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Title:

Awareness of the Usage of Pesticides and Fertilizers among the Paddy Farmers of Khulna District

Authors: Md. Gias Uddin Babu[1], Mamunor Rashid[1], Bayezid Khan[2,]* and Md. Shaharuf Islam[3]

[1]Mass Communication and Journalism Discipline, [2]Development Studies Discipline, and Environmental Science Discipline, Khulna University, Khulna-9208, Bangladesh

Corresponding Author: Bayezid Khan Email: bayezidkhan@ds.ku.ac.bd

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ABSTRACT

Farmer awareness is critical for the safe and effective use of agricultural inputs, particularly chemical fertilizers and pesticides. This study assesses the level of awareness among paddy farmers in Batiaghata and Dacope upazilas of Khulna District, focusing on three key dimensions: knowledge of proper application, understanding of health and environmental risks, and adoption of safe practices. A mixed-method approach was employed, combining quantitative surveys with qualitative key informant interviews (KII). Data were collected from 400 farmers using structured questionnaires, along with in-depth interviews of three agricultural extension officers and three agrochemical sellers from each upazila. Findings reveal that majority of farmers lack formal training and possess limited knowledge about safe application methods, timing, and crop-specific dosage. Approximately 86% and 90% of respondents reported receiving no training on fertilizer and pesticide usage, respectively. Awareness of the environmental and health consequences of excessive use was also low, particularly in Dacope, where frequent flooding may divert focus from long-term sustainability. Notably, 94% of farmers were unaware of banned pesticides. Batiaghata farmers exhibited significantly higher awareness levels, likely due to better access to extension services. The study also highlights the limited reach of agricultural extension programs and the dominant role of input sellers in influencing farmers' decisions. While sellers often provide advice, interviews suggest that recommendations may prioritize commercial interests over safety. This underscores the need for improved regulatory oversight and more robust, targeted extension services. The results indicate an urgent need for coordinated awareness initiatives by government bodies, NGOs, and mass media. Context-specific training and consistent information dissemination especially in vulnerable coastal areas—can enhance farmers' awareness and promote more sustainable agricultural practices.

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INTRODUCTION

In recent years, there has been a significant rise in the use of chemical pesticides and fertilizers in the agricultural practices of Bangladesh. This increase is primarily driven by the intensification of crop production to meet the growing food demands of a rising population. While pesticides and fertilizers have contributed to enhanced yields, their detrimental effects on human health and the environment are well-documented. Since the 1950s, the global adoption of pesticides has increased dramatically, with the Asia/Oceania region experiencing an annual compound growth rate of approximately 4.4% from 1993 to 1998 (Drogui and Lafrance, 2012). Despite continued crop losses caused by pests, many farmers globally still consider pesticide use economically beneficial (Popp et al., 2013).

In Bangladesh, pesticide use was relatively minimal before the 1970s but has increased markedly since then. The quantity of pesticides used rose from 2,200 metric tons in 1980–82 to 6.00 metric tons in 1992–94, corresponding with an expansion in modern rice cultivation from 20.3% to 49.0% of the total rice area (Rahman, 2005). In recent years, pesticide application per acre has surged by over 400%, and associated costs have increased by 600% (Shammi et al., 2017). Notably, more than 80% of total pesticide use is concentrated in rice fields (Shahidullah et al., 2023). This excessive use is causing environmental degradation, threatening biodiversity, and harming the health of farmers and consumers. Pesticide contamination of surface and groundwater has led to reductions in inland fisheries and ecosystem imbalances. The toxic effects of pesticides vary, impacting birds, bees, fish, and other aquatic organisms. The death of birds, including domestic poultry, has been linked to pesticide exposure in crop fields near residential areas (Parveen & Nakagoshi, 2001), and biodiversity loss among non-target organisms has been documented in pesticide-intensive areas (Van Mele et al., 2002).

Another serious concern is the presence of pesticide residues in food. Some chemical pesticides exhibit high persistence, enabling them to enter the food chain and be detected in meat and dairy products (Alam, 2000). Similarly, the overuse of chemical fertilizers contributes to environmental degradation, including eutrophication from nutrient runoff, which deteriorates water quality and ecosystem health (Micha et al., 2023).

Farmers' decisions regarding pesticide and fertilizer use are significantly influenced by their knowledge, attitudes, and perceptions. These are shaped by various factors such as education, participation in government and industry training programs, access to media, and peer interactions (Carlson and Mueller, 1987). However, the implementation of sustainable practices like Integrated Pest Management (IPM) faces challenges due to limited data on farmers' knowledge, perceptions, and practices (Van Mele et al., 2002).

Given these issues, Bangladesh may face serious consequences shortly if the unsafe and excessive use of agrochemicals continues. The impacts extend beyond agriculture to affect public health, biodiversity, livestock, and socio-economic stability. Thus, it is crucial to understand rice farmers' level of awareness regarding pesticide and fertilizer use. While extensive research has explored the economic aspects of agricultural inputs in Bangladesh (Hossain et al., 2018; Islam et al., 2020; Islam et al., 2022), there is a notable gap in studies examining farmers' awareness and practices related to pesticide and fertilizer usage.

This study aims to address that gap by exploring farmers' practices and evaluating their knowledge, attitudes, and perceptions (KAP) concerning the environmental and health impacts of pesticide and fertilizer use. The findings of this study will provide valuable insights for policymakers to develop advisory tools and programs that promote efficient and safe use of fertilizers and pesticides.

Additionally, the results may serve as a foundation for educational and motivational initiatives by local authorities and NGOs aimed at improving farmers' well-being and environmental sustainability.

MATERIALS AND METHODS

Research Design: The study was designed to investigate the level of awareness among paddy farmers regarding the uses of pesticides and fertilizers, with particular attention to their knowledge, attitudes, and practices (KAP). To achieve this, a mixed-method approach was adopted, combining both qualitative and quantitative methods to enhance the depth and reliability of findings.

The quantitative component involved a structured survey conducted among paddy farmers. Although the sample size was calculated using Yamane's (1967) formula assuming a 95% confidence level, the sampling technique was non-probability based; all 16 unions of Batiaghata and Dacope upazilas were selected purposively, and farmers were approached through convenience sampling within those unions.

The survey questionnaire was developed through an extensive review of relevant literature and informed by a pilot study involving 10 paddy farmers. This pilot helped assess the clarity, reliability, and relevance of the questions. Based on the findings, necessary modifications were made to finalize the instrument. The questionnaire was structured to capture multiple dimensions of awareness, which were operationalized into the following categories:

- **Knowledge:** Farmers' understanding of proper pesticide/fertilizer use, recommended doses, timing, and potential health/environmental effects.
- **Attitudes:** Farmers' beliefs and willingness to adopt safer or alternative practices, such as biofertilizers or integrated pest management.
- **Practices:** Actual behavior in the field, including methods of pesticide/fertilizer application, use of protective equipment and disposal habits.

In addition to the survey, the qualitative component includedthis Key Informant Interviews (KII) with agricultural extension officers and fertilizer/pesticide sellers from Batiaghata and Dacope upazilas. These interviews aimed to understand the role of key stakeholders in disseminating awareness-related information and influencing farmers' behavior. The KIIs provided contextual insights into the institutional and market-based support systems available to farmers regarding pesticide and fertilizer use.

In this study, the unit of analysis for the survey comprised paddy farmers, while for the KIIs, it included fertilizer and pesticide sellers, as well as agricultural extension officers within the study area.

Rationale of the Study: The study took place in Batiaghata and Dacope upazilas within the Khulna district of Bangladesh. The selection of this area was intentional. Specifically, there were seven unions under the Batiaghata upazila and nine unions under the Dacope upazila included in the study.

Population and Sampling: The population of this study consisted of all paddy farmers from Batiaghata and Dacope upazilas of Khulna district, totaling approximately 59,000 individuals. All fertilizer and pesticide sellers, along with agricultural extension officers from the same upazilas, were considered as the population for Key Informant Interviews (KII). Although Yamane's (1967) formula was used to determine an appropriate sample size for the farmer survey assuming a 95% confidence level and a known population size—the actual sampling approach was non-probability based, as all 16 unions of Batiaghata and Dacope were selected purposively. Within these purposively selected unions, farmers were chosen using convenience sampling due to logistical constraints and accessibility. Therefore, while a statistical formula was used for estimating a representative sample size, the implementation of sampling was purposive and non-random in nature.

$$n = \frac{N}{1 + Ne^2} \quad (Eq. 1)$$

In this context, 'n' represents the sample size, 'N' denotes the total population, and 'e' corresponds to the confidence interval (5%). Thus, the sample size was 400 respondents (25 from each of the 16 unions). The selection of sample respondents involved a combination of cluster sampling and random sampling techniques. For KII, only three sellers from each upazila were taken as a sample purposely from the fertilizers and pesticide sellers and three agricultural extension officers from each upazila were taken as a sample purposely.

Instruments of Data Collection: Three distinct questionnaires were formulated, encompassing close-ended questions, open-ended questions, and multiple-choice questions. These instruments were designed for gathering information from three specific groups: fertilizer and pesticide sellers, paddy farmers, and agricultural extension officers. Data was collected using Kobo Toolbox software. The analysis was conducted utilizing IBM SPSS 29.0 and Microsoft Excel.

Ethical Clearance: The research was conducted in full compliance with established ethical standards for studies involving human participants. Prior to data collection, ethical approval was obtained from the Research and Innovation Centre, Khulna University, under reference number KUECC-2023-09-59. The study ensured the voluntary participation of all respondents, and participants were informed of the research purpose, their right to refuse or withdraw at any time, and how the data would be used.

Informed consent was obtained verbally and/or in written form before each interview or survey was conducted. All participants were assured of the confidentiality and anonymity of their responses, and no personal identifiers were collected or disclosed at any stage of the research. The data were securely stored and used solely for academic purposes. The study maintained strict adherence to ethical principles concerning respect for persons, beneficence, and justice, ensuring that no physical, psychological, or social harm befell any participant throughout the research process.

RESULTS AND DISCUSSION

The study was conducted in two agriculturally significant upazilas of Khulna district Batiaghata and Dacope which differ notably in terms of environmental conditions. Batiaghata is located at a relatively higher elevation and is known for its intensive rice and vegetable cultivation, resulting in higher fertilizer and pesticide usage. In contrast, Dacope lies in a low-lying coastal region, frequently affected by seawater intrusion during cyclones and high tides, which leads to the mixing of agrochemicals with tidal water and impacts aquatic biodiversity. These environmental contrasts offer a valuable context for comparing farmers' practices and awareness regarding pesticide and fertilizer use. A comparative analysis between the two regions is presented in subsequent sections.

Demographic and Socioeconomic Profile: This section delves into the analysis, concentrating on the socioeconomic and demographic status of farmers residing in the study areas. Several variables, including age, gender, education, and farming experience, have been thoughtfully examined to portray an accurate depiction of the living conditions in these areas.

Table 1. *Demographic status of the respondents*

Variable	Variable	Respondent	Percentage (%)
Gender	Male	376	94
	Female	24	6
Age	18-35	128	32
	36-50	152	38
	Above 50	120	30

Table 1 shows that 32% of the respondents belong to the age limit of 18 to 35. The largest portion of the respondents, 38%, were under 36-50 years of age. However, only 30% of the respondents were aged 50 and above. According to this table most of the respondents, 94% were male and only 6% of the respondents were female. After analyzing data from the samples, it has been seen that most of the 40% of respondents studied up to class six to ten according to Fig. 1. Only 2% of respondents said that they studied class eleven to twelve. From this figure, it is clear that most of the respondents don't have higher education. Besides, 12% of respondents haven't any academic education. In a study conducted by Mokhele (2011), it was discovered that farmworkers with lower levels of education face a greater health risk, particularly when there is a lack of training and education regarding the use of pesticides.

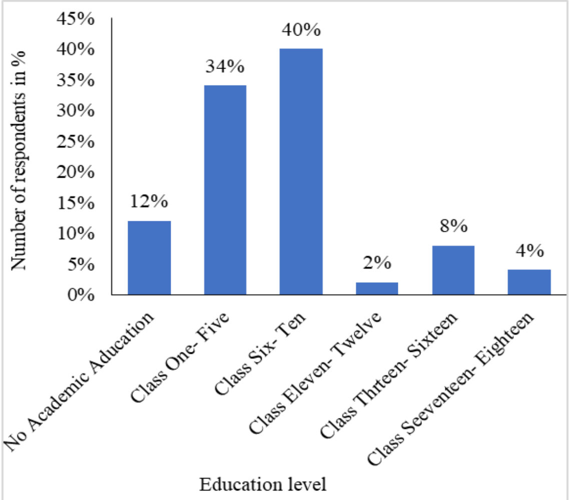

Figure 1. The education level of the respondents

Table 2. *Education Level vs. Knowledge of Application Rate*

Education Level	Know Rate	Don't Know
No education	20	28
Class 6–10	100	60
Class 11–12	7	1
Other/Unknown	81	103

The table examines the relationship between farmers' education levels and their knowledge of fertilizer/pesticide application rates. Among those with no education, 20 knew the rate, while 28 did not. Farmers with Class 6–10 education showed higher awareness (100 knew vs. 60 unaware). Only a small portion of Class 11–12 respondents lacked knowledge (7 knew, 1 did not). The "Other/Unknown" group had 81 aware and 103 unaware. A chi-square test confirmed a statistically significant association ($\chi^2 = 17.85$, $p = 0.00047$), indicating that education level strongly influences knowledge of proper application rates. Higher education correlates with greater awareness.

Table 3. Farming experience of the respondents

Years	Respondents	Percentage (%)
1-10	120	30
11-20	144	36
21-30	56	14
31-40	40	10
41-50	24	6

Table 3 illustrates that 30 % of respondents have been involved in agricultural work for 1 to 10 years. On the other hand, 36% of respondents have been involved for 11 to 20 years. So, most of the respondents have been involved with agriculture for 11 to 20 years. Besides 14% have been involved with this for 21 to 30 years and 10 % of respondents have been involved with this for 31 to 40 years. Only 6 % of respondents were involved with 41 to 50 years. Finally, 4% of respondents have been involved with this above 50 years.

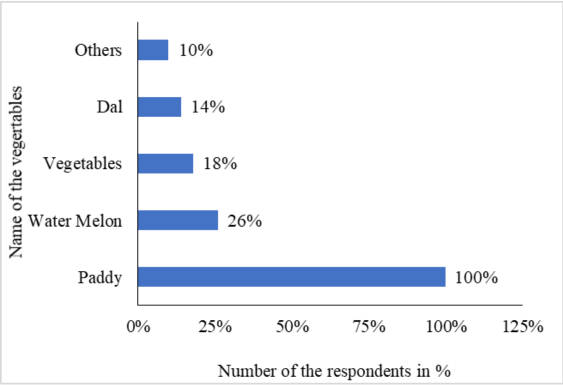

Figure 2. Varieties of crops cultivated in the study area.

A large portion of respondents, about 56% said that they cultivate a single crop every year. 44% of the respondents said that they cultivate two crops every year because they live in comparatively higher land than the others which is favorable for cultivation. When asked about the crops they cultivate (Fig. 2), 100% of respondents said that they cultivate paddy every year. On the other hand, only 14% of respondents cultivate pulses. So, most of the farmers cultivate paddy. Besides, 26% of respondents cultivate watermelon and 18% of respondents cultivate vegetables in their land.

Table 4. Types of fertilizers used by the respondents

Types of fertilizer uses	Respondent	%
Urea	368	92
Triple Super Phosphate (TSP)	352	8
Muriate of Potash (MoP)	104	26
Magnesium Sulphate	48	12
Zinc Sulphate	128	32
Sulphate of Potash (SoP)	24	6
Gypsum	216	54
Compost	8	2
Others	136	34

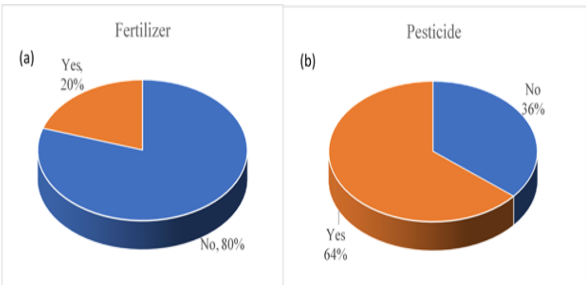

Figure 3. Use of personal protective equipment while handling a) fertilizers, and b) pesticides

The majority of the respondents, about 92% use urea in their land. 88% of the respondents apply triple super phosphate to their land. 26% of the respondents use the Muriate of Potash in their land. Magnesium sulfate is utilized by 12% of the respondents, whereas 32% of respondents apply zinc sulfate to their land. Only 6% of the respondents apply sulfate of potash. Among the respondents, 54% incorporate gypsum into their land management practices. Only 2% of the respondents use compost. Finally, 34% of the respondents use other fertilizers on their land. So, it is evident that the major fertilizers used in the study areas are urea and triple superphosphate (Table 4).

Fig. 3a indicates that 80% of the respondents don't use personal protective equipment during fertilizer application on their fields while only 20% of the respondents use personal protective equipment during fertilizer application in their agricultural field. Contrary to this Fig. 3b indicates that only 36% of the respondents don't use personal protective equipment during pesticide application in their fields and about 64% of the respondents do. So, although they do not perceive handling fertilizers as dangerous indicated by their lack of protection usages, they do consider handling pesticides a much more dangerous endeavor. This is a common trope among the farmers in the Indian subcontinent as evidenced by the study done by Shetty (2004).

Fertilizers and Pesticides Use Practices: A large portion of respondents, about 94 % use fertilizer on their land (Fig. 3a). So, the maximum number of respondents use fertilizer on their land. Only 6% of respondents do not use fertilizers on their land. Similarly, about 95% of the respondents also use pesticides on their land (Fig. 3b). Only 5% of respondents do not use pesticides on their land.

Table 5. *Gender vs. PPE Use (Pesticide)*

Gender	Use PPE	Don't Use PPE
Male	240	136
Female	15	9

Chi-square test indicates no significant association between gender and PPE use (χ^2 = 0.00, p = 1.00).

Awareness and Knowledge Analysis: The range of knowledge about the proper usage of fertilizers and pesticides by the respondents is given in Table 6. The respondents were asked about their knowledge of fertilizer and pesticide application rates. Almost half of them responded in the affirmative (52% for fertilizer and 58% for pesticide) and the other half replied in the negative. 48% of them also replied that they know the crop-wise application rate of the fertilizers. However, there is a lack of information about application methods, with 74% and 64% of the respondents stating they are unaware of the proper application method for fertilizer and pesticide, respectively. The same is true for application timing, as 62% and 68% of respondents do not know when the appropriate time is to apply fertilizers and pesticides respectively. This lack of knowledge could be attributed to the lack of proper training on fertilizer and pesticide usage as 86% and 90% of the respondents said that they did not receive any training.

Table 6. *Knowledge about the proper usage of fertilizers and pesticides.*

Knowledge about fertilizers and pesticide usage	**Fertilizer**		**Pesticide**	
	Yes (%)	No (%)	Yes (%)	No (%)
Application rate	52	48	58	42
Application method	26	74	36	64
Application timing	38	62	32	68
Crop-wise application	48	52	-	-
Training on application	14	86	10	90

Table 7. *Training vs. Knowledge of Application Method*

Training	**Know Method**	**Don't Know**
Trained	30	26
Not Trained	74	270

Chi-square test shows a strong association between training received and knowledge of proper application methods ($\chi^2 = 24.09$, $p < 0.000001$).

According to Fig. 5, 82% of the respondents think that fertilizer increases crop production. By using fertilizer 28% of the respondents think it increases soil fertility and 2% of respondents think that fertilizer controls the pest.

A large portion of respondents about 76% know fertilizer and about 88 % know about pesticides but 46% and 52% of the respondents don't think that using excess fertilizer and pesticide respectively to produce food grains is significantly harmful to human health at all. Among the 44% who believe that fertilizers pose health issues, the majority, with 54% and 40%, respectively, think that it causes serious harm to human and animal health. Similarly, among the 48% of respondents who think that pesticide-produced food causes harm, 48% and 36% of them think that it may cause serious harm to human and animal health. The rest of the data is given in Table 7.

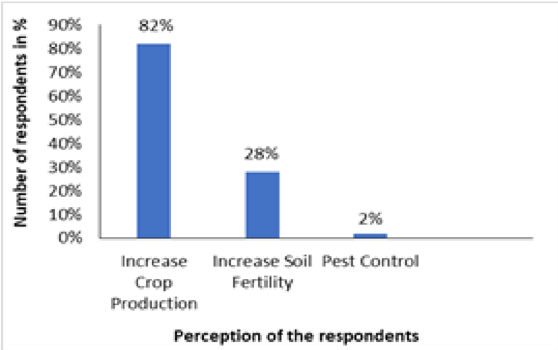

Figure 4. Perception of the respondents about the beneficial effects of fertilizers

Mokhele (2011) highlighted that, despite farmworkers being aware of the detrimental effects of pesticides, they sometimes struggled to translate this awareness into safety practices due to a lack of knowledge about the adverse effects. Parveen and Nakagoshi (2001) similarly noted that while most farmers recognize pesticides as poisonous chemicals, they may not be aware that excessive use can lead to pest resistance and improper handling may pose a health hazard.

Table 8. *Harmful effects of food grains produced with excess fertilizers and pesticides on health*

Substance	Affected group	Intensity of the harm (%)			
		None	Slight	Moderate	Serious
Fertilizers	Human health	6	12	28	54
	Cattle and other animal health	14	10	36	40
Pesticides	Human health	2	6	44	48
	Cattle and other animal health	10	8	46	36

Table 9. *Role of Excessive Fertilizers and Pesticides on the Environment*

Substance	**Affected area**	**Role of excess usages (%)**		
		None	Slight	Significant
Fertilizers	Water pollution of water reservoirs	22	60	18
	Extinction of beneficial plants, insects, and animals	34	50	16
Pesticides	Water pollution of water reservoirs	22	54	24
	Extinction of beneficial plants, insects, and animals	24	56	20

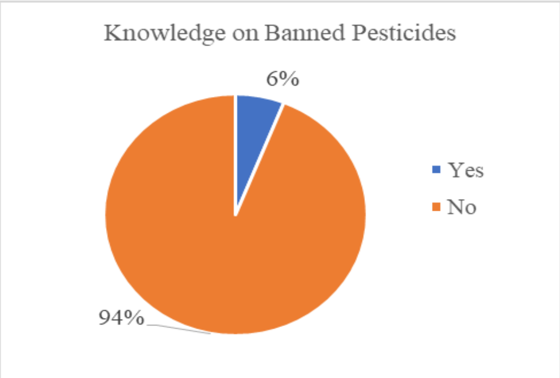

Figure 5. Knowledge of the banned pesticides among the respondents

The excessive use of pesticides has led to a reduction in the biodiversity of non-target organisms in the identified hot spots (Shetty, 2004). Table 9 shows that the majority of the respondents, 50% and 56% think that excess application of fertilizers and pesticides respectfully have only played a slight role in the extinction of beneficial insects, plants, and animals and 34% and 24% of the respondents mentioned that excess application of fertilizers and pesticides respectfully have played no role in the extinction of beneficial insects, plants and animals.

Fig. 6 identifies that a staggering 94% of the respondents don't even know about the name of any banned pesticide. So, the majority of the respondents don't have any knowledge about the banned pesticides. Only 6% of respondents know about the names of some banned pesticides which is very concerning.

Table 10. *Location (Batiaghata vs. Dacope) vs. Knowledge of Banned Pesticides*

Location	**Know**	**Don't Know**
Batiaghata	18	182
Dacope	6	194

Chi-square test shows significant association between location and banned pesticide knowledge ($\chi^2 = 5.36$, $p = 0.0206$); Batiaghata respondents were more informed.

A significant majority of the respondents, approximately 74%, expressed a lack of knowledge regarding the benefits of organic fertilizers, while only 26% indicated that they were aware of them (Fig. 7a). Moreover, 90% of respondents don't have any knowledge on making/producing organic fertilizers themselves (Fig. 7b). Only 10% of respondents replied that they know about how to make organic fertilizers.

According to Rahman (2003), farmers' awareness of the harmful effects of pesticides is not highly pronounced, as they perceive that the beneficial effects outweigh any potential harm. Alam (2000) provided a comprehensive explanation, pointing out that the primary reason for the limited awareness among farmers regarding pesticides, chemical fertilizers, and biopesticides is the lack of promotion of biofertilizers by agricultural extension workers.

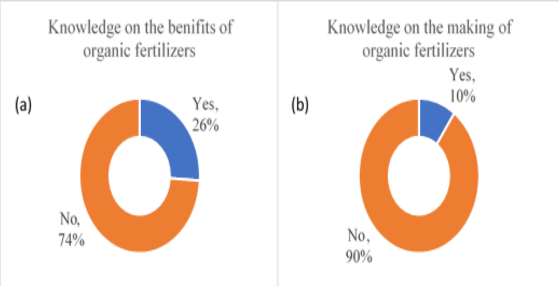

Figure 6. Knowledge about the organic fertilizers. a) benefits of organic fertilizers, b) making of the organic fertilizers

Comparative Analysis- Batiaghata vs. Dacope: The comparative analysis between Batiaghata and Dacope reveals notable spatial disparities in farmers' awareness and practices related to pesticide and fertilizer use. Batiaghata farmers exhibited significantly higher awareness of banned pesticides compared to their counterparts in Dacope (18 vs. 6 respondents, $\chi^2 = 5.36$, $p = 0.0206$), likely due to better access to agricultural extension services and more stable environmental conditions. In contrast, Dacope, frequently affected by tidal flooding and salinity intrusion, faces challenges in maintaining consistent training and outreach programs. This environmental vulnerability may also shift local priorities toward immediate yield recovery rather than long-term sustainability.

Although overall knowledge of proper application methods was low, trained farmers who were more common in Batiaghata demonstrated significantly better understanding ($\chi^2 = 24.09$, $p < 0.000001$). The use of personal protective equipment (PPE) was also more frequent among Batiaghata farmers, particularly during pesticide application, reflecting higher perceived risk and possibly greater market access to safety gear. These findings are supported by Shetty (2004), who emphasized that risk perception and resource access strongly influence PPE use in South Asia.

Moreover, Batiaghata respondents showed comparatively greater concern for the environmental impacts of excessive agrochemical use, whereas Dacope farmers, despite living in ecologically sensitive zones, were less likely to recognize the severity of such effects. This gap between ecological vulnerability and awareness reflects trends observed by Parveen and Nakagoshi (2001) and underscores the need for location-specific outreach.

Awareness of organic fertilizers and sustainable alternatives was also higher in Batiaghata. This disparity further highlights the uneven dissemination of integrated pest management (IPM) practices and sustainable input strategies, as noted by Wyckhuys and O’Neil (2007). In summary, Batiaghata demonstrates more favorable indicators of safe and informed agrochemical use, whereas Dacope requires targeted intervention to address both knowledge gaps and environmental risks.

Insights from Key Informant Interviews: All the interviewed agricultural extension officers said that due to various limitations of the Agricultural Extension Department, they are not able to bring all the farmers under their various training on organic fertilizers and integrated pest management systems. Consequently, numerous farmers lack awareness regarding the advantages of organic fertilizers and integrated pest management systems. That is why they relied on insecticides to manage pest outbreaks. Wyckhuys and O’Neil (2007)asserted that farmers who depend on insecticides to address pest outbreaks tend to have less knowledge about biological control and alternative pesticides, aligning with the outcomes of the present research.

According to prior research conducted by Gandhi and Patel (1997), farmers tend to apply higher quantities of pesticides than the recommended doses provided by Block Supervisors. This behavior is attributed to factors such as ignorance, lack of training, experience, and awareness. Additionally, traders, while selling more pesticides, often advise farmers to acquire larger quantities. The in-depth interviews with agricultural extension officers in the current study revealed that fertilizer and pesticide sellers frequently recommend farmers to apply more fertilizers and pesticides than the prescribed amount, primarily for their business gains. Moreover, the quantities suggested by sellers exceed the recommendations provided by agricultural extension officers.

All the interviewed agricultural extension officers claimed that they advise farmers to follow integrated pest management systems and organic fertilizers instead of using pesticides and chemical fertilizers. However, due to the proximity of the sellers' outlets to the farmers, they tend to seek advice from the sellers more frequently than from agricultural extension officers. Besides fertilizer and pesticide sellers also said that most of the farmers depend on them for information and advice rather than anyone else.

Sabur and Molla (2001) showed that total as well as per hectare use of all types of pesticides was found to increase from 1982-1983. In an in-depth interview, sellers claim that pests are adapting to pesticides over time. As a result, the amount of pesticide used every year on the same amount of land has to be increased compared to before. Besides, by cultivating different types of crops on the same land throughout the year, the fertility of the land is decreasing day by day. As a result, to maintain the yield, the amount of fertilizer has to be increased every year. Sellers think that selling excess pesticides and fertilizers is largely responsible for these issues.

CONCLUSION

Fertilizers and pesticides remain integral to modern agricultural practices, particularly in high-yield systems like those found in Bangladesh. However, this study reveals that a substantial portion of paddy farmers continue to use these inputs excessively, largely due to limited awareness of proper application methods and the potential environmental and health consequences. The findings indicate that most farmers lack adequate knowledge of application rates, timing, and crop-specific guidelines, with over 85% having never received formal training. This knowledge gap has led many to rely heavily on fertilizer and pesticide sellers for advice sources that, according to key informant interviews, often recommend excessive use for commercial gain rather than providing scientifically grounded guidance.

Agricultural extension departments, while formally tasked with farmer training, face structural and resource limitations that hinder their outreach capacity, particularly in ecologically vulnerable areas such as Dacope. The comparative analysis further highlights that farmers in Batiaghata exhibit significantly higher levels of awareness and safer practices, underscoring the role of geographic and institutional access in shaping farmer behavior. Conversely, Dacope farmers despite residing in a region where agrochemical runoff poses acute ecological risks demonstrated lower awareness levels, limited training exposure, and weaker engagement with sustainable practices like organic fertilization.

The role of mass media, NGOs, and extension services has also been insufficient in consistently delivering in-depth, targeted, and contextually relevant information on safe agrochemical use. Respondents frequently cited the lack of regular, practical, and locally tailored content as a major barrier to improving awareness.

To address these challenges, a coordinated approach is needed. Mass media should take a proactive role in disseminating evidence-based, locally relevant programming on fertilizer and pesticide management. Agricultural extension services must expand their training reach through structured and repeated awareness campaigns, especially in coastal and underserved areas. Moreover, NGOs and policymakers should work collaboratively to implement community-based interventions, enforce ethical conduct among agrochemical retailers, and promote integrated pest and nutrient management systems.

Ultimately, ensuring farmers have access to accurate information, quality advisory services, and sustainable alternatives is essential not only for improving agricultural productivity but also for safeguarding public health, biodiversity, and long-term environmental sustainability.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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