Original Research Article

FARMERS' EFFICIENCY IN USING SELECTED PESTICIDES FOR CONTROLLING RICE PESTS

Abstract

Farmers' efficiency in using pesticides depends on using recommended doses. The research was conducted to determine farmers' efficiency in using selected pesticides for controlling rice pests and explore the contribution of selected characteristics of the farmers to their efficiency in using selected pesticides for controlling rice pests. Data were collected from randomly selected 252 Common Interest Group (CIG) Member rice farmers of three selected unions of three selected upazillas of Brahmanbaria district of Bangladesh with the help of a pre-tested interview schedule during the period from 01 August 2022 to 30 November 2022. Findings revealed that 38.97% farmers were the efficient users of recommended doses and rest 61.03% farmers had lower to moderate efficiency in using pesticides for controlling rice pests. Based on descending order of Standardized Use Efficiency Index, 'Gola 80 EC for killing rice bug' ranked 1st followed by 'Amistar Top 325 SC for controlling sheath blight disease', and 'Thiovit 80 WG for controlling leaf scald disease'. Regression analysis indicated that 'knowledge on pesticides', 'rice farming experience', 'extension contacts', 'attitude towards use of pesticides', 'rice farming area', and 'pre-cautions for using pesticides' of the farmers had significant positive contribution to their efficiency in using selected pesticides for controlling rice pests. Agricultural advisory service providing organizations should increasing contact with the farmers having lower farming experience, lower farming area to increase their knowledge for taking necessary pre-cautions and to form favourable attitude towards judicious and efficient use of pesticides.

Keywords: Pesticides, Use efficiency, Rice pests, crop protection.

1. Introduction

Pesticides are agricultural input that enables farmers to control pests and weeds for ensuring crop production (Skevas *et al.,* 2013; Jansen and Dubois, 2014). Despite pesticides are important for sustained production, farmers used them more than their requirement (Kabir and Rainis, 2015). Abang *et al.,* (2014) revealed that losses due to pests and diseases ranged from 10% to 90% with an average of 35% to 40% for all potential food and fiber crops. Agro-pesticide technologies, including insecticides, fungicides and herbicides formed one of the driving forces behind the Green Revolution. Coupled with high-yielding crop varieties and increased land for crop production, significant yield improvements were achieved. However, this was realized at the expense of the natural environment and the health of farmers (UNU, 2003). Farmers use a wide range of pesticides to prevent crop loss from pest attack. Use of pesticides in crop production has spread rapidly worldwide since the 1950s with an estimated annual compound growth rate of 4.4% during the period 1993-1998 in the Asia/Oceania region (Yudelman *et al.*, 1998).

Pesticide use in Bangladesh, negligible until the 1970s, has recorded a dramatic rise in recent years (Kabir and Rainis, 2012). Pesticide use levels increased from 2200 metric tons in 1980–

1982 to 6500 metric tons in 1992-1994 and modern rice cultivation increased from 20.30% of total rice area to 49.00% during the same period (Rahman and Thapa, 1999).

The application of pesticide becomes an invincible part to crop cultivation (Nasrin et al., 2019). It remains unclear whether the use of chemical pesticides should be stopped or not. Environmentalists, soil scientists, hydrologists, physicians, and experts of other line departments opined to phase off chemical pesticides gradually and introduce bio-pesticides; whereas, a majority of agriculturists, food experts and agro-companies argued not to stop the use of chemical pesticides, rather to train up agricultural workers on the application (how and when) of pesticides. They argued that if chemical pesticides are not used, it will reduce 30% to 40% crops per year, which will eventually create food scarcity.

Chemical pesticides may not be harmful for human health if farmers know the residual time of a pesticide after they use (Kabir and Rainis, 2013b). According to Bangladesh Crop Protection Association (BCPA), less than 1% farmers have the skills of pesticides application and crop harvest. In Japan, agricultural workers use seven times more chemical pesticides compared to Bangladesh. However, Japanese people take safe food. This is because Japanese farmers know when to harvest crops after using pesticides. But in developing countries like Bangladesh, educating farmers is a troublesome task. Farmers have to wait 30-50 days for harvesting a crop if they spray pesticides of organochlorin group whereas, the waiting time of crop harvest is 4-7 days if they use pesticides of synthetic pyrethroid group. Bangladeshi farmers spray at morning and harvest at afternoon, which is extremely risky for consumers, due to lack of knowledge of pesticides' residual period.

Food safety and pesticides have become serious human health concern and synthetic pesticides are an environmental contaminant. Despite the harmful effects of synthetic pesticides to human health, environment and other living beings, it is not possible to replace the chemical pesticides by bio-pesticides, IPM and organic agriculture overnight (Kabir and Rainis, 2013; Parvez et al., 2018). Farmers' skill development training on the judicious use of pesticides and crop harvest time after spray of pesticides are one option to reduce health risks from harmful pesticides. Another option could be to introduce inter cropping and multiple cropping with pest repellent crop in the periphery of the crop field. However, little research has explored farmers' actual practices, while applying an approach based on practice theory could improve our understanding of these practices and the changes therein.

Therefore, it is urgent to formulate national policy to reduce health risk to produce safe food by ensuring judicious use of pesticides. Reliable statistical data are meager to indicate the farmers' efficiency in using selected pesticides for controlling rice pests in Bangladesh. However, there are some anecdotal evidence and inadequate reports on farmers' pesticide use efficiency in Bangladesh. As s results, farmers of Bangladesh are using various doses like low, moderate, recommended, over and extreme doses of pesticides due to their ignorance and uncertainty of controlling pests of major crops. Some literatures were found to find out the adoption or use of pesticides and some was found to find out the pesticide using behavior of farmers, but no literature was found to find out the farmers' pesticide use efficiency. On these considerations, the present research was conducted to: i) determine farmers' efficiency in using selected pesticides for controlling rice pests, ii) assess some selected characteristics of the rice farmers, and iii) explore the contribution of selected characteristics of the rice farmers to their efficiency in using selected pesticides for controlling rice pests.

2. Methodology

2.1 Locale of the study

Department of Agricultural Extension (DAE) formed Common Interest Group (CIG) intervention areas for rice farming were considered purposively for selecting the locale of the study. Thus, Brahmanbaria Sadar, Nabinagar and Akhaura upazilas under Brahmanbaria district were selected purposively as the locale of the study where renowned pesticides companies were selling their pesticides to the farmers and farmers were using those for controlling rice pests. Three (3) CIG intervention unions, namely Sultanpur, Shibpur and Dharokhar were then selected randomly by taking one (1) from each selected upazila as the locale of the study.

2.2 Population and sample of the study

There were 730 Member Farmers of CIGs in the three selected CIG intervention unions who were using pesticides of renowned companies for controlling rice pests. These 730 rice CIG farmers were considered as the population of the study. The sample size was determined using the formula developed by Yamane (1967) which constituted 252 CIG farmers as the sample of the study. Separate lists of rice producing CIG farmers of selected three (3) unions were collected from respective DAE offices. Proportionate random sampling technique was used for selecting sample from CIG rice farmers by using Random Number Generator apps. Reserve lists were also prepared by taking 10% of the sample to fill in the gaps in case of any respondent in the original list was missing or absent in the time of interview.

2.3 Data collection procedure

Data were collected by the researcher himself through face-to-face interviewing of the selected sample farmers by using structured interview schedule. Data were collected during the period from 01 August 2022 to 30 November 2022. However, it was not possible to collect data from nine (9) farmers in the original sample due to their unavailability at the time of interview despite several attempts to contact them. Therefore, the researcher had to collect data from nine (9) farmers from the reserve list.

2.4 Measurement of Efficiency in using selected pesticides

Efficiency in using pesticides for controlling rice pests was the dependent variable of the study. Efficiency in using selected pesticides of a farmer meant the performance of that farmer in using recommended doses of pesticides for controlling rice pests. Measurement procedures of this variable have been done based on the following steps:

Items collection: After searching of relevant literatures, initially 25 items were collected for measuring efficiency in using selected pesticides for controlling rice pests. After consultation with Advisory Committee Members, a total of 17 items were selected for pre-testing due to similarity in the items. After conducting pre-test on 36 farmers (by taken twelve from each selected unions, 14 items (Nine for disease control and five for insect control) were found available in the study area and were used by the farmers for controlling rice pest. These 14 items were selected for the final interview schedule.

Scoring System: to measure farmers' efficiency in using selected pesticides for controlling rice pests, they were asked to inform about their extent of use of 14 selected pesticides for controlling rice pests with Six (6) alternative responses with assigning following scores:

List 1: Alternative responses with assigned scores

Alternative responses	**Assigned Scores**
No use	0
Use Low dose (<25% of recommended dose)	1
Use Moderate dose (25% to <75% of recommended dose)	2
Use Recommended dose (recommended ± 25% dose)	3
Use High dose (>25% to 75% over to recommended dose)	2
Use Extreme High dose (>75% of over to recommended dose)	1

A farmer may not use all the items for rice pest (disease and insect) control. On this consideration, use efficiency of pesticides of a farmer for controlling rice pests was determined by using following two formulas:

$$E_p = \frac{\sum E_p}{n_p}$$

Where,

E_p = Use efficiency for controlling rice pests (diseases and insects) of that farmer

$\sum E_p$ = Sum of scores obtained against all the 14 items for controlling rice pests of that farmer

n_p = Number of items used for controlling rice pests of that farmer

Thus, farmers' efficiency in using pesticides for controlling rice pests could range from 0-3, where '0' indicates no use efficiency and '3' indicates highest efficiency of using pesticides.

Use Efficiency Index (UEI): Use Efficiency Index (UEI) of each of the items of pesticides was determined by using the following formula:

$$UEI = f_l \times 1 + f_m \times 2 + f_r \times 3 + f_o \times 2 + f_{ho} \times 1$$

Where,

f_l = frequency of respondents used low dose of pesticide

f_m = frequency of respondents used moderate dose of pesticide

f_r = frequency of respondents used recommended dose of pesticide

f_h = frequency of respondents used high dose of pesticide

f_e = frequency of respondents used extreme high dose of pesticide

Standardized Use Efficiency Index (SUEI): Standardized Use Efficiency Index (SUEI) of each item was determined by using the following formula:

$$SUEI = \frac{\text{UEI of the Item}}{\text{No. of farmers used the item X Highest possible score of a farmer on the item (i. e. 3)}} \text{ X 100}$$

Thus, SUEI of the items could range from 0 to 100, where ‘0’ indicates no SUEI and ‘100’ indicates highest SUEI.

Rank order was made based on the descending order of SUEI of the items to compare among all the items for controlling rice pests.

2.5 Measurements of independent variables of the study

Sixteen (16) characteristics of the rice farmers were selected after thorough searching of literatures and discussions with the Advisory Committee Members and relevant experts as the independent variables of the study. Brief measuring procedure of these variables are presented below:

List 2: Measurements of independent variables

Variables	Measuring Procedures (Score)
1. Age	One (1) for one (1) year of age
2. Education	One (1) for one (1) year of successful schooling, Zero (0) for illiterate and 0.5 for can sign only
3. Rice farming area	One (1) for one (1) hectare of rice farming area
4. Family agricultural abour	One (1) and half (0.5) for adult ($\geq$ 18 years) and adolescent ($\geq$14 to $<$18 years) respectively who engaged in agricultural rice farming
5. Rice farming Experience	One (1) for one year of rice farming experience
6. Annual rice farming income	One (1) for 1000 Bangladeshi Taka (BDT.) annual income from rice farming
7. Pesticide cost for controlling rice pests	One (1) for pesticide cost of 1000 Bangladeshi Taka (BDT.) for controlling rice pest
8. Credit received for rice farming	One (1) for 1000 Bangladeshi Taka (BDT.) credit received for rice farming
9. Rice farming training exposure	One (1) for one (1) day training received on rice farming
10. Organizational Participation	Scores of 3, 2, 1, and 0 for participation as Executive Officer, Executive Committee Member, Ordinary Member, and no participation respectively for each of seven (7) selected organizations
11. Extension contact	Scores of 3, 2, 1, and 0 for regular, occasional, rare and not at all contact respectively with each of 15 selected extension media
12. Knowledge on pesticides	Two (2) score for each of 15 selected questions on rice farming
13. Attitude towards use of pesticides	Scores of 4, 3, 2, 1, and 0 for strongly agree, agree, no opinion, disagree and strongly disagree respectively for positive statements and reverse scores for negative statements for each of 12 attitudinal statements towards use of pesticides
14. Pre-cautions for using pesticides	Scores of 4, 3, 2, 1, and 0 for very often, often, sometimes, seldom and never taking pre-cautions for using pesticides for each of nine (9) selected items
15. Adverse symptoms	Scores of 3, 2, 1, and 0 for always, often, sometimes and never

Variables	Measuring Procedures (Score)
observed after using pesticides	observed symptom
16. Performance of selected pesticides	Scores of 3, 2, 1, and 0 for high, medium, low and no performance perceived of each of 14 selected pesticides

3. Results and discussion

3.1 Farmers' efficiency in using selected pesticides for controlling rice pests

Farmers' efficiency in using selected pesticides for controlling rice pests was measured based on the extent of use of recommended doses of 14 selected pesticides by the farmers. The observed score of farmers' efficiency in using selected pesticides for controlling rice pests ranged from 1 to 3 against the possible range of 0-3. The mean score was 2.13 with the standard deviation 0.34. Based on their pesticide use efficiency, the farmers were classified into five categories such as Low, Moderate, Recommended, High and Extreme high dose users as shown in Table 1.

Table 1. Distribution of the rice farmers according to their pesticide use efficiency categories

Items		Category-wise number of users					
		Low dose users	Medium dose users	Recom-mended dose users	High dose users	Extreme high dose users	Total
For controlling rice diseases	1. Thiovit 80 WG for controlling leaf scald disease	29	33	91	40	20	213
	2. Amistar Top 325 SC for controlling sheath blight disease	25	30	98	40	21	214
	3. Differ 300 EC for controlling bacterial blight disease	25	31	75	39	31	201
	4. Bavistin DF for controlling brown spot disease	29	32	71	38	28	198
	5. Nativo 75 WG for controlling rice blast disease	29	35	63	43	28	198
	6. Razdan 10G for controlling tungro virus disease	35	25	71	27	31	189
	7. Brifur 5G for controlling ufra disease of rice	29	30	79	37	30	205
	8. Combi-2 30 EC for controlling sheath rot disease	29	30	82	34	27	202
	9. Aimcozim 50 WP for controlling foot rot and bakanae disease	30	25	66	35	31	187
- n g	10. Gola 80 EC for killing rice	24	30	99	32	21	206

	bug						
	11. Plenum 50 WG for killing brown plant hopper	29	30	73	39	28	199
	12. Mortar 48 EC for killing rice leaf roller	33	30	77	31	31	202
	13. Virtako 40 WG for killing rice yellow stem borer	37	25	70	30	33	195
	14. Sevin 85 SP for killing of rice thrips	27	30	78	38	23	196
Total		410	416	1093	503	383	2805
%		410/2805 = 14.62	416/2805 = 14.83	1093/2805 = 38.97	503/2805 = 17.93	383/2805 = 13.65	100

If all the farmers used all the 14 selected pesticides, then multiplication of number of farmers (252) and number of pesticides (14) would be 3528, but all the farmers did not use all the 14 selected pesticides for controlling rice pests (diseases and insects). So, the multiplication number was 2805 instead of 3528. Percentage of a category of farmers was determined by dividing the total number of farmers of that category against all the 14 pesticides by 2805. Then, it was found that 38.97% farmers were the users of recommended doses of pesticides for controlling rice pests, i.e., they had perfect efficiency of using pesticides. Rest 61.03% farmers used either lower or higher doses of pesticides for controlling rice pests i.e., they had lower efficiency in using pesticides. Out of these 61.03% farmers, 14.62%, 14.83%, 17.93% and 13.65% of farmers were low, moderate, high and extreme high user of pesticides respectively.

Rahman (2003) revealed that about 37% of farmers used pesticides once, 31% applied twice, and the rest applied for 3–5 times in a crop season. Cultivation of traditional and modern rice varieties, potatoes, spices, vegetables and cotton are the prime determinants of pesticide use. Rahaman *et al.*, (2018) reported that farmers of Bangladesh mostly sought advice on pesticide use from pesticide dealers or retailers and a very few farmers contacted government extension workers for this purpose as results their efficiency of using pesticides might be lower.

The findings of the present study clearly indicate that farmers' efficiency in using selected pesticides for controlling rice pests were not up to the mark. Lower use of pesticides may decrease production and higher use may increase cost of production and environmental pollution. Therefore, it may be said that there is scope to increase the efficiency of farmers for using recommended doses of pesticides for rice pest control by proper advising the farmers about judicious use of pesticides by relevant agricultural advisory service providing organizations.

Comparative use efficiency of the selected pesticides

To compare the use efficiency of the selected pesticides, Standardized Use Efficiency Index (SUEI) were made for each of 14 selected pesticides. Rank Order was made based on the descending order of SUEI among the dimensions (for controlling disease and insect separately) and among all the pesticides as shown in Table 2.

Table 2. Standardized Use Efficiency Index of the pesticides with Rank Orders

	Category-wise number of users	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Items		Low dose users	Medium dose users	Recommended dose users	High dose users	Extreme high dose users	Total					
For controlling rice diseases	1. Thiovit 80 WG for controlling leaf scald disease	29	33	91	40	20	213	468	639	73.24	2	3
	2. Amistar Top 325 SC for controlling sheath blight disease	25	30	98	40	21	214	480	642	74.77	1	2
	3. Differ 300 EC for controlling bacterial blight disease	25	31	75	39	31	201	421	603	69.82	5	7
	4. Bavistin DF for controlling brown spot disease	29	32	71	38	28	198	410	594	69.02	6	9
	5. Nativo 75 WG for controlling rice blast disease	29	35	63	43	28	198	402	594	67.68	7	11
	6. Razdan 10G for controlling tungro virus disease	35	25	71	27	31	189	383	567	67.55	9	13
	7. Brifur 5G for controlling ufra disease of rice	29	30	79	37	30	205	430	615	69.92	4	6
	8. Combi-2 30 EC for controlling sheath rot disease	29	30	82	34	27	202	430	606	70.96	3	5
	9. Aimcozim 50 WP for controlling foot rot and bakanae disease	30	25	66	35	31	187	379	561	67.56	8	12
For controlling rice insects	10. Gola 80 EC for killing rice bug	24	30	99	32	21	206	466	618	75.40	1	1
	11. Plenum 50 WG for killing brown plant hopper	29	30	73	39	28	199	414	597	69.35	3	8
	12. Mortar 48 EC for killing rice leaf roller	33	30	77	31	31	202	417	606	68.81	4	10
	13. Virtako 40 WG for killing rice yellow stem borer	37	25	70	30	33	195	390	585	66.67	5	14
	14. Sevin 85 SP for killing of rice thrips	27	30	78	38	23	196	420	588	71.43	2	4

Among the pesticides for controlling rice diseases, 'Amistar Top 325 SC for controlling sheath blight disease' ranked 1st followed by 'Thiovit 80 WG for controlling leaf scald disease', 'Combi-2 30 EC for controlling sheath rot disease', 'Brifur 5G for controlling ufra disease of rice', 'Differ 300 EC for controlling bacterial blight disease", 'Bavistin DF for controlling brown spot disease', 'Nativo 75 WG for controlling rice blast disease', 'Aimcozim 50 WP for controlling foot rot and bakanae disease', and 'Razdan 10G for controlling tungro virus disease'.

Among the pesticides for controlling rice insect, ‘Gola 80 EC for killing rice bug’ ranked 1st followed by ‘Sevin 85 SP for killing of rice thrips’, ‘Plenum 50 WG for killing brown plant hopper’, ‘Mortar 48 EC for killing rice leaf roller’, and ‘Virtako 40 WG for killing rice yellow stem borer’.

Among all the 14 selected pesticides, ‘Gola 80 EC for killing rice bug’ ranked 1st followed by ‘Amistar Top 325 SC for controlling sheath blight disease’, ‘Thiovit 80 WG for controlling leaf scald disease’, ‘Sevin 85 SP for killing of rice thrips’, ‘Combi-2 30 EC for controlling sheath rot disease’, ‘Brifur 5G for controlling ufra disease of rice’, ‘Differ 300 EC for controlling bacterial blight disease”, ‘Plenum 50 WG for killing brown plant hopper’, ‘Bavistin DF for controlling brown spot disease’, ‘Mortar 48 EC for killing rice leaf roller’, ‘Nativo 75 WG for controlling rice blast disease’, ‘Aimcozim 50 WP for controlling foot rot and bakanae disease’, ‘Razdan 10G for controlling tungro virus disease’ and ‘Virtako 40 WG for killing rice yellow stem borer’.

3.2 Salient features of selected characteristics of the rice farmers

Sixteen (16) characteristics of the farmers were considered as the independent variables of the study which might have contribution their use efficiency of pesticides for controlling ric3e pests. Measuring procedures of these variables are discussed in the methodology section. Salient features like possible range, observed range, mean and standard deviation of these characteristics are presented in Table 3.

Table 3. Salient features of the selected characteristics of the farmers

Characteristics	Possible range	Observed range	Mean	Std. Deviation
1. Age	Unknown	20-63	40.98	12.311
2. Education	Unknown	0-14.00	6.5913	3.45656
3. Rice farming area	Unknown	0.09-1.51	0.4996	0.28671
4. Family agricultural labour	Unknown	1-5	3.38	1.118
5. Rice farming experience	Unknown	2-45	20.23	10.173
6. Annual rice farming income	Unknown	50-151	101.66	28.323
7. Pesticide cost for controlling rice pests	Unknown	1-7	4.60	1.673
8. Credit received for rice farming	Unknown	0- 120	66.71	33.39
9. Rice farming training exposure	Unknown	0-5	3.13	1.60
10. Organizational Participation	0-21	6-17	11.47	3.508
11. Extension contact	0-45	14-39	25.50	7.635
12. Knowledge on pesticides	0-30	11-28	19.77	3.647
13. Attitude towards use of pesticides	0-48	19-42	30.92	7.107
14. Pre-cautions for using pesticides	0-36	15-31	23.24	4.531
15. Adverse symptoms observed after using pesticides	0-33	9-20	14.48	3.533
16. Performance of selected pesticides	0-42	13-36	26.75	5.864

3.3 Contribution of selected characteristics of the farmers to their efficiency in using selected pesticides for controlling rice pests

To find out the contribution of the 16 selected characteristics of the farmers (independent variables: X) to their efficiency in using selected pesticides (dependent variable: Y), full model regression analysis was run. The results of full model regression analyses are presented in Table 4.

Table 4. Results of full model regression showing the contribution of the selected characteristics of the farmers to their efficiency in using selected pesticides

Selected characteristics of the farmers	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
Constant	0.149	0.207		0.719	0.473		
Age (X_1)	0.000	0.002	0.005	0.057	0.954	0.343	2.917
Education (X_2)	0.009	0.005	0.091	1.832	0.068	0.921	1.086
Rice farming area (X_3)	0.144	0.059	0.121*	2.436	0.016	0.933	1.071
Family agricultural labour (X_4)	0.005	0.015	0.017	0.337	0.736	0.927	1.079
Rice farming experience (X_5)	0.007	0.003	0.212*	2.554	0.011	0.334	2.992
Annual rice farming income (X_6)	0.000	0.001	0.014	0.292	0.770	0.949	1.054
Pesticide cost for controlling rice pests (X_7)	0.010	0.010	0.050	1.001	0.318	0.923	1.084
Credit received for rice farming (X_8)	0.001	0.000	0.058	1.181	0.239	0.959	1.043
Rice farming training exposure (X_9)	0.005	0.011	0.024	0.484	0.629	0.905	1.105
Organizational Participation(X_{10})	0.001	0.005	0.011	0.217	0.828	0.948	1.055
Extension contact (X_{11})	0.008	0.002	0.171**	3.289	0.001	0.847	1.180
Knowledge on pesticides (X_{12})	0.042	0.005	0.447**	8.054	0.000	0.744	1.343
Attitude towards use of pesticides (X_{13})	0.006	0.002	0.129**	2.592	0.010	0.923	1.083
Pre-cautions for using pesticides (X_{14})	0.007	0.004	0.099*	2.032	0.043	0.960	1.041
Adverse symptoms observed after using pesticides (X_{15})	0.002	0.005	0.022	0.441	0.660	0.943	1.060
Performance of selected pesticides (X_{16})	0.005	0.003	0.085	1.600	0.111	0.817	1.224

*Significant at 0.05 Level, **Significant at 0.01 Level

R = 0.679, R Square = 0.461, Adjusted R Square = 0.424, F ratio = 12.554 at 0.000 level

It was observed that the full model regression results revealed that out of 16 selected characteristics of the farmers, six (6) characteristics such as rice farming area (X_3), rice farming experience (X_5), extension contact (X_{11}), knowledge on pesticides (X_{12}), attitude towards use of pesticides (X_{13}), and Pre-cautions for using pesticides (X_{14}) had significant positive contribution to their efficiency in using pesticides for controlling rice pests.

In Collinearity Statistics, it was found that the Tolerance of the independent variables were $\geq$0.343 and the Variance Inflation Factor (VIF) of the independent variables were $\leq$2.917. Miles (2014) suggested that generally, a Tolerance of <0.25 or VIF of >4 indicates that multicollinearity might exist, and further investigation is required. When Tolerance is lower than 0.1 or VIF is higher than 10, there is significant multicollinearity that needs to be corrected. James et al., (2013) also reported that VIF of 5 or less is not problematic for collinearity in a multivariable (linear or logistic) model. In the full model regression analysis results, it was found that Tolerance and VIF of all the independent variables were in the acceptable range, i.e., there were acceptable multicollinearity among the independent variables. On these considerations, the results of the full model regression analysis were accepted.

Multiple R, R^2 and adjusted R^2 in the regression analysis were 0.679, 0.461 and 0.424 respectively, and the corresponding F-ratio of 12.554 was significant at 0.000 level. The regression equation so obtained was as follows:

$$Y = 0.149 + 0.447(X_{12}) + 0.212(X_5) + 0.171(X_{11}) + 0.129(X_{13}) + 0.121(X_3) + 0.099(X_{14})$$

Regression analysis revealed that the whole model of 16 independent variables explained 42.4 percent of the total variation in efficiency in using pesticides for controlling rice pests. But since the standardized regression coefficient of six (6) variables formed the equation and were significant, it might be assumed that whatever contribution was there, it was due to these six (6) variables.

Results of multiple regression analysis again indicated that 'Knowledge on pesticides (X_{12})' of the farmers was by far the most important characteristic which strongly and positively influenced their efficiency in using pesticides for controlling rice pests. 'Rice farming experience (X_5)', 'extension contacts (X_{11})', 'attitude towards use of pesticides (X_{13})', 'rice farming area (X_3)', and 'pre-cautions for using pesticides (X_{14})' of the farmers also had remarkable positive influence on their efficiency in using selected pesticides for controlling rice pests. Since the rest ten (10) variables or characteristics of the farmers had non-significant contribution to their efficiency in using pesticides, it was inferred that these characteristics had minimum contribution to the total explained variation of 42.4 percent. On the basis of regression analysis, contributions of significant six (6) independent variables to efficiency in using pesticides as the dependent variable are presented below in order of importance.

Knowledge on pesticides (X_{12}): From the results of multiple regression analysis, it was revealed that knowledge on pesticides of the farmers had strong positive contribution to their efficiency in using pesticides for controlling rice pest. Knowledge plays an important role in decision making process. It is the precursor to the adoption of any innovation. A knowledgeable person could understand the merits and demerits of any technology easily in a short time. Therefore, farmers having high knowledge could easily make them able to efficient in using pesticides for controlling rice pest. This might be the reason for knowledge having the positive contribution to efficient use of pesticides for controlling rice pests. Ali *et al.*, (2020) revealed that inadequate protective behaviour of farmers in pesticide use was mainly due to lack of knowledge. Fan *et al.*, (2015) found that the protective behaviour of farmers were affected by their level of knowledge.

Rice farming experience (X_5): Regression analysis indicated that experience in rice farming of the farmers had significant and positive influence on their efficiency in using pesticides for controlling rice pests it was found to be the second important positive contributor to efficiency in using pesticides. Experience in rice farming makes farmers efficient and judicious in using pesticides for controlling rice pests. The present study proved that the farmers who have more experience in rice farming, had higher efficiency in using pesticides for controlling rice pests. Hamidi (2004) found a significant positive relationship between experience in rice farming of the farmers and the adoption. Mkhabela (2005) reported that more experience in farming increased the efficiency level of farmers, But Fasasi (2007) found that farming experience of farmers had negative influence on their level of technical efficiency.

Extension contacts (X_{11}): Regression analysis indicated that extension contact of the farmers had third highest significant positive influence on their efficiency in using pesticides for controlling rice pests. Farmers having greater contact with the extension agents obviously had higher efficiency in using pesticides for controlling rice pests (Haque et al., 2016). Rahaman (2018) reported that farmers of Bangladesh mostly sought advice on pesticide use from pesticide dealers or retailers and a very few farmers contacted government extension workers for this purpose. This might be the reason for extension contact having the positive significant influence on efficiency in using pesticides.

Attitude towards use of pesticides (X_{13}): Regression analysis indicated that attitude towards use of pesticides of the farmers was the fourth important contributor and had significant positive influence on their efficiency in using pesticides for controlling rice pests. It was very logical that farmers could use efficiently pesticides for rice pest control, if they had favourable attitude towards use of pesticides. Kabir and Rainis, (2017) mentioned that farmers perception is an important factor to judicial use of pesticides in vegetable cultivation.

Rice farming area (X_3): Regression analysis indicated that rice farming area of the farmers was the 5th important contributor and had significant positive influence on their efficiency in using pesticides for rice control. Rahman and Umar (2009) found that land ownership of farmers was an important factor related to their technical efficiency. As a result, farmers having more rice farming area might have the capacity to use pesticides efficiently for controlling rice pests.

P**re-cautions for using pesticides** (X_{14}): Regression analysis indicated that pre-cautions for using pesticides of the farmers had sixth important positive contribution to their efficiency in using pesticides for controlling rice pests. Pre-cautions make an individual efficient to use an innovation efficiently. This might be the reason for pre-cautions for using pesticides having the positive significant influence on efficiency in using pesticides.

4. Conclusion

Farmers of Bangladesh mostly use pesticides as suggested by the dealers or retailers. As a result, farmers' use of pesticides is far from recommended doses. Findings of the study revealed that 38.97% farmers were the efficient users of recommended doses of pesticides for controlling rice pests. Rest 61.03% farmers used either lower or higher doses of pesticides for controlling rice pests i.e., they had lower efficiency in using pesticides. Out of these 61.03% farmers, 14.62% and 14.83% were low and moderate users respectively; and 17.93% and 13.65% had high and extreme high user of pesticides respectively for pest control. Regression analysis indicated that 'Knowledge on pesticides' of the farmers was by far the most important characteristic which strongly and positively influenced their efficiency in using pesticides for controlling rice pests. 'Rice farming experience', 'extension contacts', 'attitude towards use of pesticides', 'rice farming area', and 'pre-cautions for using pesticides' of the farmers also had significant positive influence on their efficiency in using selected pesticides for controlling rice pests. Lower use of pesticides may decrease production and higher use may increase cost of production and environmental pollution. Therefore, it may be concluded that agricultural advisory service providing organizations should provide necessary training and motivational campaigning by increase contact with the farmers having lower farming experience, lower farming area to increase their knowledge for taking necessary pre-cautions and to form favourable attitude towards judicious and efficient use of pesticides for controlling rice pests.

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