Review Article

INTERRELATIONSHIP OF FARMER'S KNOWLEDGE AND ATTITUDE IN FERTILIZER APPLICATION ON BORO RICE PRODUCTION IN SUNAMGANJ DISTRICT OF BANGLADESH: A SYSTEMATIC LITERATURE REVIEW AND KEY INDICATORS FOR FUTURE RESEARCH

ABSTRACT

For maintaining of sustainable agriculture and production of maximum crop yield it is required to add proper amount of fertilizer on time through observation, investigation and elevation of the interrelationship of farmer's knowledge and attitude toward fertilizer application. The use of fertilizer is affected by farmers' knowledge and attitude as they are interrelated. In order to influence the future fertilizer decision of farmers several factors and effects are analysed in this study. The purpose of the study is to evaluate the interrelationship of farmer's knowledge and attitude regarding fertilizer application in Boro rice production as it is the most contributing crop in Bangladesh. Fertilizer performs major role in Boro Rice production. In haor areas farmer chiefly cultivate Boro rice. Proper knowledge and improved attitude have significant contribution to increase Boro Rice production. This review highlights the various factors that increase knowledge and attitude toward fertilizer application which lead to improved social and economic condition of farmers. Finally, the review concludes with recommendation for policy makers, civil society organization, extension agents and researcher.

Keywords: Fertilizer application, knowledge, attitude, Boro rice, Systematic Review

1. Introduction

Agriculture is the backbone of Bangladesh (BBS, 2011; Mondal, 2011). About 14% of the nation's GDP comes from this industry, provides 46% of the total employment (BBS, 2016). With a cropping intensity of 192%, crop cultivation is the main agricultural activity in Bangladesh. In terms of value addition, rice is the main crop, making up over 60% of the overall value of crop agriculture. Rice makes for more than 90% of all cereal

output and is grown on about 75% of all cultivated land (Assaduzzaman et al., 2010). is the fourth largest producer of rice in the world (Awal and Siddique, 2011). This crop is very important in Bangladesh for several reasons. While the traditional consumption pattern has been considerably varied by the invasion of western dietary habits, rice is still a staple meal in Bangladesh (Islam, 2012). It plays a big role in the social and cultural identity of the country. The ubiquitous expression "Macche Bhat-e Bangali" embodies the essence of Bangladeshi nationality, meaning "Fish and rice is what defines a Bengali." It is an essential component of celebrations like "Paus Praban," "Durgapuja," and "Annaprashan," where eating rice is seen as a religious and cultural emblem (Islam, 2012). According to Ahmed (2004), rice has been the most important commodity for Bangladesh's economy. In Bangladesh, like in many other countries, "rice security" is seen as "food security" (Brolley, 2015). Because political instability in the country is mostly caused by the insecurity of rice, rice security is not just an economic concern but also a social and political issue (Nath, 2015).

Bangladesh previously referred as the “Bottomless Basket,” has now been redefined as the “Full of Food Basket” (Kabir et al., 2015). After the country gained its independence, rice production increased threefold; it went from producing about 11 million tons of milled rice in 1971–1972 to approximately 35 million tons in 2014–2015 (AIS, 2016). In this specific crop subsector, the country has attained self-sufficiency and has even engaged in the export market on occasion (BER, 2015). Because of the growing population, there will likely be a greater need for rice in the future. According to Kabir et al. (2015), by 2050, the current population of 162.2 million is expected to increase to 215.4 million. The amount of rice needed will be significantly impacted by this demographic transition; 44.59 million tons (as milled rice) is the expected amount. The need for manufacturing is predicted to rise by 27% by 2050 as compared to 2014.

Rice (Oryza sativa L.) is grown in more than 100 countries across 160 million hectares of land, making up 11% of the world’s agricultural area. It produces over 700 million tons of rice which feeds over 50% of people worldwide (IRRI 2010). Rice is Asia’s main crop where 90% of the world's rice is grown and consumed (Sarker et al., 2013).

Rice occupies more than three-fourth of the total cropped area and more than 90% of the total cereal area. In Bangladesh, Boro rice has gain popularity as a potential crop

to reach the goal of rice self-sufficiency. Boro rice is recognized as the leading cereal crop in Bangladesh, crucial for farmers' livelihoods and national food supply(Hossain et al. 2024).The crop's cultivation is particularly vital in the North-West region, where it significantly contributes to agricultural development(Mainuddin et al. 2021).Research indicates that Boro rice varieties, such as Binadhan-24, exhibit high yield potential, with recorded yields reaching up to 7.03 tons per hectare(Hossain et al. 2024).The adaptability of Boro rice to different environments enhances its production stability, making it a reliable choice for farmers(Islam et al. 2024).While Boro rice is paramount for Bangladesh's agricultural landscape, challenges such as soil salinity and credit constraints can impact its cultivation efficiency and sustainability (PAUL et al. 2024)(Rabbany et al. 2021). Addressing these issues is crucial for maintaining the crop's significance in the future. Boro rice is produced during the period from November to April and gives a much better yield than the rice that is produced during the monsoon, namely aman, rice or the pre monsoon, aus rice. This could be as a result of the fact that Boro rice is grown mostly under irrigated conditions which favour water and nutrient control (BRRI, 2020). In the past three decades, the Bangladesh government has introduced a series of policies and programs to enhance rice production especially Boro rice, to meet the food security and reduce poverty in the rural areas. These policies have intended and emphasized on improvement in agricultural output which involves capital expenditure on irrigation facilities, subsidies on fertilizers and popularizing of high yielding rice varieties (Ahmed et.al., 2013).

However, most of the farmers do not possess adequate knowledge about the methods and proper amount of balanced Fertilizers play an important role in increasing food production. Nowadays, fertilizer use is characterized by excessive N application, moderate P use, and neglecting K and micro-nutrients consequently, thus nutrient imbalance occurs in crop plants. Microorganisms can be harmful to human health if consumed in higher quantities (Carmichael, 2001).

Knowledge and proper attitude of the farmers in fertilizer application are important factors for increased agricultural production. fertilization. Attitudes are influenced by the past usage of fertilizer and perceived benefits or risks of fertilizer use and perceived credibility of information provided by extension agents and other sources

(Meijer et al., 2015). Analysis of different factors can help improve the ability of an individual to do his or her job better.

The major elements of fertilizer used in Boro rice cultivation in Bangladesh are nitrogen (N), phosphorus (P) and potassium (K) which play an important role in plants growth, photosynthesis, health and quality of the produce as stated by Ali et al., (2015). Nitrogen is of significance to rice crops because it improves on the vegetative growth and enhances the grain yield. Nonetheless, nitrogen fertilizers like the urea type are highly susceptible to loss through volatilization, leaching and runoff hence its low efficiency and contaminates the environment (Khatun et al., 2020). Phosphorus, for example plays an important role in root formation and energy transfer in plants while potassium works on water absorption and resistance to diseases. It is imperative that these macronutrients be applied in the correct proportions in order to obtain good yields and at the same time preserve the soil. However, fertilizers are extremely important for the production of Boro rice, many farmers in Bangladesh find it hard to apply the inputs properly. Some of the challenges include inadequate information on appropriate type and quantities of fertilizers to be applied, and time when such fertilizer application should be carried out (Lim et al., 2013). Some farmers continue using conventional techniques, while others use the information provided by local traders which could be misleading concerning the exact nutrients needed by the plants. This leads to the over application or under application of the nutrient salts that can be very detrimental to crop yield and the environment (Islam et al., 2018).

As modern farming practices fertilizer application requires that farmers have adequate knowledge and practice which can be enriched by extension services (Qamar, 2005; Agholor et al., 2013). In Bangladesh the Department of Agricultural Extension (DAE) has been assigned with the task of extending services to the farmers with emphasis on dissemination of new technology and enhancement of agricultural production. The DAE operates hand in hand with the research institutions including the BRRI and the Bangladesh Agricultural Research Institute (BARI) for delivering information regarding new developed auspicious crop varieties, use of appropriate amount of fertilizers and controlling over pest problems (Ahmed et al., 2013). Some of the current issues affecting agricultural extension services in Bangladesh include low human capital in terms of extension agents and their ability to dispense information and knowledge to

divers areas including the Sunamganj District (Islam et al., 2018). Some of the constraints that hinder the farmers in these areas from gaining access to extension services are: inadequate physical access, low literacy levels and inability to attend training sessions due to lack of means. Unfortunately, the datasets developed at universities and other research institutions and institutions are often different from those that farmers have. This gap may limit the application of optimal practices in the use of fertilizers and other mechanisms in agriculture to low impact extension services in increasing agricultural productivity and sustainability of crops.

There has been awareness of the need for enhancing the quality and availability of the agricultural extension service throughout the country and most especially for the small-scale farmers who are very vulnerable and encounter many problems in the process of adopting change. It has given rise to the creation of extension practices that include farmer field schools, the use of participatory techniques and information and communication technology (ICT) in the transmission of information to farmers (Islam et al., 2018). These approaches are designed to exacerbate farmers' participation in the learning-teaching processes to equip them with necessary knowledge for decision making with regard to the uptake and application of fertilizer and other farming practices.

2. Farmers' Knowledge and Attitudes toward Fertilizer Application

The covert category of cultural elements which is understandable by interpreting verbal and non-verbal language is known as knowledge. Therefore, knowledge is explained as "sum of relationships of meanings that people generate in minds from available information, their experience, their feelings and their ideas''(Ferreira,2002).

Attitude is the way of manner, disposition, expressing feelings and position about an individual or thing, tendency or orientation, especially related to their mental state. From the psychological point of view, attitude is a psychological construct, a mental and emotional entity that inherits in or characterizes a person (Richard, 2017).

Farmers' perceptions include their knowledge, attitude, awareness about the type of fertilizer to use, quantity to apply, time of application and effects of applying the

fertilizer on the yields and the environment (Lim et al., 2013). And specifically for Boro rice production the knowledge about N, P and K fertilizers is of humongous significance as these three nutrients determine the yield of the crop in large extent (Ali et al., 2015). But knowing the type of fertilizer to be used, is not enough to warrant the correct use of the fertilizer. On this regard, attitudes towards fertilizers and willingness to change also help in defining farmers' behaviour and decisions. These include past experiences that people have had, perceived benefits from adopting the new practice, perceived risks associated with the change, social norms and the level of trust the people have on the extension agents and other sources of information as described by Meijer et al. (2015). For instance, farmers who have had positive content effects with fertilizers for, increased yields and enhanced income, will have positive attitude towards the use of fertilizers. On the other side, farmers that have faced issues such as poor yields and adverse effects on the environment because of poor application of fertilizers may be more skeptical about new techniques. However, other factors such as social beliefs and norms as well as peers' influence also determine farmers' perceptions to fertilizers. There may be a tendency by farmer to emulate their close neighbours since they are actually observing them to have changed their behaviour in applying new fertilizer practices.

The purpose of the following section is to review the previous studies conducted by different researchers related to the present study. The study was mainly concerned with the factors influencing the relationship between fertilizer application with attitude and knowledge. The focus is to obtain the deeper understanding of the concept and its relevance for the production of Boro rice. Thus, an attempt was made in this chapter to review some interlinked literatures on this aspect from home and abroad. The researcher, therefore, made an effort to review researcher directly or indirectly associate to the present study for collecting inevitable information through seeking relevant studies, journals, periodicals, bulletins, website etc. An attempt is made here to put together some of the closely related research findings in the area. However, the available literatures in connection with this study are briefly described below:

2.1. Effect of fertilizers on Boro rice production in Bangladesh

Islam & Muttaleb(2016) conducted a study on “Effect of potassium fertilization on yield and potassium nutrition of Boro rice in a wetland ecosystem of Bangladesh” and reported that potassium fertilization is crucial for improving the yield of Boro rice in K-deficient soils of the haor area. The soil in the experimental area was strongly acidic with low organic matter and exchangeable potassium levels. Increasing K fertilizer application rates improved K balance, prevent soil depletion, reduced grain sterility, increased both grain and straw yields. While K enhances overall nutrient uptake, it may reduce the efficiency of nutrient use at excessive levels. An optimal K dose greater than 100 kg/ha was suggested to prevent K depletion in the soil.

Salwa et.al.(2020) conducted a study on “EFFECTS OF FERTILIZERS ON GROWTH AND YIELD OF BORO RICE VARIETIES AT DEKAR HAOR IN SUNAMGANJ DISTRICTS” and evaluated the effects of balanced fertilizer application on growth and yield of different Boro rice varieties, particularly focusing on BRRI dhan58, which matures earlier and is more resilient to flood prone areas. They reported that with balanced fertilizer application the number of tillers per hill was highest in BRRI dhan28 and BRRI dhan29. Further, BRRI dhan 28 showed the tallest plant height, lower BCR (1.15) and BRRI dhan29 produced the highest grain yield (7.66 t ha-1), straw yield (9.23 t ha-1) and highest net return (Tk. 35,480) with a benefit-cost ratio (BCR) of (1.45). The study found that the application of recommended fertilizers significantly increased total spikelets and grains per panicle, contributing to higher overall yields. Post-harvest soil analysis showed improved nutrient status, with increased organic matter and higher levels of nitrogen, phosphorus, potassium, and sulfur in soils treated with balanced fertilizers.

Basak et.al.(2015) in their study stated that integrating organic fertilisers alongside chemical options are important to enrich soil quality and maintain agricultural productivity. Chemical fertilisers, particularly nitrogen, phosphorus, and potassium contributing approximately 40% to overall crop yields. High cropping intensity and rice yields correlate with increased fertiliser application, underscoring the dependency on chemical inputs for food production. Projections exhibit a growing demand for fertilisers, specially urea, TSP, and MP to support rice production through 2050, driven

by the increasing contribution of Boro rice. The researcher also stated that maintaining current yield levels will require significant fertiliser inputs, careful planning and resource management. Organic fertilisers, such as bio slurry, can significantly enhance soil fertility and reduce reliance on chemical inputs, potentially covering a substantial portion of fertiliser demand.

Galib et.al.(2022) conducted a study on “Organic and Inorganic Fertilizer Management for Boro Rice Cultivation in a Single Boro Cropping Area” and reported that the combination of poultry manure with inorganic fertilizers (PM × T4) significantly improved growth traits, yield components, and nutrient concentrations in BRRI dhan89 compared to other treatments. Nutrient uptake was highest in treatments involving poultry manure, indicating its effectiveness in enhancing nutrient availability and plant growth. The study found that practicing a combined organic and inorganic fertilizer approach can enhance Boro rice production in Bangladesh.

Mahmud et.al.(2016) stated that the integration of organic and inorganic fertilizers boosts grain yield and improve overall biomass production. Further combining organic and inorganic fertilizers can optimize nutrient uptake and improve rice yields. They also reported that application of vermicompost and NPKS fertilizers significantly increased plant height (95.78 cm), flag leaf length (8.3 t ha-1), panicle length, filled grain per panicle, straw yield, enhances vegetative growth and maximized the number of effective tillers, exhibiting improved nutrient absorption. Non-effective tiller counts were lowest in treatments with higher nutrient applications, indicated the importance of balanced fertilization.

Miah et.al.(2016) stated that deep placement not only improved yields but also reduced fertilizer usage by 30-45%, enhancing nitrogen use efficiency. Further the researcher reported that deep placement minimizes nitrogen losses through volatilization and runoff, leading to more stable and available nitrogen for plant uptake. The economic analysis indicated that deep placement practices yield higher net returns for farmers. Deep placement of NPK fertilizer at specified rates can significantly boost rice yields and farm income in flood-prone areas of southern Bangladesh.

Salam et.al.(2021) conducted a study on “Do organic fertilizer impact on yield and efficiency of rice farms? Empirical evidence from Bangladesh” and reported that organic fertilizer users get higher rice yields and require less labour and other inputs. They stated that the organic fertilizers are capable to enhance soil health and productivity while reducing reliance on chemical fertilizers. Organic fertilizer application is related with improved soil condition, leading to better yields and reduced dependency on chemical fertilizers.

Shohel et.al.(2016) conducted a study on “integrated use of organic and inorganic fertilizers on the growth and yield of Boro rice (cv. BRRI dhan 29)” and reported that combining all three organic manures (cow dung, poultry manure water hyacinth) with fertilizers resulted in the highest panicle length, effective tillers per hill, straw yield, grain yield which indicated increased Boro rice production. The combined application of organic and inorganic fertilizers significantly enhances rice yield components compared to the use of chemical fertilizers alone.

Islam et.al conducted a study on “Effect of integrated use of manure and fertilizer on the yield and yield components of Boro rice (cv. BRRI dhan55)” and evaluated the combined use of organic and inorganic fertilizers to maximize the yield of the salinity-tolerant BRRI dhan55 variety, thereby contributing to food self-sufficiency in Bangladesh. The highest plant height and tiller count were observed with the recommended dose of USG (2.7g). Grain yield peaked at 4.90 t ha -1 with 2.7g USG, supported by favourable crop characteristics such as effective tillers and grains per panicle. The integrated use of USG at 2.7g per four hills, along with other fertilizers, is optimal for maximizing the yield of BRRI dhan55.

2.2. Factors affecting towards fertilizer application in Rice Production

Bagum et.al.(2021) in their study stated that there is a significant gap between the actual and potential rice production in Bangladesh due to imbalanced fertilizers application by farmers. They identified various factors influencing farmers' work performance, including knowledge, attitude, ease of use of technology, and motivation, which are crucial for enhancing rice production. The researcher revealed that knowledge, motivation, and ease of use of technology significantly influence farmers'

work performance, with motivation being the strongest predictor. The regression model explained 56.1% of the variance in farmers' work performance which reported that enhancing farmers' motivation and knowledge is essential for improving their work performance in fertilizer application, ultimately lead to higher rice yields.

Again, Bagum et.al.(2019) conducted a study on “Determinant Factors of Farmers' Performance Regarding Fertilizer Application: An Overview from Bangladesh” where they have identified unbalanced fertilizer use and lack of knowledge among farmers as key factors contributing to nutrient deficiencies and reduced rice yields. The researcher stated that positive relationships were found between farmers' performance and characteristics such as age, household size, educational level and training received. Interestingly, annual income did not significantly influence performance, suggesting that knowledge and attitudes may play a more critical role in effective fertilizer application. They also found that 45.3% of the variance in farmers' performance could be explained by selected characteristics with knowledge being the most significant predictor. Other contributing factors included age, training received, and extension media contact, while annual income and educational level were not statistically significant.

Li & Wu (2021) analysed various issues and factors about the insufficient application of organic fertilizers among rice farmers and reported about the need to understand the motivations behind farmers' behaviours, particularly the influence of social norms, value perception, and education level on the application of organic fertilizers. Social norms significantly influence rice farmers' behaviour regarding organic fertilizer application, with a positive correlation observed at a 1% significance level. While education level moderates the impact of social norms on organic fertilizer application with higher education correlating with a stronger influence of social norms. Farmers with higher education levels are more likely to comply with social norms to maintain their social status and avoid societal condemnation.

Khushi & Tabassum (2018) examined farmers' attitudes and influencing psychological factors towards rice production despite challenges. An overwhelming 98% of farmers exhibited favourable attitudes towards rice production, suggesting a strong commitment to continue cultivation despite economic pressures. Only 2% of

respondents showed unfavourable attitudes, indicating a generally positive outlook among rice producers. Education, occupation, and farm size etc are identified as significant factors influencing attitudes, with educated farmers showing more favourable views towards fertilizer application in rice cultivation. Interestingly, smaller farm holders had a more positive attitude towards rice production.

2.3. Key factors of adoption decision for recommended fertilizer doses in Bangladesh:

Sunny et.al.(2022) investigated the factors influencing Boro rice farmers' decisions regarding the adoption of recommended fertilizer doses and reported that farmers' age, land typology, soil water retention, knowledge, and availability of cow dung significantly impact their fertilizer application decisions. The study found significant differences in land ownership, farm size, and information-seeking behaviour among different groups of adopters and non-adopters. Most respondents owned their land, with a notable percentage of adopters actively seeking information on fertilizer application. Key determinants influencing fertilizer adoption included household labour availability, soil conditions, and farmers' knowledge. Younger farmers and those with better access to information were more likely to adopt higher fertilizer doses. Most farmers relied on personal experience and advice from traders rather than scientific recommendations for fertilizer application. Family labour availability and land type significantly influence fertilizer adoption decisions, with younger farmers being more open to new practices. Environmental awareness was found to negatively correlate with adoption, indicating that immediate yield expectations often overshadow sustainable practices.

Sunny et.al.(2018) investigated Key Factors Influencing Farming Decisions Based on Soil Testing and Fertilizer Recommendation Facilities (STFRF)-A Case Study on Rural Bangladesh and reported that younger farmers (≤40 years) showed a higher adoption rate of STFRF compared to older farmers, indicating age as a significant factor in technology adoption. Education level positively correlated with adoption, while farming experience had a negative relationship. The analysis stated that younger age, higher education and increased income positively influenced the likelihood of adopting STFRF, while larger farm size negatively impacted adoption rates. Knowledge of

STFRF was a significant determinant, with increased knowledge leading to a higher probability of adoption among farmers. The influence of participatory communication techniques was noted for reaching illiterate farmers. Adopters expressed a desire to improve crop quality and understand soil deficiencies. Also many adopters reported dissatisfaction with service quality due to delayed materials and inadequate training from service providers. Non-adopters expressed frustration over a lack of outreach and support from extension workers due to a gap in service delivery.

Mou et.al. (2019) reported that the adoption rates is low of recommended fertilizer doses (RFD) among Bangladeshi farmers, who often rely on traditional practices rather than scientific recommendations. Key factors influencing adoption include personal, institutional, environmental, and socioeconomic characteristics with a focus on understanding farmers' perceptions and attitudes towards RFD. The factors such as education, family size, and farming experience are essential for understanding the context in which farmers make decisions about fertilizer use. Innovativeness was defined as the speed at which farmers adopted the recommended fertilizer dose, measured from the first awareness to final adoption. The majority of respondents had secondary education, with a significant portion having high farming experience, indicating a potential for better adoption of RFD. Family size varied, with most respondents belonging to small families, which may influence their agricultural practices and resource allocation. Older, more experienced farmers with secondary education were more likely to adopt RFD, while those with lower educational levels and family sizes showed less innovation. Positive correlations were found between education, farm size, income, and adoption of RFD, suggesting that enhancing these factors could improve fertilizer use practices among farmers compared to larger farm holders, who were more inclined to explore new technologies.

2.4. Perceived problems or constraints towards fertiliser application in Bangladesh

Sunny et.al.(2022) conducted a study on What influences Bangladeshi Boro rice farmers' adoption decisions of recommended fertilizer doses: A case study on Dinajpur district and reported that farmers often lack comprehensive knowledge about recommended fertilizer doses and their environmental benefits, leading to an aversion

to following guidelines. Farmers frequently do not have a full understanding of the correct amounts of fertilizers they should be using or how these recommended doses can benefit the environment. Because of this lack of knowledge, they may be hesitant or unwilling to follow the guidelines provided. Essentially, without proper information or understanding, farmers might not see the value in adhering to the recommendations, which can lead to practices that are less effective or even harmful to the environment.

Islam & Beg (2021) conducted a study on Information and behavior: Evidence from fertilizer quantity recommendations in Bangladesh and reported that economic pressures and the heavy reliance on subsidies have led to inefficient fertilizer use, exacerbating environmental issues and increasing costs for farmers. Ultimately the production has decreased. Due to financial challenges and a strong dependence on government subsidies, farmers are using fertilizers inefficiently. This inefficiency not only worsens environmental problems—such as soil degradation, water pollution, and greenhouse gas emissions—but also drives up costs for farmers. As a result of these factors, overall agricultural production has decreased, likely because the land becomes less fertile and less productive over time due to improper fertilizer use.

Shabur et.al.(2024) conducted a study on Analysis of the barriers and possible approaches for adopting Industry 4.0 in the fertilizer sector of Bangladesh and found that fertilizer production sector faces challenges in adopting modern technologies (Industry 4.0), primarily due to insufficient knowledge and fear of job losses, which indirectly affects fertilizer availability and application practices. The fertilizer production industry is struggling to implement modern technologies associated with Industry 4.0, such as automation, data analytics, and advanced manufacturing techniques. The main reasons for this struggle are a lack of knowledge about these technologies and concerns that adopting them could lead to job losses. These challenges in modernizing the production process can indirectly lead to problems with the availability of fertilizers and how they are used by farmers. If the industry cannot efficiently produce or distribute fertilizers due to outdated practices, it can negatively impact how effectively fertilizers are applied in agriculture.

2.5. A Systematic Review of Relationship between selected characteristics of Farmers and their Knowledge about Fertilizer Application.

Very few studies have been found to be specifically undertaken in a scientific way in the direction of recent study. There an Effort has been made in subsequent subsection to review some interlinked literature in this aspect.

2.5.1. Age and Knowledge about Fertilizer Application

Table 1. Age and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Age	Knowledge of women farmers about using organic fertilizer in organic farming practice	No relationship	Bangladesh
Islam *et.al.*(2018)	Age	Knowledge gap about fertilizer application	No relationship	Bangladesh
Thomas *et.al.*(2023)	Age	Knowledge about bio-fertilizer application	No relationship	India
Das *et.al.*(2019)	Age	Farmers knowledge about N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings indicate a consistent relationship between age of the farmers and their knowledge about fertilizer application.

2.5.2. Education and Knowledge about Fertilizer Application

Table 2. Education and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Education	Knowledge of women farmers about using organic fertilizer in organic farming practice	Positive relationship	Bangladesh
Islam *et.al.*(2018)	Education	Knowledge gap about fertilizer application	Negative relationship	Bangladesh
Thomas *et.al.*(2023)	Education	Knowledge about bio-fertilizer application	Positive relationship	India

Das *et.al.*(2019)	Education	Farmers knowledge about N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings did not indicate either inconsistent or consistent relationship between education of the farmers and their knowledge about fertilizer application.

2.5.3. Organisational participation and Knowledge about Fertilizer Application

Table 3. Organisational participation and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Islam *et.al.*(2018)	Organisational participation	Knowledge gap about fertilizer application	No relationship	Bangladesh
Das *et.al.*(2019)	Organisational participation	Farmers knowledge about N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings indicate a consistent relationship between organisational participation of the farmers and their knowledge about fertilizer application.

2.5.4. Cosmopoliteness and Knowledge about Fertilizer Application

Table 4. Cosmopoliteness and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Cosmopoliteness	Knowledge of women farmers about using organic fertilizer in organic farming practice	Positive relationship	Bangladesh
Islam *et.al.*(2018)	Cosmopoliteness	Knowledge gap about fertilizer application	Positive relationship	Bangladesh
Das *et.al.*(2019)	Cosmopoliteness	Farmers knowledge about N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings indicate an inconsistent relationship between cosmopoliteness of the farmers and their knowledge about fertilizer application.

2.5.5. Farm size and Knowledge about Fertilizer Application

Table 5. Farm size and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Farm size	Knowledge of women farmers about using organic fertilizer in organic farming practice	Positive relationship	Bangladesh
Islam *et.al.*(2018)	Farm size	Knowledge gap about fertilizer application	No relationship	Bangladesh
Das *et.al.*(2019)	Farm size	Farmers knowledge about N_2-fortified organic manure application as fertilizer	Positive relationship	Bangladesh

The findings indicate an inconsistent relationship between farm size of the farmers and their knowledge about fertilizer application.

2.5.6. Extension media contact and Knowledge about Fertilizer Application

Table 6. Extension media contact and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Extension media contact	Knowledge of women farmers about using organic fertilizer in organic farming practice	Positive relationship	Bangladesh
Islam *et.al.*(2018)	Extension media contact	Knowledge gap about fertilizer application	No relationship	Bangladesh
Das *et.al.*(2019)	Extension media contact	Farmers knowledge about N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings indicate an inconsistent relationship between extension media contact of the farmers and their knowledge about fertilizer application.

2.5.7. Farming experience and Knowledge about Fertilizer Application

Table 7. Farming experience and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Farming experience	Knowledge of women farmers about using organic fertilizer in organic farming practice	No relationship	Bangladesh
Islam *et.al.*(2018)	Farming experience	Knowledge gap about fertilizer application	Negative relationship	Bangladesh
Das *et.al.*(2019)	Farming experience	Farmers knowledge about N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings indicate an inconsistent relationship between farming experience of the farmers and their knowledge about fertilizer application.

2.5.8. Training Received and Knowledge about Fertilizer Application

Table 8. Training received and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Training Received	Knowledge of women farmers about using organic fertilizer in organic farming practice	Positive relationship	Bangladesh
Islam *et.al.*(2018)	Training Received	Knowledge gap about fertilizer application	Positive relationship	Bangladesh
Das *et.al.*(2019)	Training Received	Farmers knowledge about N_2-fortified organic manure application as fertilizer	Positive relationship	Bangladesh

The findings indicate a consistent relationship between training received of the farmers and their knowledge about fertilizer application.

2.5.9. Annual family income and Knowledge about Fertilizer Application

Table 9. Annual family income and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Annual family income	Knowledge of women farmers about using organic fertilizer in organic farming practice	No relationship	Bangladesh
Islam *et.al.*(2018)	Annual family income	Knowledge gap about fertilizer application	No relationship	Bangladesh
Das *et.al.*(2019)	Annual family income	Farmers knowledge about N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings indicate a consistent relationship between annual family income of the farmers and their knowledge about fertilizer application.

2.5.10. Farm holding and Knowledge about Fertilizer Application

Table 10. Farm holding and Knowledge about Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Goswami *et.al.*(2021)	Farm holding	Knowledge of women farmers about using organic fertilizer in organic farming practice	Positive relationship	Bangladesh
Thomas *et.al.*(2023)	Farm holding	Knowledge about bio-fertilizer application	Positive relationship	India

The findings indicate a consistent relationship between farm holding of the farmers and their knowledge about fertilizer application.

2.6. A Systematic Review of Relationship between selected characteristics of Farmers and their attitude toward Fertilizer Application.

2.6.1. Age and attitude toward Fertilizer Application

Table 11. Age and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh *et.al.*(2020)	Age	Attitude toward using fertilizer in organic farming	Positive relationship	Bangladesh
Hasan *et.al.*(2015)	Age	Influence on attitude toward using agro chemicals as fertilizers	No relationship	Bangladesh
Das *et.al.*(2019)	Age	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh
Sarwar *et.al.*(2022)	Age	Attitude of women farmers toward using organic fertilizer in organic farming	No relationship	Bangladesh

The findings indicate an inconsistent relationship between age of the farmers and their attitude toward fertilizer application.

2.6.2. Education and attitude toward Fertilizer Application

Table 12. Education and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh *et.al.*(2020)	Education	Attitude toward using fertilizer in organic farming	No relationship	Bangladesh
Hasan *et.al.*(2015)	Education	Influence on attitude toward using agrochemicals as fertilizers	No relationship	Bangladesh
Das *et.al.*(2019)	Education	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

Sarwar *et.al.*(2022)	Education	Attitude of women farmers toward using organic fertilizer in organic farming	Positive relationship	Bangladesh

The findings indicate an in consistent relationship between education of the farmers and their attitude toward fertilizer application.

2.6.3. Extension media contact and attitude toward Fertilizer Application

Table 13. Extension media contact and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh*et.al.*(2020)	Extension media contact	Attitude toward using fertilizer in organic farming	Positive relationship	Bangladesh
Hasan *et.al.*(2015)	Extension media contact	Influence on attitude toward using agrochemicals as fertilizers	Positive relationship	Bangladesh
Das *et.al.*(2019)	Extension media contact	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh
Sarwar *et.al.*(2022)	Extension media contact	Attitude of women farmers toward using organic fertilizer in organic farming	Positive relationship	Bangladesh

The findings indicate an inconsistent relationship between extension media contact of the farmers and their attitude toward fertilizer application.

2.6.4. Farm size or area and attitude toward Fertilizer Application

Table 14. Farm size and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh *et.al.*(2020)	Farm Size	Attitude toward using fertilizer in organic farming	No relationship	Bangladesh

Hasan *et.al.*(2015)	Farm Size	Influence on attitude toward using agro chemicals as fertilizers	No relationship	Bangladesh
Das *et.al.*(2019)	Farm Size	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh
Sarwar *et.al.*(2022)	Farm Size	Attitude of women farmers toward using organic fertilizer in organic farming	No relationship	Bangladesh

The findings indicate a consistent relationship between farm size of the farmers and their attitude toward fertilizer application.

2.6.5. Annual income and attitude toward Fertilizer Application

Table 15. Annual income and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh *et.al.*(2020)	Annual income	Attitude toward using fertilizer in organic farming	No relationship	Bangladesh
Hasan *et.al.*(2015)	Annual income	Influence on attitude toward using agro chemicals as fertilizers	Positive relationship	Bangladesh
Das *et.al.*(2019)	Annual income	Farmers attitude toward N_2-fortified organic manure application as fertilizer	Negative relationship	Bangladesh
Sarwar *et.al.*(2022)	Annual income	Attitude of women farmers toward using organic fertilizer in organic farming	No relationship	Bangladesh

The findings did not indicate either consistent or inconsistent relationship between annual income of the farmers and their attitude toward fertilizer application.

2.6.6. Cosmopoliteness and attitude toward Fertilizer Application

Table 16. Cosmopoliteness and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh *et.al.*(2020)	Cosmopoliteness	Attitude toward using fertilizer in organic farming	Positive relationship	Bangladesh
Das *et.al.*(2019)	Cosmopoliteness	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh
Sarwar *et.al.*(2022)	Cosmopoliteness	Attitude of women farmers toward using organic fertilizer in organic farming	No relationship	Bangladesh

The findings indicate an inconsistent relationship between cosmopoliteness of the farmers and their attitude toward fertilizer application.

2.6.7. Farming Experience and attitude toward Fertilizer Application

Table 17. Farming experience and attitude toward Fertilizer Application of farmers

The findings indicate a consistent relationship between farming experience of the farmers and their attitude toward fertilizer application.

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh *et.al.*(2020)	Farming Experience	Attitude toward using fertilizer in organic farming	No relationship	Bangladesh
Das *et.al.*(2019)	Farming Experience	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh
Sarwar *et.al.*(2022)	Farming Experience	Attitude of women farmers toward using organic fertilizer in organic farming	No relationship	Bangladesh

2.6.8. Family Size and attitude toward Fertilizer Application

Table 18. Family size and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Ghosh *et.al.*(2020)	Family size	Attitude toward using fertilizer in organic farming	No relationship	Bangladesh
Hasan *et.al.*(2015)	Family size	Influence on attitude toward using agro chemicals as fertilizers	No relationship	Bangladesh
Das *et.al.*(2019)	Family size	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh

The findings indicate a consistent relationship between family size of the farmers and their attitude toward fertilizer application.

2.6.9. Training received and attitude toward Fertilizer Application

Table 19. Training received and attitude toward Fertilizer Application of farmers

Researcher and year	Independent variable	Dependent variable	Relationship	Country
Hasan *et.al.*(2015)	Training received	Influence on attitude toward using agro chemicals as fertilizers	No relationship	Bangladesh
Das *et.al.*(2019)	Training received	Farmers attitude toward N_2-fortified organic manure application as fertilizer	No relationship	Bangladesh
Sarwar *et.al.*(2022)	Training received	Attitude of women farmers toward using organic fertilizer in organic farming	Positive relationship	Bangladesh

The findings indicate an inconsistent relationship between training received of the farmers and their attitude toward fertilizer application.

2.7. Conceptual framework of the study

This study is concerned with relationship between the fertilizer application and farmers' knowledge and attitude. Thus the knowledge and attitude are the main focus of the study and some selected characteristics of the farmers were considered as those might have relationship with knowledge and attitude of farmers. Farmers' knowledge and attitude regarding fertilizer application by farmers may be influenced and affected through interacting forces of many factors. It is not possible to deal with all the factors in a single study. Based on this discussion, previous studies research and the review of literature the conceptual framework of this study has been formulated as shown in Figure 1.

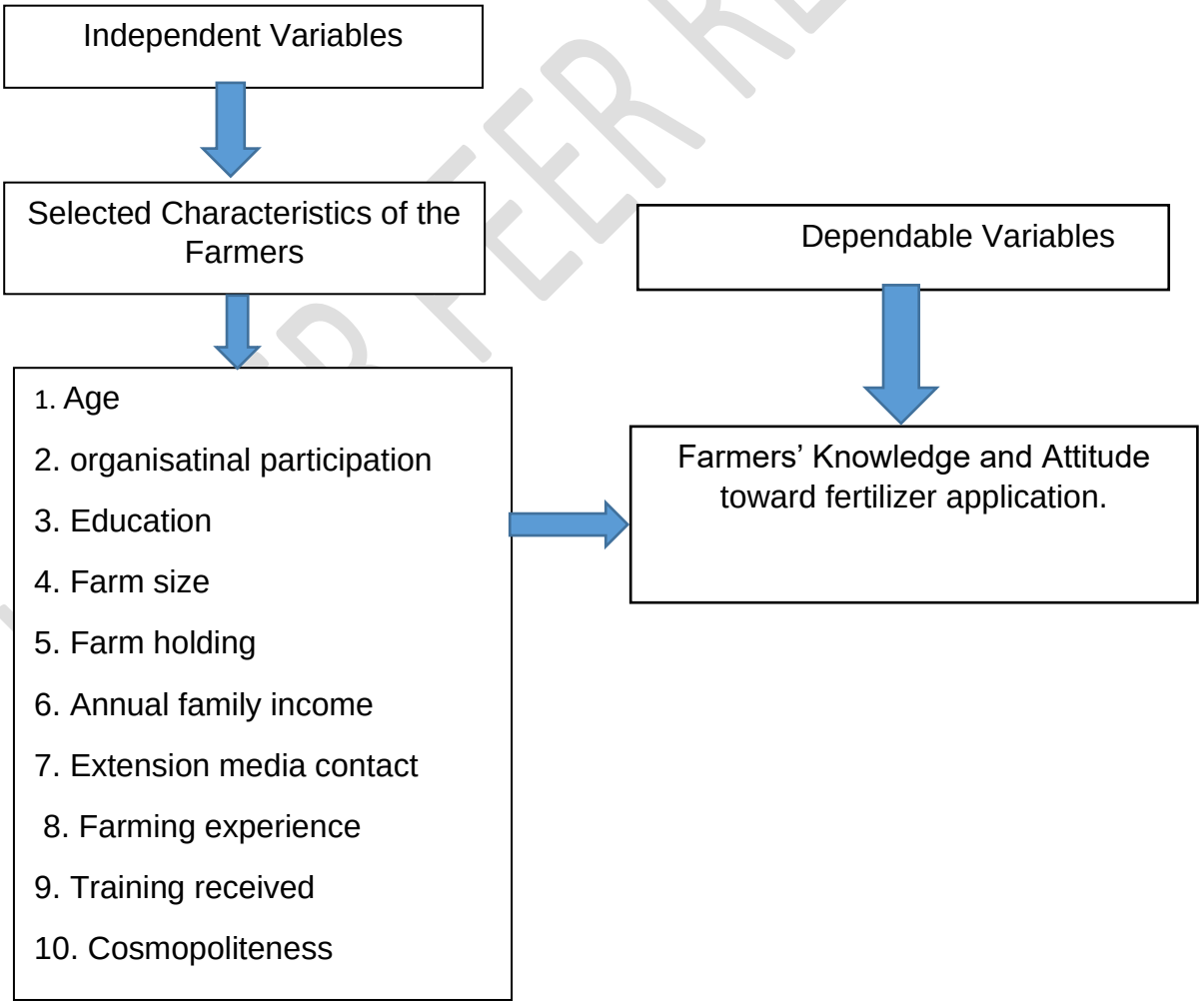

Fig 1. Conceptual Framework of the study

3. Conclusion

The study concluded that farmers held highly favourable attitude and knowledge toward fertilizer application. The sustainable increase of Boro Rice production for food sufficiency requires effort to enhance the knowledge and attitude of farmers in fertilizer application. However, lack of knowledge and proper attitude toward fertilizer application emerged to be constraints perceived by farmers. Thus, it is suggested that massive and relevant training program should be taken for the farmers to upgrade the knowledge and attitude toward fertilizer application. The farmers should be explained in detail the procedure of timely and balanced application of fertilizer so that they do not find it difficult and can maximize the Boro rice production. Besides government can take some public awareness through media activities and advocacy to influence farmer's knowledge and attitude in using balance dose of fertilizer and can emphasize on the use of timely application of fertilizers for a sustainable Rice production.

4. Recommendations for Further Study

A small piece of study has been conducted which cannot provide all the information for the proper understanding of the interrelationship between knowledge and attitude toward farmers' fertilizer application in rice production. Therefore, the following recommendations were made for further study:

1. The present study was conducted in Sunamganj upazila under Sylhet district. It is recommended that similar studies should be conducted in other areas of Bangladesh.

2. This study investigated the relationships of 10 characteristics for knowledge and 9 charecteristics for attitude of the farmers toward fertilizer application. Therefore, it is recommended that further study may be conducted with different explanatory and focus variable.

3. More research should be conducted to investigate the comparative effect with other extension methods and also for identifying factors influencing the effect.

Data availability statement

This is a systematic review of literature, so the data were detailed in the manuscript.

Additional information

No additional information is available for this paper.

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