | Reason behind harmfulness to the consumer | i) poisonous chemical* | ii) natural abstract | iii) not poisonous |
| | | 64 | 20 | 16 |
| Q8 | Reason behind using pesticides | i) to control harmful insect/disease* | ii) to control beneficial insect | iii) to increase the soil fertility |
| | | 42 | 13 | 45 |
| Q9 | Effect of excessive use of pesticides in the crop field | i) create pest resistant* | ii) production increase | iii) reduce the pest attack |
| | | 10 | 31 | 59 |
| Q10 | Worst impact for improper handling of pesticides | i) cause health hazard* | ii) increase cost | iii) crop damage |
| | | 23 | 43 | 34 |

Note : `*` indicate the appropriate answer

### 3.8 Attitude towards the pesticide use

About two third of the respondents think pesticide is the best way to control pest. The largest number of farmers showed favorable attitude towards the timely and balanced application of pesticide (statement 5), followed by the statement 7, 1 and 2 (**figure 9**). The highest number of e farmers showed neutral attitude towards the statement 3, which is on the issue of ecosystem. About half of the respondents showed unfavorable attitude towards the statement 10, which the pesticide is responsible for health hazard or food poisoning. Therefore, the attitude of the farmer was found varied depending upon the issue but there was no significant relationship between the socioeconomic characteristics of the respondent farmers. On an average the farmers showed favorable attitude towards the pesticide use.

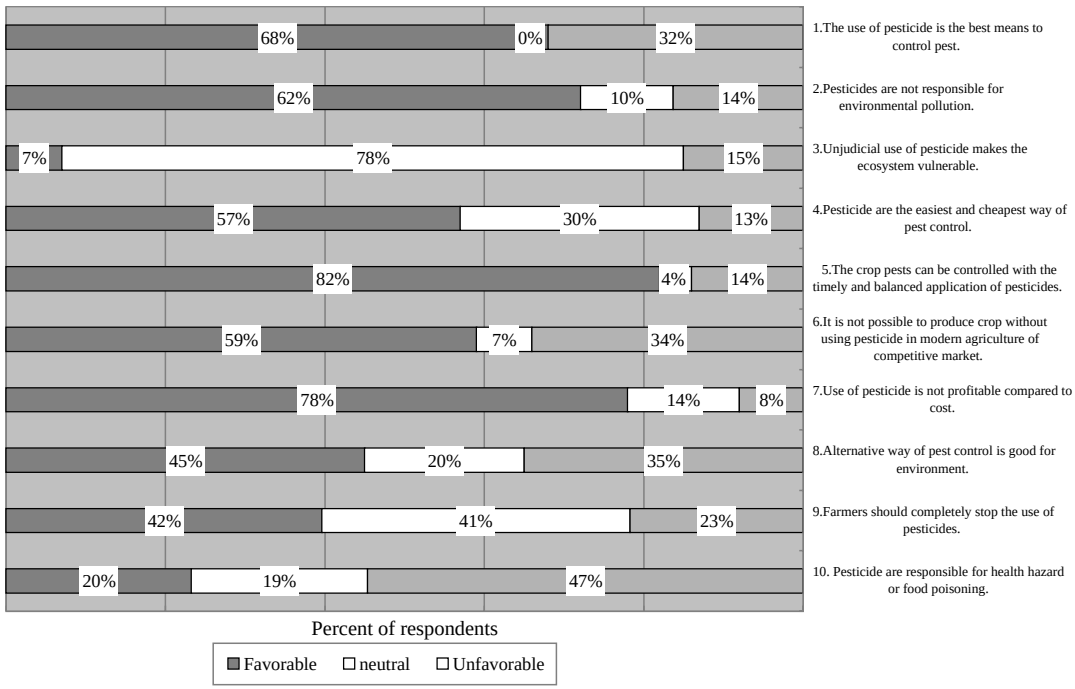


**Figure 9.** Dimension of the attitude of the respondent farmers towards the chemical pesticide use

### 3.9 Perception about the environmental impact of pesticide

The average value of perception of the farmers about the 5 major issues was varied from 2.4 to 2.7 (**table 3**). The level of perception of the respondents about the ecological and impact on air and health hazard were higher than the impact on soil and water. Respondents have poor perception regarding the impact on water. A good proportion of the farmers didn't have any perception about any of the issues. Some respondents did not response to the statement, either.

### 3.10 Socio-economic characteristics of the respondent farmers

The socio-economic characteristics of the respondents are shown in table 4;

**Age:** The age of the respondent farmers ranged from 23 to 70 years, the average being 40.45 years. Seventy three percent of the respondent is below 45 years old and 27% are above 45. It is evident from the present survey that most of the respondent farmers are relatively young.

**Education:** The average level of education of the respondent farmers was 6.20 years of schooling ranging from 0 to 14 years of schooling. Thirteen percent of the respondent has no formal schooling experiences, 33% have had 1 to 5 years and 43% have had 6-10 years of schooling. Only 9 % have had 12 to 14 years of schooling.

**Land under cultivation:** The average land under cultivation of the respondent farmers was 1.42 hectare which is much higher than the national average of .20 hectare (BBS, 1995). This is because farmers having comparatively larger land under cultivation usually use pesticide for plant protection. The range of land under cultivation was 0.18 to 4.05 hectare. It is found that almost all of the cultivable areas of the respondent farmers are in rice cultivation.

**Table 3** Level of perception of the respondent farmers of Bangladesh towards the impact of the pesticides on the environment

| Index of statement | Statement | Mean value | Std. | Degree of perception of the respondents (%) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Not respond | No. | Poor | Strong |
| I. Ecological impact | | | | | | | |
| S1 | Many types of birds, fish and plant become extinct by the effect of highly toxic pesticide. | 3.3 | 0.5 | 19 | 36 | 25 | 20 |
| S2 | Unbalance use of pesticide make the ecosystem worst. | 2.2 | 0.8 | 11 | 35 | 31 | 23 |
| S3 | Many species of harbecious plant of medicinal value extinct by the continuous use of highly toxic pesticides. | 2.7 | 0.6 | 0 | 49 | 21 | 30 |
| S4 | Natural beauty of rural areas have not destroyed by the excessive pesticide use (such as, extinct of many wild flowers, butterflies, fireflies, etc.) | 2.4 | 1 | 14 | 28 | 38 | 20 |
| S5 | Many fish are caused by diseases by the pesticidal effect. | 2.7 | 0.8 | 0 | 21 | 35 | 44 |
| Average | | 2.7 | | | | | |
| II. Impact on soil | | | | | | | |
| S1 | Application of toxic chemicals in the crop field harm the earthwarms, soil microbes which deteriorated soil fertility. | 2.3 | 0.5 | 14 | 30 | 36 | 20 |
| S2 | Use of excessive pesticide accumulate in the soil which is responsible for soil toxicity. | 2.3 | 0.5 | 12 | 45 | 0 | 43 |
| S3 | Pesticide accumulate in soil not harmful for the crop. | 1.6 | 1.3 | 22 | 20 | 38 | 20 |
| S4 | Many pesticide such as, DDT, aldrin, heptachlor, dieldrin and chlordane remain unchanged in the soil but not harmful for the soil. | 3.3 | 1.4 | 18 | 26 | 26 | 30 |
| S5 | Pesticide has no effect on soil structure. | 3.3 | 1.3 | 30 | 25 | 25 | 20 |
| Average | | 2.6 | | | | | |
| III. Impact on water | | | | | | | |
| S1 | Long time and heavy use of pesticides may pollute the aquatic environment through the contamination of unused portions of pesticides. | 3.1 | 0.7 | 22 | 30 | 18 | 30 |
| S2 | Through irrigation water pesticides runoff to the rivers, canals, etc. | 2 | 1.1 | 18 | 27 | 20 | 35 |
| S3 | Many fishes have been extinceted by the effect of pesticides used in the crop field. | 2.7 | 1.2 | 15 | 35 | 19 | 31 |
| S4 | Ground water is not polluted by pesticide leaching from crop field. | 2.7 | 0.9 | 17 | 36 | 17 | 30 |
| S5 | Pesticide is not responsible for water pollution. | 1.3 | 1.3 | 26 | 21 | 31 | 22 |
| Average | | 2.4 | | | | | |
| IV. Impact on air and health hazard | | | | | | | |
| S1 | It is very dangerous for the applicator to be affected by the poisonous pesticides if not properly handled. | 3.2 | 0.8 | 9 | 36 | 20 | 35 |
| S2 | Several diseases have been observed to be caused by pesticide used. | 2.2 | 0.6 | 12 | 44 | 6 | 38 |
| S3 | Food produce by using pesticide is safe for the consumers. | 2.2 | 1.2 | 20 | 35 | 18 | 27 |
| S4 | During the pesticide spray the air polluted by spray drift which causes health hazard to the applicator neighbours. | 3.1 | 0.8 | 23 | 23 | 31 | 23 |
| S5 | The granular insectide used in the paddy field exposed to the air and pollute the surroundings. | 2.7 | 0.9 | 25 | 35 | 33 | 7 |
| Average | | 2.7 | | | | | |

**Table 4** Socio-economic characteristics of the respondent farmers in Bangladesh

| Characteristics | % of respondent | Min | Max | Mean | STD |
|---|---|---|---|---|---|
| 1. Age(yrs) | | 23 | 70 | 40.45 | 9.59 |
| Below 45 years | 73 | | | | |
| Above 45 years | 27 | | | | |
| 2. Level of education | | 0 | 14 | 6.2 | 4.09 |
| No schooling | 13 | | | | |
| 1 to 5 years of schooling | 43 | | | | |
| 6 to 10 yrs. of schooling | 33 | | | | |
| 11 to 14 yrs.of schooling | 9 | | | | |
| 3. Total land area(ha) | | 0.18 | 4.05 | 1.12 | 0.79 |
| 4. Area under paddy cultivation (ha) | | 0.15 | 3.24 | 0.89 | 0.65 |
| 5. Total farming experience(yrs) | | 2 | 50 | 19.52 | 10.09 |
| 6. Paddy farming experience (yrs.) | | 1 | 50 | 17.95 | 10.92 |

| Occupation | Primary | | Secondary | |
|---|---|---|---|---|
| | No. | % | No. | % |
| Agriculture | 50 | 58 | 35 | 41 |
| Business | 20 | 23 | 18 | 21 |
| Service | 5 | 6 | 0 | 0 |
| Wage labor | 7 | 8 | 7 | 8 |
| Others | 4 | 5 | 2 | 2 |

**Farming experience:** The average farming experience of the respondent farmers was 19.52 years ranging from 2 to 50 years. The experience of paddy farming ranged from 1 to 50 years with an average of 17.95. It seems that some respondent farmers did not start rice farming from the beginning.

**Occupation:** Among the respondent farmers 58% and 41% of them are doing farming as the primary and secondary occupation respectively. The second highest proportion of respondents is engaged in business, which is 23% as primary and 21% as secondary occupation. The business activities are mostly small and medium size shop keeping. Also some well being farmers are doing stock business, buy farm products in the season at the time of cheaper prices and sell in the off season at high prices. Only 5% of the respondents are engaged in service as primary occupation. Services include mostly teaching in the school and religious educational institutions.

## 4. Discussions

Unfortunately for rice farmers in Asia, there is no shortage of rice pests, with major crop losses occurring from several classes of pests and a number of pest types within each class. As perceptions about the severity of rice pests have evolved in Asia, rice producers have become heavy users of all types of pesticides. The case of Bangladesh is no exception in this situation.

The respondent farmers used mostly insecticides, because in Bangladesh insect infestation is more serious than diseases in rice production. The rate of application of insecticide was found 1 to 10 kg/ha with less frequency of 1 to 4 sprays per crops. The rate of application and frequency was less for the small to medium farmers than the large farmers. The rich farmers used more frequent and high dose of pesticide. But nobody has ever exceeded the recommended level. Among the pesticide used except

Malathion all of them are either extremely or highly hazardous class of WHO. Bashudin 10G an obsolete pesticide commonly used by the farmers to control stem borer and, which is supposed to no longer be used, but still being in farmer's use. The farmers are still using the organophosphorous pesticides such as monocrotophos, DDVP, which are known for wide spectrum toxicity (Rola and Pingali, 1993). Farmers also used phosphamidon, which is extremely hazardous. Monocrotophos and phosphamidon are subjected to the prior informed consent of WHO (WHO, 1998) before use. Almost all of the carbamates pesticides are classified as highly hazardous and pyrethroids as moderately hazardous. All of the pesticide is highly to moderately toxic to the birds, bees, fish and other aquatic animals. The mass killing of birds including poultry is due to use of toxic pesticides in the crop field adjacent to the homestead. In fact the insecticide use in rice field is mainly reactive rather than prophylactic. Not only the insecticide is contaminating the environment; ultimately it is entering the food cycle through respective food crops.

Due to lack of strict enforcement of regulation and supervision, the traders have been marketing extremely hazardous pesticides. According to 'The Pesticide Rules, 1985' that all pesticide either manufactured or imported should be registered to the Authority. For registration an application is submitted with the relevant data which is reviewed by a Technical Advisory Committee with a sample of the specific pesticide. The required data include; physical and chemical properties, efficacy data, toxicological data, residues and their fate in the environment. But in practice the assessment of environmental impacts or residue analysis is hardly undertaken due to the lack of expertise in the field as well as laboratory facilities (Gaston, 1986). The registration is valid for 3 years. In chapter II, section 8 of the regulation, it is said that the certificate of registration may be cancelled but not mentioned when the certificate will be cancelled. Regarding import in chapter IV it is mentioned that 'No pesticide shall be imported through a rout other than the recognized custom frontier stations of Bangladesh'. But huge amount of banned and highly toxic pesticides are being smuggled from India through the boarder (Ahmed, 1992). It has been reported by the Institute of Development Policy Analysis that the pesticide like Eldrin and Endrin are sold with different labels in Bangladesh. The suppliers continue to sell many chemical pesticides proscribed by the government, and 12 particularly controversial pesticides dubbed the `dirty dozen` by activists campaigning worldwide to stop its manufacture (IPS, 1998). There is a provision of licensing of the pesticide dealers for sale but it is not clearly stated what will be required for the qualification of the license holder, so anyone may get license. Therefore, it is found that the registered dealer also does not have any knowledge about the pesticide handling. The regulation said it could be duplicate and transferred to anybody. It is not said in the regulation that the sales dealer might have training on pesticide. The main drawback of this regulation is in chapter VII section 33 subsection I (a) which gives the provision to state the name of the manufacturer, formulator or repacker in the label even he/she is not the person in whose name the pesticide is registered. For this reason it is very difficult to identify the respective person for punishment. Therefore, taking the advantage of the weak point of regulation the illegal business of pesticide is going on and it is not uncommon that the violation of rules is taking place.

In Bangladesh the cropping intensity is higher, farmers are producing three crops in a year and more or less the pesticide are being in used for three of the crops. Therefore, the health and environment are continuously exposed to the pesticide that is being used in the crop field. Moreover, the farmers used mostly hand sprayer and other traditional methods. The spray methods they used are associated with high risk of exposure and contamination (Pingali and Roger, 1995). The sprayer they used usually not in a good condition and user doesn't have training regarding the safe use of pesticide. The traditional meth-

ods are very much unscientific and high risk of health, environmental contamination. Nobody has been reported to use any protective measure during and after the pesticide application.

Because of cost involvement calendar spray is not common phenomenon for Bangladeshi farmers. The farmers applied pesticide by the presence of pest and at action threshold. But it is not undoubted that their conception about the action threshold might not be the real one situation. No respondents have been found to have formal training regarding pesticide use. Therefore, there is prevalence of application at wrong time and wrong pesticide. The Pesticide Association of Bangladesh reported many farmers apply pesticide mixed with basal dose of fertilizer as preventive measure, without any basis by the encouragement of the traders.

Farmers perceived that the pesticides they used were very effective (100% pests controlled) or effective (more than 75% pest controlled), which encouraged them to use more chemical pesticides to prevent the loss. Nobody had perceived that pesticide might create pest resistance and destroy the natural enemies. To the farmers pesticide is always and only the effective means to pest control. Although most of them followed any of other alternative methods to pest control, among which crop rotation were adopted by the highest proportion of the farmers followed by timely planting and resistant varieties. Only 2% farmers used IPM technique to pest management. Because IPM is a knowledge-intensive technology that leads to changes in the knowledge, attitudes, and practices it is difficult to follow by the less educated farmers like Bangladesh (Rola and Pingali, 1993).

Farmers possessed poor to moderate level of knowledge about the different aspects of pesticide application. Average knowledge score varied from 0.58 to 3.7 for different questions. Only 41 percent farmers said that sprayer is the appropriate way to pesticide application and rest of them said either traditional method or releasing in one corner of the crop field. Most of the farmers know that pesticide is a poisonous chemical, but they think that excessive use may reduce the pest attack instead of creating pest resistance. Similarly most of them don't know that improper handling may cause health hazard. A good number of farmers think that pesticide not only control pest as well it increases the soil fertility. This might be due to the reason that the over campaigning of pesticide company representative. The knowledge of farmers was greatly influenced by their level of education. The average level of education of the farmers was 6 years of schooling. The low level of education coupled with lack of communication exposure of the farmers might be a reason to have low level of knowledge regarding the harmful impacts of pesticide on health and environment.

Due to low level of knowledge the farmers are using highly toxic pesticide and responsible for making the environment and ecosystem vulnerable. Taking the opportunity of the illiteracy the pesticide trader and dealers are pushing the farmers the dangerous pesticide to use in their crop field. Not only that the suppliers pack the pesticides in insoluble containers, quite often in bottle to attract the farmers who use the bottles and other containers for different domestic purposes without realizing the hazards (IPS, 1998). In this regards it might be mentioned that the pesticide distribution in Bangladesh is fully under private sector. The respective company has field representative of their own, those who are responsible for sales of pesticide in a specific area directly to the farmers. Besides, monthly salary there is provision of commission on the basis total sales annually for the field representatives. Therefore, they are always trying to convince the farmers to use their products keeping their monetary gain as the main target.

In general the farmers showed favorable attitude towards the pesticide application. As the farmers perceived that the pesticide is effective way of pest control without any detrimental effect, they formed

the favorable attitude towards the pesticide use. Many farmers think that the pesticide is a medicine to treat the crop to be recovered from the pest attack. The issues, which were not perceived by the farmers, they showed neutral attitude towards them. It might be due to the influence of socio-economic characteristic such as, age and education and occupation (Rola and Pingali 1993).

Knowledge, attitude and perception of the farmers determine the practice of the pesticide. The farmer's perception about the impact of the pesticide on the environment was not good. It might be due to the fact that the average age and education of the farmers were low. Because perceptions are influenced by individual's socioeconomic characteristics, experience (age) and education could significantly reduce the error in one's perception. It is quite difficult to perceive the impact of pesticide with an average low level (6 years of schooling) and without any training. The perception of the farmers regarding the impact of pesticide was not very strong. Their perception was at moderate level ranging from 2.4 to 2.7. The proportion of the farmers having strong perception towards the different aspect was varied from minimum 7 to maximum 44 %. But the frequency is higher around 20 to 30 percent. The same proportion of the respondents has no perception. Due to the lack of education and mass media campaign of the farmers were not able to perceive the possible negative impact of the pesticide on the ecosystem, soil, water, air and health. More over, due to the over publicity of the pesticide trader's farmers only know the `so called` benefit; the traders never explained the negative impact of the pesticide to the farmers. In most of the cases the pesticide traders push the farmers to buy and use when it is not necessary. It is worth mentioning that there are over 20,000 registered pesticide dealers and the same number would be as unregistered and are selling pesticide along with other commodities even with food. Although the pesticide regulation does not suppose to permit anybody to sell pesticide without the government authority's supervision of license as well as the storage and shop.

## 5. Conclusions

In Bangladesh in the recent years growing use of pesticides by farmers, unaware of the negative effects pose a big challenge to health, environment and the declining economy of the country. Cropland is a major source of sediment and the sediment resulting from soil erosion is regarded as the largest pollutant that affects water quality. The occurrence of fish epidemics in different parts of the country is apprehended by the scientist and local people that fish mortalities in the open water of Bangladesh have occurred due to uncontrolled use of pesticides in irrigated rice field (Ahsan, 1990).

Some extremely hazardous pesticides are used in Bangladesh, although these are prohibited in the producing countries. Among the insecticides used by the Bangladeshi farmers, Bashudin 10 G, Diazinon 60 EC, Sumithion 60 EC and Padan 50 SP have already been banned for use on rice in Indonesia in 1986. But in Bangladesh, these are not restricted yet. Moreover, in Bangladesh the existing pesticide laws and regulations are not strictly enforced in relation to import, formulation, repackaging, distribution, advertising and use of pesticides. Therefore, obsolete pesticide like Bashudin are also still being using by the farmers and available in market even in low price compared to others (Rola and Widawsky, 1998).

The environmental degradation linked to agriculture is the impact of toxicity from improper pesticide use. Here, the damage is less on agricultural productivity than the people who may be inadequately protected from the chemicals are (Ramaswamy, 1995). The greatest threat of toxic exposure is from the used crop, which puts both producers and consumers at risk. The other type of toxicity-related damage is

from pesticide run-off, and especially from pesticide residues in ground water. Therefore, modifications in regulations concerning pesticide handling and application will minimize most pesticide-related environmental and health damage. The hazardous pesticide should be withdrawn from the market as early as possible. The provision of penalty for violating the regulations might be included in the registration terms and conditions. Along with strict regulation, the farmers the end user should be educated to be perceived the probable impact of their practice towards the health and environment. The farmers should be provided with proper training and mass media campaign.

## References

Ahmed. Q.F. 1992. Study of Socio-economic and Environmental Effect of Chemical Agriculture. University Press, Dhaka.

Ali, M.Y. 1994. Fisheries and Environment: Environment and Development in Bangladesh, V2, University Press, Dhaka.

Barzman, M. and Das, L. 2000. Ecologing rice-based systems in Bangladesh. . LEISA, ILEIA Newsletter for Low External Input and Sustainable Agriculture 16(4): 16-17.

BBS, 1995. Yearbook of Agricultural Statistics of Bangladesh 1995. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Dhaka.

Carlson, G.A. and Mueller. 1987. Farmers` perceptions, education and adoption of pest management strategies for small farmers. Proceedings of the 11th International Congress of Plant Protection 1:147-154, Manila.

Dahal, L. 1995. A study on Pesticide Pollution in Nepal. National Conservation Strategy Implementation Project, National Planning Commission, HMG Nepal, and IUCN-The World Conservation Union, Kathmandu.

Farah, J. 1944. Pesticides policies in developing countries: Do they encourage excessive use? World Bank, Discussion Paper No. 238. Washington D.C.

Food and Agriculture Organization (FAO), 1995. World Agriculture: Towards 2010, an FAO Study. (Nikos Alexandratos, editor) pp-18-19, John Wiley & Sons, Rome.

Gaston, C.P. 1986. Pesticide usage, registration and regulatory practices among selected countries in Asia. Agro Chemicals News in Brief, Pesticides, ESCAP/FAO/UNIDO, Special Issue, December 1986, Fertilizer Advisory, Development and Information Network for Asia and the Pacific (FADINAP).

IPS, 1998. Agriculture-Bangladesh: Pesticide Overuse Takes Serious Turn. Inter Press Service World News. URL: http://www.oneworld.org/ips2/jan98/bangladesh2.html

Islam, M.A., 2000. Consequences of increased pesticide use. In Huq, S; Rahman, A. and Conway. G. R, pp. 117-123. (eds.): Environmental Aspects of Agricultural Development in Bangladesh. The University Press, Dhaka, Bangladesh

Kalam, K.M.H.A. 1998. Bangladesh Country Paper. Environmental Assessment for Agricultural Development in Asia and the Pacific, pp. 141-152. Asian Productivity Organization (APO), Tokyo.

McLaughin, A., and Mineau, P., 1996. The impact of agricultural practices on biodiversity. Agriculture, ecosystems and environment 55, 201-212, Elsevier Netherlands (Online publication). URL: http://www.elsevier.nl/locate/agee

Mueller, K.E. 1980. Field Problems of Tropical Rice. IRRI, Los Banos, Laguna.

Pesticide Association of Bangladesh, 2000. Pesticides Consumption Report for the Year 1999/2000. PAB, Dhaka.

Pingali, P.L and P.A. Roger. (eds.) 1995. Impact of Pesticides on Farmer Health and the Rice Environment.Kluwer Academic Publisher, Boston.

Ramaswamy, S.1995. Pest Control and Environment, Bangladesh Agricultural Research Council, Dhaka.

Rola, A.C. and D.A. Widawsky, 1998. Pests, Pesticides, and integrated pest management in rice. In Impact of Rice Research edited by Pingali P.L. and Hossain, M. Thailand Development Research Institute and IRRI, Philippines. pp. 135-158.

Rola, A.C. and Pingali, P.L. 1993. Pesticides rice productivity and farmers` health an economic assessment. International Rice Research Institute, Philippines and World Resources Institute USA.

Shepard, B.M., Barrion, A.T. and Litsinger, J.A. 1995. Rice Feeding Insects of Tropical Asia. IRRI, Los Banos, Laguna.

The Bangladesh Gazette. Extraordinary Publication by Authority. The Pesticide Rules, 1985. Ministry of Agriculture, Peoples Republic of Bangladesh, Dhaka.

World Health Organization. 1998. The WHO Recommended Classification of Pesticides by Hazard and Guidelines of classification 1998-99. WHO/PCS/98.21/Rev.1

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