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An assessment of using eco-friendly crop production practices by the project beneficiaries and non-beneficiaries in Bangladesh

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Abstract
The purposes of this study were to determine the present state of use of eco-friendly crop production practices by the beneficiaries of "safe crop production through eco-friendly approaches" project and non-beneficiary smallholder farmers and to explore the factors that may influence their use. The study's population was the smallholder farmers of 2 villages (Darirampur and Birrampur Uzanpara) of Rampur union under Trishal upazila (sub-district) of Bangladesh. 60 beneficiaries and 60 non-beneficiaries were randomly selected as samples from a population of 270 beneficiaries and 585 non-beneficiaries. Thus, the total sample was 120 smallholder farmers. Data were collected using a structured questionnaire. The respondents were asked to give responses regarding their use of 21 practices following a 4-point rating scale. The highest proportion (95%) of the beneficiaries had medium extent of use, whereas highest proportion (85%) of the non-beneficiaries had low extent of use. The multiple linear regression analysis showed educational level, annual income, training experience, extension media contact, knowledge, and attitude toward eco-friendly crop production practices were the influential variables for the beneficiaries explaining 81.8% variation. However, for the non-beneficiaries, annual income, training experience, organizational participation, and credit received were the influential variables explaining 78.1% variation. The beneficiaries are more environmentally conscious than the non-beneficiaries, which highlights the need for authorities to involve more farmers in future projects to ensure safe crop production and better environmental health.

Keywords Eco-friendly practices · Smallholder farmers · Project beneficiary

1 Introduction

The main challenge for humanity is providing food for the 11 billion by the end of this century. [1]. Despite heavy inputs like fertilizers and pesticides, green revolution technology has increased global productivity by 40% [2]. Pesticides, particularly those used against pests, are crucial in modern agricultural production [3] due to their ability to keep crops pest-free and ensure high crop yields, contributing to the significant increase in agricultural production [4]. The situation is similarly similar in Bangladesh, which has a population of 166.50 million and a density of 1125 persons per square kilometer, making it one of the world's most densely inhabited nations [5]. With 58% of the population in rural areas

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[6], the agriculture sector contributes 11.20% of the country's GDP in 2022–23 [7]. With a total land area of 14.8 million hectares, the nation must use its 14.3 million hectares of cultivable land to meet its population's food needs [6].

The people of the agrarian community live in extreme poverty and even suffer from food insecurity from time to time [8]. For the most part, they rely on traditional agricultural techniques and meteorological factors to produce their crops [9]. As a result, every year they face various natural calamities such as floods, droughts and cyclones which take lives and destroy crops, livestock and property [10]. Bangladesh has achieved notable strides in achieving its goal of achieving food grain self-sufficiency, mostly attributed to the notable augmentation of its agricultural sector [11]. For instance, nearly half of all rice acreage is now planted with advanced cultivars [12]. To maintain efficient and rapid agricultural expansion, intensification is necessary on a continuous basis [13]. However, there is growing fear that intensive farming may not be environmentally friendly and that it may harm other lucrative businesses like fishing, particularly by contaminating the water [14].

Since the 1950s, the use of agrochemicals has expanded by 150–300%, posing a major risk to both public health and the environment [15]. Compared to 1960 (758 metric tons) and 1980 (3028 metric tons), the amounts of pesticides applied in Bangladesh has grown significantly, reaching over 19,000 metric tons in 2000 [16]. In 2018, the total amount of pesticides applied nationwide rose to 38,691 metric tons [6]. The extensive use of banned pesticides in Bangladesh raises concerns about the possible effects of this rapid increase in pesticide use on farmers' health and the environment, notably pesticide poisoning [3]. However, the extensive use of pesticides poses a significant obstacle to the development of sustainable agriculture [17], leading to the contamination of food, water, and air—all essential elements of life [18, 19]. The irresponsible application of pesticides is causing three things: biodiversity loss, a decline in beneficial insects and spiders, and a progressive rise in agricultural production costs [20] which is creating a burden on the smallholder farmers [21].

Eco-friendly agriculture can be way to minimize the abundant use of agro-chemicals for crop production [22]. Shanka [2] studied about different eco-friendly crop production practices in African region like intercropping, cover crops, use of green manure, vermicomposting, crop rotation, Integrated Nutrient Management (INM), Integrated Pest Management (IPM) etc. and their role in lessening the use of pesticides. On the other hand, Ram et al. [23] showed the intensive use of eco-friendly crop production practices in India also. However, although there are a few instances, no such eco-friendly method is used by farmers at the grassroots level in Bangladesh [16]. Agrochemical use in the agriculture sector of Bangladesh can be reduced by a number of relatively simple interventions [24]. Keeping the aforementioned issues in mind, the Bangladeshi government launched a project named "Safe Crop Production through Eco-friendly Approaches".

Several studies have been conducted on eco-friendly agriculture in different countries. Among them, Verma et al. [25] studied about eco-friendly approach called use of plant growth-promoting rhizobacteria, Shanka [2] studied about the roles of eco-friendly low input technologies in crop production in sub-Saharan Africa, Amoo et al. [26] studied on another eco-friendly approach called biofertilizer, Zuma et al. [22] studied on incorporating cropping system to mitigate the effects of climate change, Morya & Kumar [27] studied on eco-friendly pest management system. But no studies were found on the extent of use of eco-friendly crop production practices by the smallholder farmers and making any comparison among their usage. In addition to that, no literature was found to identify the factors that may influence the use of eco-friendly crop production practices by the smallholder farmers.

Thus, this study is undertaken to determine the extent of use of eco-friendly crop production practices by the project beneficiary and non-beneficiary smallholder farmers and whether there are any differences between their use. Finally, this study will also identify the factors that may influence the use of eco-friendly crop production practices by the two groups of smallholder farmers.

2 Methodology

2.1 Study location

The study was conducted in two villages (Darirampur and Birrampur Uzanpara) of Rampur union under Trishal Upazila (sub-district) of Mymensingh district (Fig. 1). These two villages are important because of their landscape and diversity which are suitable for agricultural production. For that reason, majority of the people (74%) of these two villages are engaged in agricultural activities compared to other villages of Rampur union. On the other hand, the investigational study region was purposefully chosen because Rampur Union was one of the areas where the project "Safe Crop

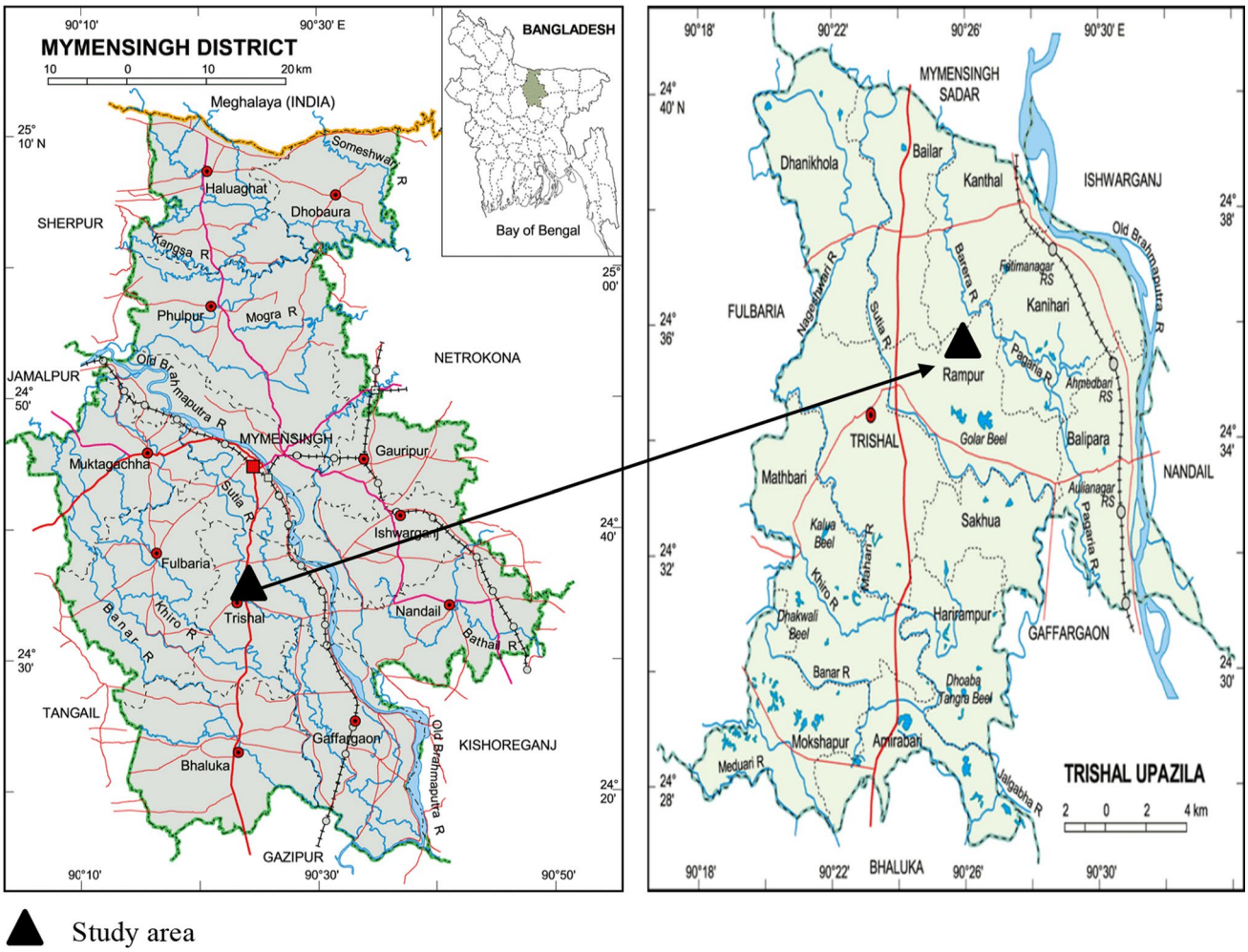

Fig. 1 Map of Mymensingh district and Trishal upazila (sub-district) showing the study area

Production through Eco-friendly Approaches" was intensively implemented and Rampur union was declared as an "IMP Model Union" by the Government of Bangladesh.

2.2 Population and sampling

The smallholder farmers in 2 villages of Rampur union were considered as the target population of the study. From the 2 villages, 60 smallholder farmers were considered as representative from the project beneficiaries of the project "Safe Crop Production through Eco-Friendly Approaches" and another 60 were considered as a representative from the non-beneficiary smallholder farmers. Simple random sampling technique was used for selecting the smallholder farmers from the 2 villages. Thus, the total sample of the study was 120 smallholder farmers (60 from each of the project beneficiary and non-beneficiary smallholder farmers' groups). The sampling technique is presented in Table 1.

2.3 Household survey

An organized interview schedule was created utilizing existing literature on pertinent subjects to gather information from individual farmers. Understanding farmers' socioeconomic, personal, and contextual origins is essential to understanding why they employ eco-friendly crop production techniques. For this reason, the purpose of the interview schedule's first portion was to gather information regarding smallholder farmers' age, educational level, household size, farm size, annual family income, farming experience, agricultural training experience, organizational participation, credit received, extension media contact, knowledge of and attitude toward eco-friendly crop production practices (Table 2).

Table 1 Distribution of population and sample of the smallholder farmers in the study area

Name of the villages	Project beneficiary smallholder farmers		Non-beneficiary smallholder farmers	
	Population	Sample size	Population	Sample size
Darirampur	120	30 (25%)	300	30 (10%)
Birrampur Uzanpara	150	30 (20%)	285	30 (10.6%)
Total	270	60	585	60

Numerical values in the parenthesis indicate the percentage of sampled respondents from the study's population

2.4 Data collection and measurement of variables

An organized questionnaire-based household survey, three key informant interviews (KIIs), and five focus group discussions (FGDs) were the study's principal sources of data and information. To complement the original data, secondary data was gathered from publications, scholarly journals, and unpublished works, like thesis and reports. The study's empirical data were gathered during March and April of 2022. The researcher did everything to build the necessary rapport with the participants so that they would feel comfortable answering the questions on the schedule. The next section provides a summary of each data collection technique.

2.4.1 Measurement of use of eco-friendly crop production practices

The extent of use of eco-friendly crop production practices by the project beneficiary and non-beneficiary smallholder farmers was the dependent variable of the study. To measure this, a 4-point rating scale was used. A total of 21 eco-friendly crop production practices were included in the questionnaire. These practices were identified by searching literatures from Rebouh et al. [28], Zhang et al. [29], Bahadur et al. [30], Devarinti [31]. The respondents were asked to rate their use on a 4-point rating scale, with the options "frequently," "occasionally," "rarely," and "never" and the scores that were awarded were 3, 2, 1, and 0, respectively [32]. Weights of responses were added and compared to the chosen 21 practices to get the final score and therefore, the score for the extent of use of eco-friendly crop production practices of a respondent could vary from 0 to 63. Independent sample t-test was performed at 5% level of significance to compare the use of eco-friendly crop production practices by the two groups of smallholder farmers.

Frequency counts of the responses were recorded to compute the Use Index (UI) for each of the eco-friendly crop production practices [33]. For determining the extent of use of individual practices, rank order was made based on Use Index (UI). Use Index was computed by using the following formula:

$$Use\ Index = \left(N_1 \times 3\right) + \left(N_2 \times 2\right) + \left(N_3 \times 1\right) + \left(N_4 \times 0\right) \quad (1)$$

Here, N_1 = Number of farmers using frequently; N_2 = Number of farmers using occasionally; N_3 = Number of farmers using rarely; N_4 = Number of farmers never used

In summary, the UI value of a practice may be calculated by summing the frequency counts of all the cells in the scale. A value of 0 denotes "no usage," while a value of 180 denotes "maximum use" for that specific practice.

Multiple linear regression analysis was used to identify influential factors that might have significant effects on the use of eco-friendly crop production practices by smallholder farmers [34]. Once more, a step-wise multiple regression analysis was carried out to comprehend the role that each of the significant factors had in explaining variation in the use of eco-friendly crop production practices [35]. This tool was used to identify the significant independent variables that have an effect on the dependent variable. It helps to reveal the value of adjusted R^2, that is, the amount of change of the dependent variable by the independent variables. The equation of multiple regression is as follows:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + e \quad (2)$$

Here, $y = y^{\wedge} + e$ = Use of eco-friendly crop production practices (Scale score); β_0 = Intercept; X_1 = Age (Yrs.); $X_{2=}$ Educational level (No.); $X_{3=}$ Household size (No.); $X_{4=}$ Farm size (Ha); $X_{5=}$ Annual family income (BDT); $X_{6=}$ Farming experience (Yrs.); $X_{7=}$ Agricultural training experience (Days); $X_{8=}$ Organizational participation (Scale score); $X_{9=}$ Credit received (Scale score); $X_{10=}$

Table 2 Measurement of independent variables of this study

Respondents' characteristics	Type of indicator	Unit	Response scale of item
1. Age	Individual	Years (Yrs.)	–
2. Educational level	Individual	For each year of schooling = 1; No schooling = 0	–
3. Household size	Individual	Number (No.)	–
4. Farm size	Individual	Hectare (Ha)	–
5. Annual family income	Individual	Bangladeshi Taka (BDT)	–
6. Farming experience	Individual	Years (Yrs.)	–
7. Agricultural training experience	Individual	Days	–
8. Organizational participation (5)	Aggregated	Score between 0 and 10	2 = Executive member; 1 = Ordinary member; 0 = No participation
9. Credit received	Individual	Bangladeshi Taka (BDT)	–
10. Extension media contact (16)	Aggregated	Score between 0 and 48	3 = Frequently; 2 = Occasionally; 1 = Rarely: 0 = Not at all
11. Knowledge (20)	Aggregated	Score between 0 and 47	Random marks according to the importance of the questions
12. Attitude (24)	Aggregated	Score between 24 and 120	5 = Strongly agree, 4 = Agree, 3 = No opinion, 2 = Disagree, 1 = Strongly Disagree

Numbers in the parenthesis indicates total items under each of the respective variables

Extension media contact (Scale score); $X_{11=}$ Knowledge of eco-friendly crop production practices (Score); $X_{12=}$ Attitude toward eco-friendly crop production practices (Scale score)

The study's objectives were followed throughout the compilation, tabulation, and analysis of the gathered data to find out mean, standard deviation, range, frequency and other statistical measurements. The data analysis was done using the Statistical Package for Social Science (SPSS v.21).

3 Results

3.1 Socio-economic characteristics of the two groups of smallholder farmers

The study made an effort to examine the socioeconomic characteristics of the two smallholder farming groups that were chosen as the sample of the study. Twelve selected characteristics of the smallholder farmers such as: age, educational level, household size, farm size, annual family income, farming experience, agricultural training experience, organizational participation, credit received, extension media contact, knowledge of and attitude toward eco-friendly crop production practices constituted independent variables of the study. Table 3 displays the descriptive parameters of the socioeconomic traits of the smallholder farmers.

Table 3 represents that the majority of the project beneficiary farmers (71.7%) and more than half of the non-beneficiary farmers (56.7%) were middle-aged. The t value of -1.02 indicated that there was no significant difference between the ages of the two groups. A considerable proportion of the project beneficiary farmers (43.3%) have secondary level education while less than half (46.7%) of the non-beneficiary farmers were illiterate. The t value of 1.93 indicated that there was no significant difference between the educational levels of the two groups of farmers. Ogunmefun and Achike [36] assert that farmers' educational attainment affects their ability to manage their operations and implement appropriate technology. Table 3 shows that about two-thirds (65%) of the project beneficiary farmers and less than half (43.4%) of the non-beneficiary farmers had large household size. The t value of 1.40 indicated that there was no significant difference in the household size.

Highest proportion of the project beneficiary farmers (95%) and absolute majority (96.7%) of the non-beneficiary smallholder farmers had small farm size but the t value of 0.47 indicated that there was no significant difference. Data presented in Table 3 shows that the highest proportion of the project beneficiary farmers (86.7%) had low-income and similar result was found for the non-beneficiary farmers where more than three-fourths (78.3%) had low-income. The t value of -0.51 indicated that there was no significant difference. The majority of the project beneficiary farmers (43.4%) had high farming experiences, whereas, the majority of the non-beneficiary farmers (40%) had medium farming experience. Highly experienced farmers are able to forecast market conditions and farm output [37]. The t value of -0.66 indicated that there was no significant difference.

Table 3 shows that majority of the project beneficiary farmers (70%) had short-duration training experience but the majority of the non-beneficiary farmers (71.6%) had no training experience. The t value of 7.17 clearly indicated that there was a significant difference. Training improves farmers' capacity to run their operations profitably and efficiently while also maximizing farm yield [38]. Majority of the project beneficiary farmers (75%) and majority of the non-beneficiary farmers (85%) had low organizational participation but the t value of 4.17 clearly indicated that there was a significant difference. Table 3 also represents that majority of the project beneficiary farmers (81.7%) and non-beneficiary farmers (66.7%) had received no credit. It is because farmers receive credit with high-interest rates which becomes a huge burden for them to pay the interest rate if production is not satisfactory [39]. The t value of -1.33 clearly indicated that there was no significant difference.

Highest proportions of the project beneficiary farmers (80%) and non-beneficiary farmers (65%) had medium extension media contact. Having access to extension agents makes it possible to obtain reliable information for a variety of farming tasks [40]. The t value of 11.75 clearly indicated that there was a significant difference. Data presented in Table 3 also show that more than half (51.7%) of the project beneficiary farmers had high level of knowledge, whereas more than half of the non-beneficiary farmers (86.7%) had a moderate level of knowledge. The t value of 20.23 clearly indicated that there was a significant difference. Knowledge of eco-friendly crop production practices is an important aspect of motivating farmers to use and incorporate those practices into their farming activities [41]. Finally, majority proportion (78.3%) of the project beneficiary farmers had a favorable attitude, whereas all of the non-beneficiary farmers (100%) had a moderately favorable attitude toward eco-friendly crop production practices. The t value of 19.78 clearly indicated that there was a significant difference. Attitude toward eco-friendly crop production practices is an important factor in

Table 3 Socio-economic characteristics of the smallholder farmers

Characteristics with categories	Project beneficiary farmers ($n_1 = 60$)			Non-beneficiary farmers ($n_2 = 60$)			t value
	No	%	Mean ± SD*	No	%	Mean ± SD*	
Age (Years)							
Young (up to 35)	11	18.3	44.49 ± 10.66	15	25.0	42.60 ± 9.43	− 1.02
Middle-aged (36–50)	43	71.7		34	56.7		
Old (> 50)	6	10.0		15	18.3		
Educational level (Total years of schooling)							
Illiterate (0)	18	30.0	6.23 ± 4.75	28	46.7	4.53 ± 4.79	1.93
Primary (1–5)	9	15.0		8	13.3		
Secondary (6–10)	26	43.3		16	26.7		
Above secondary (> 10)	7	11.7		8	13.3		
Household size (No. of members)							
Small (up to 4)	6	10.0	6.78 ± 2.01	11	18.3	5.80 ± 1.72	1.40
Medium (5–6)	15	25.0		23	38.3		
Large (> 6)	39	65.0		26	43.4		
Farm size (Hectare)							
Landless (0.002–0.02 ha)	0	0	0.48 ± 0.17	0	0	0.34 ± 0.07	0.47
Marginal (0.021–0.2 ha)	3	5		2	3.3		
Small (0.21–0.99 ha)	57	95		58	96.7		
Annual family income ('000' BDT)							
Low (up to 100)	52	86.7	77.16 ± 22.30	47	78.3	83.25 ± 41.81	− 0.51
Medium (100.1–200.0)	8	13.3		13	21.7		
High (> 200)	0	0		0	0		
Farming experience (Years)							
Low (up to 10)	14	23.3	18.45 ± 9.96	15	25.0	19.15 ± 6.2	− 0.66
Medium (11–20)	20	33.3		24	40.0		
High (> 20)	26	43.4		21	35.0		
Agricultural training experience (Days)							
No training (0)	0	0	3.02 ± 0.97	43	71.6	0.72 ± 1.24	7.17*
Short duration (1–3)	42	70		16	26.7		
Medium duration (4–7)	18	30		1	1.7		
Long duration (> 7)	0	0		0	0		
Organizational participation (Score)							
No participation (0)	0	0	3.0 ± 0.84	5	8.3	2.02 ± 1.06	4.17*
Low participation (1–3)	45	75		51	85.0		
Medium participation (4–7)	15	25		4	6.7		
High participation (> 7)	0	0		0	0		
Credit received ('000' BDT)							
No credit (0)	49	81.7	14.67 ± 36.52	40	66.7	31.17 ± 88.35	− 1.33
Low credit (1–50)	5	8.3		13	21.7		
Medium credit (50.1–100.0)	5	8.3		5	8.3		
High credit (> 100.1)	1	1.7		2	3.3		
Extension media contact (Score)							
Low (up to 16)	0	0	30.85 ± 6.84	21	35	17.17 ± 1.92	11.75*
Medium (17–32)	48	80		39	65		
High (> 32)	12	20		0	0		
Knowledge of eco-friendly crop production practices (Score)							

Table 3 (continued)

Characteristics with categories	Project beneficiary farmers ($n_1 = 60$)			Non-beneficiary farmers ($n_2 = 60$)			t value
	No	%	Mean ± SD*	No	%	Mean ± SD*	
Poor knowledge (up to 16)	0	0	32.43 ± 3.44	8	13.3	19.38 ± 2.67	20.23*
Moderate knowledge (17–32)	29	48.3		52	86.7		
High knowledge (> 32)	31	51.7		0	0		
Attitude toward eco-friendly crop production practices (Score)							
Unfavorable (up to 40)	0	0	85.73 ± 6.22	0	0	67.25 ± 2.92	19.78*
Moderately favorable (41–80)	13	21.7		60	100		
Favorable (> 80)	47	78.3		0	0		

*SD = Standard deviation; *BDT* Bangladeshi Taka; The t value at a 5% level of significance is 1.98 with 118 df

*Significant at 0.05 level of significance

the adoption and use of those practices. It is expected that negative attitudes toward the agrochemicals will increase the use of eco-friendly crop production practices by the non-beneficiary farmers [42].

3.2 Extent of use of eco-friendly crop production practices by the two groups of smallholder farmers

The primary goal of the study was to assess the extent of use of eco-friendly crop production practices by the project beneficiary and non-beneficiary smallholder farmers which is presented in Fig. 2. The scores obtained for the use of eco-friendly crop production practices by the beneficiaries ranged from 29 to 44 and the obtained score for the non-beneficiaries ranged from 11 to 26, against a possible range of 0–63. Based on the possible range, the respondents were classified into three categories: 'low use (up to 21)', 'medium use (22–42)' and 'high use (> 42)'. Similar technique was followed by Alam et al. [43] in their study concerning with the use of agrochemicals in pineapple farming. This classification technique is also followed by Islam and Islam [44], Roy et al. [45], Rahman [46], and Farouque and Sarker [47] in their respective studies. Data presented in Fig. 2 show that the highest proportion of the project beneficiary farmers (95%) had medium use and on the contrary, the highest proportion of the non-beneficiary farmers (85%) had low use of the eco-friendly crop production practices. The t value was found 31.21 which clearly indicate that there was a significant difference in the use. That means the use of eco-friendly crop production practices by the project beneficiary smallholder farmers is much higher than the non-beneficiary smallholder farmers.

It was found from Fig. 2 that the use of eco-friendly crop production practices by the project beneficiary smallholder farmers is much higher than that of non-beneficiary smallholder farmers. This may be due to that as the beneficiary smallholder farmers were involved in the project related to eco-friendly crop production techniques, they got different interventions from the project like different biological pest controlling equipment (yellow sticky trap, sex pheromone trap, net house etc.), biofertilizers, training on different non-chemical agricultural practices, demonstrations on organic farming and organic pest management, field days, workshops which resulted in better knowledge and attitude of the beneficiary farmers toward eco-friendly crop production practices. For that reason, the highest proportion (95%) of

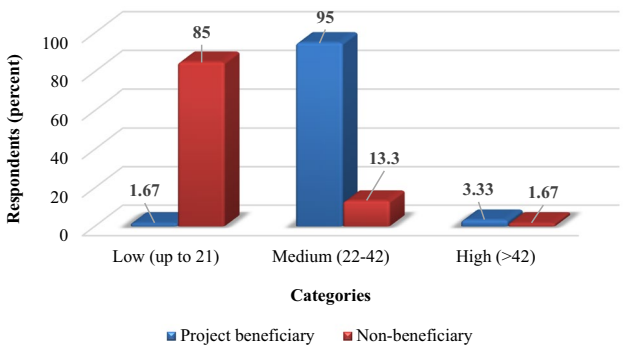

Fig. 2 Distribution of the smallholder farmers based on their use of eco-friendly crop production practices

the project beneficiary farmers had medium use of the eco-friendly crop production practices compared to the non-beneficiary farmers. Mondal et al. [48] in their study found that about 46% of farmers used the practices of organic vegetable production in Thailand as they had proper knowledge. A study conducted by Nurzaman [49] found similar findings between two groups of farmers where the FFS farmers had a significantly higher practice of IPM than the non-FFS farmers. Mukta et al. [50] and Negatu et al. [42] also reported similar findings in their studies.

3.3 Rank order based on the use of eco-friendly crop production practices

For a better understanding of the use of eco-friendly crop production practices by the two groups (project beneficiary and non-beneficiary) of smallholder farmers, the Use Index (UI) was computed and presented in Table 4.

In case of the project beneficiary smallholder farmers, the first one is 'Use of yellow sticky trap (UI-180)'. This may be due to the availability and cheap price of the yellow sticky trap in the local market. Other possibilities might be due to the efficiency of the yellow sticky trap for controlling insects, its simplicity and ease of use in the crop field which are supported by the study of Heinz et al. [51]. "Cultivation of cover crops" had the lowest score (UI-5), placing it at the bottom of the list (21st). This may be due to the reason that the project beneficiary farmers didn't aware of this practice and different GOs and NGOs didn't introduce this practice to the project beneficiary farmers. That's why this practice was least used by them in the study area. Neill & Lee [52] found similar causes for less use of cover crops by the farmers.

Similarly, for a better picture of the extent of use of eco-friendly crop production practices by the non-beneficiary smallholder farmers, the Use Index (UI) was computed and presented in Table 4.

The first one is the 'Practicing intercropping (UI-161)'. This may be due to that the non-beneficiary smallholder farmer has very limited agricultural land and that's why they try to obtain as much profit as possible from those limited land area through intercropping. In many cases, intercropping is done to compensate for the failure of the main crop and also the ergonomic usage of the limited agricultural land. Gebru [53] reported similar findings in his study. Lastly, the practice named 'Cultivation of cover crops' got the lowest score (UI-2) and hence got the lowest (21st) position in the order. This can be because different GOs and NGOs failed to inform the farming community about this practice and non-beneficiary farmers were unaware of it. Neill & Lee [52] found similar causes for less use of cover crops by the farmers.

Table 4 Rank order of the eco-friendly crop production practices based on their use

Practices	Use Index (UI)		Rank order	
	B	N	B	N
1. Use of yellow sticky trap	180	3	1	20
2. Using sex pheromone trap	179	13	2	12
3. Practicing crop rotation	177	137	3	4
4. Judicious use of chemical fertilizers	172	138	4	3
5. Adopting line logo perching	171	160	5	2
6. Practice of intercropping	166	161	6	1
7. Farm yard manure application	161	112	7	5
8. Use of mulching	118	99	8	6
9. Practice of mechanical weeding techniques	114	96	9	7
10. Use of poison bait	110	9	10	15
11. Cultivation of green manure crops	105	84	11	8
12. Application of Vermi-compost	85	6	12	17
13. Application of botanical pesticides	81	5	13	18
14. Using of light trap	70	4	14	19
15. Using neem leaves in seed storage	67	16	15	11
16. Synchronizing planting time	57	34	16	10
17. Practicing zero tillage	51	39	17	9
18. Applying Tricho-compost	50	12	18	13
19. Adopting net house	21	7	19	16
20. Insect repulsive crop cultivation	10	10	20	14
21. Cultivation of cover crops	5	2	21	21

B for project beneficiary farmers and N for non-beneficiary smallholder farmers

3.4 Factors influencing the use of eco-friendly crop production practices

To ascertain the components and their significance in predicting the focal variable, multiple linear regression analysis was done i.e., use of eco-friendly crop production practices by the two groups of smallholder farmers. Table 5 represents the summary of the multiple linear regression analysis for the project beneficiary smallholder farmers.

Six of the twelve variables were found to be significant, with an F value of 23.151 and an R^2 of 0.855. This suggests that around 85.5% of the use of eco-friendly crop production practices might be explained by the combined influence of these six explanatory variables. Table 5 indicates the coefficient of educational level ($t = 2.601$; $p < 0.05$), annual family income ($t = 2.402$; $p < 0.05$), agricultural training experience ($t = 3.640$; $p < 0.05$), extension media contact ($t = 2.973$; $p < 0.05$), knowledge of eco-friendly crop product ion practices ($t = 3.542$; $p < 0.05$) and attitude toward eco-friendly crop production practices ($t = 2.626$; $p < 0.05$) had significant influence in predicting their use.

The regression coefficient indicates that if educational level changes by 1 number (one year of schooling) then the use changes by 0.116. That means project beneficiary farmers who belong to high educational levels will have more use of eco-friendly crop production practices. Sarker and Itohara [33] reported similar findings in the case of the extent of practices of organic farming technologies. Smallholder project beneficiary farmers' annual family income had a significant positive coefficient value which was 0.024. The regression coefficient indicates that if annual family income changes by 1 number (1 thousand BDT) then the use changes by 0.024. That means project beneficiary farmers having high annual family income have more use of eco-friendly crop production practices. This result is consistent with that of Vidogbéna et al. [54], who discovered that the use of environmentally friendly nets for vegetable production was significantly influenced by the farmers' income. The regression coefficient indicates that if agricultural training experience changes 1 number (one day) then the use changes by 0.778. That means project beneficiary farmers having high agricultural training experience will have more use of eco-friendly crop production practices. Sarker and Itohara [33] also reported similar finding.

The regression coefficient indicates that if extension media contact changes 1 number (one scale score) then the use changes by 0.310. That means project beneficiary farmers having high extension media contact will have more use of eco-friendly crop production practices. Similar results regarding vegetable growers' adoption of environmentally friendly management strategies were reported by Pyasi et al. [55]. The regression coefficient also indicates that if knowledge changes 1 number (one score) then the use changes by 0.246. That means project beneficiary farmers having high knowledge will have more use of eco-friendly crop production practices. Uddin [56] reported similar findings in his study of sustainable agriculture. The regression coefficient indicates that if the attitude changes 1 number (one scale score)

Table 5 Summary of linear regression analysis of the project beneficiary smallholder farmers explaining the dependent variable

Explanatory variables	Unstandardized coefficients		Standardized coefficients	t	Sig
	B	Std. Error	Beta		
(Constant)	4.368	5.204	–	1.476	0.147
Age (X_1)	0.001	2.959	0.004	0.044	0.965
Educational level (X_2)	0.116	0.024	0.176	2.601	0.012
Household size (X_3)	− 0.033	0.045	− 0.021	− 0.350	0.728
Farm size (X_4)	− 1.617	0.096	− 0.088	− 1.483	0.145
Annual family income (X_5)	0.024	0.009	0.167	2.402	0.020
Farming experience (X_6)	− 0.008	0.010	− 0.025	− 0.270	0.789
Agricultural training experience (X_7)	0.788	0.029	0.242	3.640	0.001
Organizational participation (X_8)	0.327	0.216	0.088	1.486	0.144
Credit received (X_9)	− 0.004	0.220	− 0.045	− 0.774	0.443
Extension media contact (X_{10})	0.310	0.005	0.258	2.973	0.005
Knowledge of eco-friendly crop production practices (X_{11})	0.246	0.104	0.269	3.542	0.001
Attitude toward eco-friendly crop production practices (X_{12})	0.106	0.045	0.213	2.626	0.012

$n_1 = 60$, $R = 0.925$, $R^2 = 0.855$, Adjusted $R^2 = 0.818$, F-value = 23.151

then use changes by 0.106. That means project beneficiary farmers having a favorable attitude will have more use of eco-friendly crop production practices. This finding is in line with Sarker et al. [57] where they found farmers' attitude has a significant effect on organic homestead gardening. Considerable proportion (43.3%) of the project beneficiary farmers had secondary level of education which affected their use of eco-friendly crop production practices. Besides as they were part of the project, they got sufficient training, came in contact with different extension media which caused their better knowledge and attitude toward eco-friendly crop production practices which ultimately resulted in their increase in annual family income.

The outcomes of a step-wise multiple regression analysis are displayed in Table 6 to help comprehend the role of each significant variable in explaining variance in the level of usage of eco-friendly crop production practices by the project beneficiary smallholder farmers.

Table 6 shows the percentage of different variables that explains the dependent variable. The analysis revealed that extension media contact (X_{10}) expresses the dependent variable by 59.7%, attitude toward eco-friendly crop production practices (X_{12}) expresses 9.0%, knowledge of eco-friendly crop production practices (X_{11}) expresses 5.0%, agricultural training experience (X_7) expresses 4.6%, educational level (X_2) expresses 1.9% and annual family income (X_5) expresses 1.4%. Mandal [58] explored similar findings where he found that the extension media contact was the major factor that contributed to explain the dependent variable i.e., the use of brinjal production technologies by the farmers.

Table 7 represents the summary of the multiple linear regression analysis for the non-beneficiary smallholder farmers.

According to the results, four of the twelve variables had a significant F value of 18.488 and an R^2 of 0.825. This suggests that about 82.5 percent of the use of eco-friendly crop production practices might be explained by the combined effects of explanatory variables. Table 7 indicates the coefficient of annual family income ($t = 3.301$; $p < 0.05$), agricultural training experience ($t = 2.813$; $p < 0.05$), organizational participation ($t = 4.387$; $p < 0.05$) and credit received ($t = 3.845$; $p < 0.05$) had significant influence in predicting their use.

The regression coefficient indicates that if annual family income changes 1 number (1 thousand BDT) then the use changes by 0.024. That means non-beneficiary farmers having high annual family income will have more use of eco-friendly crop production practices. This finding is in line with Vidogbéna et al. [54] where they found that the income of the farmers had significant effect on the adoption of eco-friendly nets for vegetable production. The regression coefficient indicates that if agricultural training experience changes 1 number (one day) then the use changes by 0.472. That means non-beneficiary farmers having high agricultural training experience will have more use of eco-friendly crop production practices. Sarker & Itohara [33] also reported similar finding.

The regression coefficient indicates that if organizational participation changes 1 number (one scale score) then the use changes by 1.046. That means non-beneficiary farmers having high organizational participation will have more use of eco-friendly crop production practices. Uddin [56] reported similar findings in his study of sustainable agriculture. The regression coefficient indicates that if credit received changes 1 number (one thousand BDT) then the use changes by 0.011. That means non-beneficiary farmers who received high credit will have more use of eco-friendly crop production practices. Similar results regarding vegetable growers' adoption of eco-friendly management strategies were reported by Pyasi et al. [55]. As the non-beneficiary smallholder farmers were involved with different organizations, they got training on different issues of agriculture from time to time. Again, as they received credit support from different organizations, they were capable of giving better input to their crop production and hence got better annual family income.

Table 6 Step-wise multiple regression analysis of the project beneficiary smallholder farmers

Models	Multiple R	Multiple R^2	Variation explained (percent)	t value
Constant + X_{10}	0.604	0.597	59.7	9.40**
Constant + X_{10} + X_{12}	0.698	0.687	9.0	4.21**
Constant + X_{10} + X_{12} + X_{11}	0.750	0.737	5.0	3.41**
Constant + X_{10} + X_{12} + X_{11} + X_7	0.798	0.783	4.6	3.61**
Constant + X_{10} + X_{12} + X_{11} + X_7 + X_2	0.819	0.802	1.9	2.48**
Constant + X_{10} + X_{12} + X_{11} + X_7 + X_2 + X_5	0.835	0.816	1.4	2.28**

**Significance at 0.01 level of probability; Source: Own analysis

Table 7 Summary of linear regression analysis of the non-beneficiary smallholder farmers explaining the dependent variable

Explanatory variables	Unstandardized coefficients		Standardized coefficients	t	Sig
	B	Std. Error	Beta		
(Constant)	4.092	5.159	–	0.793	0.432
Age (X_1)	0.005	0.027	0.015	0.190	0.850
Educational level (X_2)	0.069	0.075	0.104	0.919	0.363
Household size (X_3)	– 0.182	0.123	0-0.099	– 1.476	0.147
Farm size (X_4)	1.138	2.632	0.028	0.432	0.668
Annual family income (X_5)	0.024	0.007	0.317	3.301	0.002
Farming experience (X_6)	0.015	0.038	0.029	0.389	0.699
Agricultural training experience (X_7)	0.472	0.168	– 0.184	2.813	0.007
Organizational participation (X_8)	1.046	0.238	0.349	4.387	0.000
Credit received (X_9)	0.011	0.003	0.294	3.845	0.000
Extension media contact (X_{10})	0.099	0.123	0.060	0.803	0.426
Knowledge of eco-friendly crop production practices (X_{11})	0.137	0.096	0.116	1.427	0.160
Attitude toward eco-friendly crop production practices (X_{12})	0.076	0.075	0.070	1.016	0.315

$n_2 = 60$, $R = 0.908$, $R^2 = 0.825$, adjusted $R^2 = 0.781$, F-value = 18.488

A step-wise multiple regression analysis was performed and the results are shown in Table 8 to help comprehend the role of each significant variable in explaining variance in the level of usage of eco-friendly crop production practices by the non-beneficiary smallholder farmers.

The Table 8 shows the percentage of different variables that explains the dependent variable. The analysis revealed that annual family income (X_5) expresses the dependent variable by 64.1%, organizational participation (X_8) expresses 7.0%, credit received (X_9) expresses 4.0% and agricultural training experience (X_7) expresses 2.9%. Akpan et al. [59] discovered comparable outcomes, concluding that the farmers' yearly family income was the primary factor that helped to explain the dependent variable, or the intensity of fertilizer use among small-holder crop farmers in the Abak Agricultural Zone of Akwa Ibom State, Nigeria.

4 Conclusions and recommendations

This study shown that the eco-friendly crop production practices, which were also easy to incorporate into their routine farming operations, had a significant positive impact on the smallholder farmers who were the project's beneficiaries. However, because they were left out of the project, the farmers who were the non-beneficiaries, do not have the necessary information or incentive to produce crops in an eco-friendly manner. It is recommended that adequate steps be taken to include more smallholder farmers in future projects in order to ensure safe crop production. In this case, a number of GOs and NGOs may take the necessary steps to establish and implement the same.

The results of the linear regression analysis showed that the six variables (educational level, annual family income, agricultural training experience, extension media contact, knowledge of eco-friendly crop production practices, and

Table 8 Step-wise multiple regression analysis of the non-beneficiary smallholder farmers

Models	Multiple R	Multiple R^2	Variation explained (percent)	t value
Constant + X_5	0.653	0.641	64.1	3.72**
Constant + X_5 + X_8	0.726	0.711	7.0	3.85**
Constant + X_5 + X_8 + X_9	0.768	0.751	4.0	3.14**
Constant + X_5 + X_8 + X_9 + X_7	0.799	0.780	2.9	2.88**

** Significance at 0.01 level of probability; Source: Own analysis

attitude toward eco-friendly crop production practices) explained 85.5% of the total variation in the use of eco-friendly crop production by the project beneficiary smallholder farmers. On the other hand, it was found that the four variables—annual family income, agricultural training experience, organizational participation, and credit received—accounted for 78.1% of the variation in the usage of eco-friendly crop production by the smallholder farmers who were not recipients. It is strongly recommended that the relevant authorities should continue to monitor farmers after the project is finished so they can apply the knowledge they have gained to their respective fields.

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Data availability The corresponding author can provide the datasets created and/or analyzed during the current study upon reasonable request.

Declarations

Ethics approval It should be mentioned in the text that there was no chance to apply for Study Ethics Board (REB) permission because there was no institutional ethical board to approve social science research. Because of this academic constraint, the study was exempt from needing ethics approval.

Consent to participate All study participants gave the authors their informed consent before their data was used in a scholarly publication. This research did not involve any minors.

Competing interests No potential conflict of interest was reported by the authors.

References

1. UNCCD (United Nations Convention to Combat Desertification). The Global Land Outlook, 1st ed.; UNCCD: Bonn, Germany. 2017.
2. Shanka D. Roles of eco-friendly low input technologies in crop production in Sub-Saharan Africa. Cogent Food Agric. 2020;6(1):184. https://doi.org/10.1080/23311932.2020.1843882.
3. Ali MP, Kabir MMM, Haque SS, Qin X, Nasrin S, Landis D, Ahmed N. Farmers' behavior in pesticide use: insights study from smallholder and intensive agricultural farms in Bangladesh. Sci Total Environ. 2020;5(1):74–80. https://doi.org/10.1016/j.scitotenv.2020.141160.
4. Fan L, Niu H, Yang X, Qin W, Bento CP, Ritsema CJ, Geissen V. Factors affecting farmers' behavior in pesticide use: Insights from a field study in northern China. Sci Total Environ. 2015;537:360–8. https://doi.org/10.1016/j.scitotenv.2015.07.150.
5. BBS. Statistical Year Book. Bangladesh Bureau of Statistics, Statistics and Information Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. 2020.
6. BBS. Statistical Year Book. Bangladesh Bureau of Statistics, Statistics and Information Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. 2019.
7. BBS (2023). Statistical Year Book. Bangladesh Bureau of Statistics, Statistics and Information Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh.
8. Hamadani JD, Hasan MI, Baldi AJ, Hossain SJ, Shiraji S, Bhuiyan MSA, Pasricha SR. Immediate impact of stay-at-home orders to control COVID-19 transmission on socioeconomic conditions, food insecurity, mental health, and intimate partner violence in Bangladeshi women and their families: an interrupted time series. Lancet Glob Health. 2020;8(11):1380–9. https://doi.org/10.1016/S2214-109X(20)30366-1.
9. Kumar U, Werner S, Roy S, Ashraf S, Hoang LP, Datta DK, Ludwig F. Role of information in farmers' response to weather and water-related stresses in the lower Bengal Delta. Bangladesh Sustainability. 2020. https://doi.org/10.3390/su12166598.
10. Islam MR. Climate change, natural disasters and socioeconomic livelihood vulnerabilities: migration decision among the char land people in Bangladesh. Soc Indic Res. 2018;136(2):575–93. https://doi.org/10.1007/s11205-017-1563-y.
11. Roy D, Deb DS, Sheheli S. Food security in Bangladesh: insight from available literature. J Nutr Food Sec. 2019;4(1):66–75.
12. Rahman KA, Zhang D. Effects of fertilizer broadcasting on the excessive use of inorganic fertilizers and environmental sustainability. Sustainability. 2018;10(3):759. https://doi.org/10.3390/su10030759.

13. Jamal MR, Kristiansen P, Kabir MJ, Kumar L, Lobry de Bruyn L. Trajectories of cropping system intensification under changing environment in south-west coastal Bangladesh. Int J Agric Sus. 2022; 20(5):722–742. https://doi.org/10.1080/14735903.2021.1975436.
14. Giller KE, Delaune T, Silva JV. The future of farming: who will produce our food? Food Sec. 2021;13:1073–99. https://doi.org/10.1007/s12571-021-01184.
15. Rahman KM, Debnath SC. Agrochemical use, environmental and health hazards in Bangladesh. Int Res J Interdisc Multidisc Stud. 2015;1(6):75–9.
16. Islam MS, Alam MS, Uddin MN, Zabir AA, Islam MS, Haque KA, Hossain SA. Farm-level pesticides use in Patuakhali and Comilla region of Bangladesh and associated health risk. J Health Environ Res. 2016;2(4):20–6.
17. Kabir MH, Rainis R. Adoption and intensity of integrated pest management (IPM) vegetable farming in bangladesh: an approach to sustainable agricultural development. Environ Dev Sus. 2015;17(6):1413–29. https://doi.org/10.1007/s10668-014-9613-y.
18. Sharma D, Nagpal A, Pakade YB, Katnoria JK. Analytical methods for estimation of organophosphorus pesticide residues in fruits and vegetables: a review. Talanta. 2015;82(4):1077–89. https://doi.org/10.1016/j.talanta.2010.06.043.
19. Zhang M, Zeiss MR, Geng S. Agricultural pesticide use and food safety: California's model. J Integrative Agric. 2015;14(11):2340–57. https://doi.org/10.1016/S2095-3119(15)61126-1.
20. Coria J, Elgueta S. Towards safer use of pesticides in Chile. Environ Sci Poll Rese. 2022;29(16):22785–97. https://doi.org/10.1007/s11356-022-18843-6.
21. Cheng J, Wang Q, Li D, Yu J. Comparative analysis of environmental and economic performance of agricultural cooperatives and smallholder farmers for apple production in China. Agric. 2022;12(8):1281. https://doi.org/10.3390/agriculture12081281.
22. Zuma M, Arthur G, Coopoosamy R, Naidoo K. Incorporating cropping systems with eco-friendly strategies and solutions to mitigate the effects of climate change on crop production. J Agric Food Res. 2023. https://doi.org/10.1016/j.jafr.2023.100722.
23. Ram RM, Keswani C, Bisen K, Tripathi R, Singh SP, Singh HB. Biocontrol technology: eco-friendly approaches for sustainable agriculture. In: Omics Tech Bio-eng. 2018; 177–190. https://doi.org/10.1016/B978-0-12-815870-8.00010-3
24. Akter M, Fan L, Rahman MM, Geissen V, Ritsema CJ. Vegetable farmers' behaviour and knowledge related to pesticide use and related health problems: a case study from Bangladesh. J of Cleaner Produc. 2018;200:122–33. https://doi.org/10.1016/j.jclepro.2018.07.130.
25. Verma DK, Pandey AK, Mohapatra B, Srivastava S, Kumar V, Talukdar D, Asthir B. Plant growth-promoting rhizobacteria: an eco-friendly approach for sustainable agriculture and improved crop production. Micro Sus Agric Soil Health Env Protec. 2019. https://doi.org/10.1201/9781351247061-1.
26. Amoo AE, Enagbonma BJ, Ayangbenro AS, Babalola OO. Biofertilizer: an eco-friendly approach for sustainable crop production. Food Sec Safety Afr Persp. 2021. https://doi.org/10.1007/978-3-030-50672-8_32.
27. Morya GP, Kumar R. Eco-friendly pest management in sustaining crop production. Int J Pure App Biosci. 2019;7(1):177–82. https://doi.org/10.18782/2320-7051.7270.
28. Rebouh NY, Khugaev CV, Utkina AO, Isaev KV, Mohamed ES, Kucher DE. Contribution of eco-friendly agricultural practices in improving and stabilizing wheat crop yield: a review. Agronomy. 2023;13(9):2400. https://doi.org/10.3390/agronomy13092400.
29. Zhang L, Li X, Yu J, Yao X. Toward cleaner production: what drives farmers to adopt eco-friendly agricultural production? J Clean Produc. 2018;184:550–8. https://doi.org/10.1016/j.jclepro.2018.02.272.
30. Bahadur S, Verma SK, Prasad SK, Madane AJ, Maurya SP, Gaurav VV, Sihag SK. Eco-friendly weed management for sustainable crop production-a review. J Crop Weed. 2015;11(1):181–9.
31. Devarinti SR. Natural farming: eco-friendly and sustainable. Agrotech. 2016;5:147. https://doi.org/10.4172/2168-9881.1000147.
32. Santaweesuk S, Boonyakawee P, Siriwong W. Knowledge, Attitude and Practice of Pesticide Use and Serum Cholinesterase Levels among Rice Farmers in Nakhon Nayok Province, Thailand. J Health Res. 2020;34(5):379–87. https://doi.org/10.1108/JHR-09-2019-0204.
33. Sarker MA, Itohara Y. Factors influencing the extent of practice of organic farming technologies: a case study of Tangail District in Bangladesh. Am J Agric Biol Sci. 2008;3(3):584–90.
34. Izzah N, Samad A, Anua SM, Ruslan R, Hamzah NA. Knowledge, Attitude and Practice (KAP) on Pesticide Exposure among Farmers in Kota Bharu. Malaysian J Med Health Sci. 2020;4(1):23–8.
35. Sakiluzzaman M, Sarker MA, Rahman MZ, Hasan M. Determinants of rural youth's participation in commercial agriculture: a case study from Southern Bangladesh. Int J Econ Comm Manag. 2018;6(4):507–24.
36. Ogunmefun SO, Achike AI. Socioeconomic characteristics and constraints of pond fish farmers in Lagos state, Nigeria. Agric Sci Res J. 2017;7:304–17.
37. Olaoye OJ, Ashley-Dejo SS, Fakoya EO, Ikeweinwe NB, Alegbeleye WO, Ashaolu FO, Adelaja OA. Assessment of socio-economic analysis of fish farming in Oyo state, Nigeria. Glob J Sci Front Res D Agric Vet. 2013;13:44–55.
38. Ituma OE, Ukah NJ. Training skill needs of secondary school agricultural science graduate in fish farming in Ebonyi state, Nigeria. Int J Bus Manag. 2017;3:186–91.
39. Popp J, Peto K, Nagy J. Pesticide productivity and food security: a review. Agron Sust Dev. 2013;33(4):243–55. https://doi.org/10.1007/s13593-012-0105-x.
40. Odini S. Access to and use of agricultural information by small scale women farmers in support of efforts to attain food security in Vihiga County, Kenya. J Emerg Trends Econ Manag. 2014;5:80–6.
41. Solanki D, Lakhera JP, Sharma KC, Johari SK. Knowledge of beneficiary and non-beneficiary farmers regarding maize production technology. Rajasthan J Ext Edu. 2011;19:51–4.
42. Negatu B, Kromhout H, Mekonnen Y, Vermeulen R. Use of chemical pesticides in Ethiopia: a cross-sectional comparative study on knowledge, attitude and practice of farmers and farm workers in three farming systems. Ann Occu Hyg. 2016;60(5):551–66. https://doi.org/10.1093/annhyg/mew004.
43. Alam MA, Sarker MA, Hoque MJ, Khan MSH. Use of agrochemicals in pineapple farming: a case study from Madhupur forest areas of Bangladesh. J South Pacific Agric. 2020;22:10–6.
44. Islam MS, Islam MM. Evaluation of knowledge, attitude and practice (KAP) of farmers regarding organic farming. Fund Appl Agric. 2020;5(3):393–403. https://doi.org/10.5455/faa.102709.

45. Roy D, Farouque G, Rahman Z. Practice of soil and crop management technologies by the FFS farmers for maintaining sustainable agriculture. European Aca Res. 2014;2(6):8282–97.
46. Rahman M. Practice of indigenous knowledge system by the farmers in maintaining ecosystem in Bangladesh. J of Agric Sci. 2012;57(3):155–68. https://doi.org/10.2298/JAS1203155R.
47. Farouque MG, Sarker MA. Farmers' knowledge and practice of organic vegetable cultivation: a field level study of two villages from Bangladesh. J Agric Ext Rural Dev. 2018;10(5):99–107. https://doi.org/10.5897/JAERD2018.0948.
48. Mondal S, Haitook T, Simaraks. Farmers' knowledge, attitude and practice toward organic vegetable cultivation in Northeast Thailand. Kasetsart J Soc Sci. 2014; 35:158–166.
49. Nurzaman M. Knowledge, Attitude and Practice of FFS and Non-FFS Farmers in Respect of IPM. MS Thesis, Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh, Bangladesh. 2000.
50. Mukta MZN, Van Paassen A, Leeuwis C. The role of culture on pest management innovation; a comparative analysis of two farmer communities in Bangladesh. Innovation Dev. 2022. https://doi.org/10.1080/2157930X.2022.2064960.
51. Heinz KM, Parrella MP, Newman JP. Time-efficient use of yellow sticky traps in monitoring insect populations. J of Econ Entom. 1992;85(6):2263–9. https://doi.org/10.1093/jee/85.6.2263.
52. Neill SP, Lee DR. Explaining the adoption and dis-adoption of sustainable agriculture: the case of cover crops in Northern Honduras. Econ Dev Cul Change. 2001;49(4):793–820.
53. Gebru H. A review on the comparative advantage of intercropping systems. J of Bio Agric Healthc. 2015;5(9):28–38.
54. Vidogbéna F, Adégbidi ABEA, Tossou R, Assogba-Komlan F, Martin T, Ngouajio M, Zander KK. Exploring factors that shape small-scale farmers' opinions on the adoption of eco-friendly nets for vegetable production. Environ Dev Sust. 2016;18(6):1749–70. https://doi.org/10.1007/s10668-015-9717-z.
55. Pyasi R, Jaiswal A, Chaurasaia PC. Adoption of eco-friendly management practices by vegetable growers. J Plant Dev Sci. 2012;4(1):77–80.
56. Uddin MN. Farmers' Perception of sustainable agriculture: a comparative study between CARE-beneficiaries and non-beneficiaries. MS Thesis, Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh, Bangladesh. 2004.
57. Sarker MA, Halim A, Rahman MZ. Farmers' attitude towards organic homestead gardening programme of world vision. Bangladesh J Ext Edu. 2002;14(1&2):41–5.
58. Mandal G. Use of brinjal production technologies by the farmers of Kashiani upazila under Gopalganj district. PhD diss., Dept. of Agricultural Extension & Information System, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. 2015.
59. Akpan SB, Udoh EJ, Nkanta VS. Factors influencing fertilizer use intensity among small holder crop farmers in Abak Agricultural Zone in Akwa Ibom State, Nigeria. J Bio Agric Healthc. 2012;2(1):54–66.