KNOWLEDGE OF FARMERS ON INTEGRATED SOIL FERTILITY MANAGEMENT IN SELECTED AREAS OF MYMENSINGH SADAR UPAZILA, MYMENSINGH DISTRICT, BANGLADESH

ABSTRACT

A major global concern is the decline in soil fertility and the resulting reduction in crop yields in developing nations due to improper soil fertility management practices. Furthermore, to improve food security and environmental sustainability in farming systems, both the national and international communities acknowledge that an integrated approach to managing soil fertility is necessary. Considering the importance of soil fertility, the study aimed to assess farmers' knowledge on farmers' knowledge on integrated soil fertility management as well as identify the influential factors that may affect their knowledge along with figuring out the problems faced by the farmers in practicing integrated soil fertility management. Data were collected from three villages of Mymensingh sadar upazila (sub-district) under Mymensingh district purposively and analyzed using Multiple Linear Regression Models. Findings indicated that the majority (66.66%) of the non-FFS farmers were found to have a low level of knowledge on integrated soil fertility management whereas 60% of the FFS farmers had a higher level of integrated soil fertility and nutrient management knowledge. There are several factors that influence the knowledge of farmers on integrated soil fertility management. For the Non-FFS famers farm size, annual family income, and training; and for FFS farmers, exposure to extension media and training significantly influence the knowledge level of the farmers on integrated soil fertility management. Analysis shows that these factors explained 91% variation (for Non-FFS) and 89% variation (for FFS) in the farmers' knowledge on integrated soil fertility management. There were notable differences between FFS and non-FFS farmers in terms of the problems they experienced while practicing integrated soil fertility management**.** In order to address the difficulties that non-FFS farmers face, a number of governmental and non-governmental organizations can

actively work to raise farmers' awareness of and knowledge about integrated soil fertility management by putting appropriate policies in place. These include providing technical education, training, and group-based extension activities like Farmer Field School.

Keywords: Knowledge, farmers, integrated soil fertility management, farmer field school

INTRODUCTION

Since over 95% of the world's food originates from land, the availability of fertile soils is crucial to maintaining a sufficient supply of food for everyone. However, efforts are required to increase soil quality [1,2]. A major global concern is the decline in soil fertility and the resulting reduction in crop yields in developing nations due to improper soil fertility management practices [3,4]. Climate change is a contributing element to these concerns, as noted by Swaminathan and Kesavan [5]; IPCC [6]; Khatri-Chhetri et al. [7]. Extreme weather events, such as droughts, floods, intense heat waves, and an increase in the frequency of wildfires, are brought on by fluctuating climatic circumstances [4].

Bangladesh is known for its dense population on limited land, accelerated urbanization without planning, food and nutrition insecurity, and Asia's lowest level of climate change resilience [8]. Thus, in order to meet the demands of Bangladesh's growing population, sustainable soil fertility management and crop production are required [9].

Even though soil conservation and soil fertility maintenance techniques are widely recognized [10,3,4], farmers in developing countries like Bangladesh face several obstacles to their proper adoption and implementation, including a lack of adaptable technology, scarce financial and material resources, limited access to farm inputs, and growing population pressure on land resources [4]. Bangladesh's agriculture has been affected by a number of issues, including soil pollution and nutrient shortages, poor crop and soil management, conversion of agricultural land to other uses, pest and disease risks, and natural disasters [11]. In order to implement improved agricultural production technology, it is imperative to get over the obstacles that the majority of farmers in a community confront [12].

In order to achieve food security and environmental sustainability in farming systems, both the national and international communities acknowledge that an integrated approach to managing soil fertility is necessary. This approach should maximize crop productivity while minimizing the depletion of soil nutrients and the physical and chemical deterioration of soil, which can result in land degradation, including soil erosion [13,2,14,15].

The term Integrated Soil Fertility Management (ISFM) refers to the practice of utilizing organic resources including composts, green manures, crop residues, bovine manures, and biofertilizers in conjunction with mineral fertilizers [16,2]. Its fundamental idea is to maintain crop and soil productivity by optimizing all available plant nutrient sources in an integrated way. This system integrates all aspects of organic and mineral plant nutrient sources into the crop production system of the Food and Agriculture Organization of the United Nations [17,2]. It uses these resources wisely and efficiently to produce crops in a sustainable manner [18,2].

Due to farmers' knowledge of soil fertility and management [19,20,4], farming system diversity, and other factors, integrated soil fertility management approaches generally differ from farmer to farmer, even at the local scale [21,22,23]. Additionally, farmers and researchers typically have different levels of knowledge and information [24], which makes it difficult for farmers to implement suggestions for soil fertility management [25].

Several studies have been conducted on soil fertility and integrated soil fertility management in different parts of the world, e.g., Kome et al. [4]; Havlin and Heiniger [26]; Mugwe et al. [27]; Tesfahunegn et al. [28]; Martey and Kuwornu [29]; Adolwa et al. [30]; Dawoe et al. [19]; Vanlauwe et al. [31]; Mowo et al. [32]; Corbeels et al. [33]. However, very limited research has been carried out in Bangladesh on integrated soil fertility management, e.g., Farouque and Takeya [34]; Saleque et al. [35]; Farouque and Takeya [13]. Farouque and Takeya [34] revealed the farmers' perceptions of integrated soil fertility management for sustainable crop production. Soil fertility management is an important pre-requisite for maintaining soil fertility and enhancing crop productivity. Farmers' knowledge of integrated soil fertility management is necessary for sustaining agro-ecosystems through site-specific management. None of the research was conducted on farmers' knowledge of integrated soil fertility management in Bangladesh. Thus, this study intends to assess farmers' knowledge on integrated soil fertility management as well as explore influential factors affecting their knowledge of integrated soil fertility management and figure out the problems faced by farmers in practicing integrated soil fertility management.

METHODOLOGY

Study area, population, sample size and data collection

For the purpose of performing this study, three villages—Vobokhali, Churkhai, and Narayanpur—of the Vobokhali union under the Mymensingh sadar Upazila were purposely selected (see Figure 1.) It is located between 24°40' and 7°32' North and between 90°26' and 90°15' East. The Brahmaputra river flows alongside the Mymensingh district.

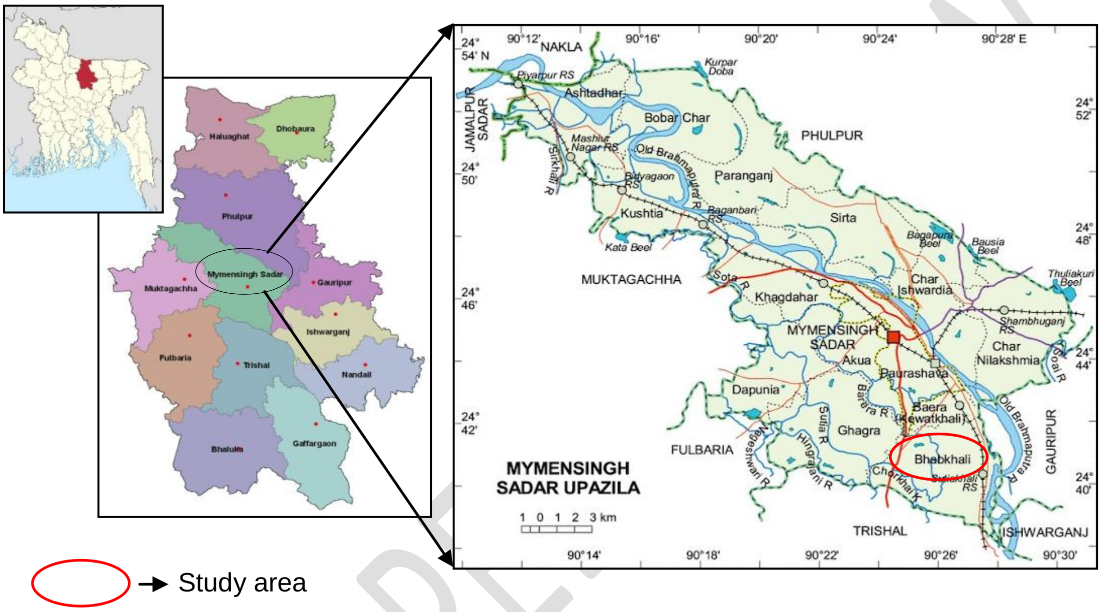

Fig. 1. Map of Bangladesh showing the study area

Within the chosen villages, the selection of farmers was based on sampling criteria of whether farmers participated in Farmer Field School (FFS) or not. There were around 700 farmers in the selected three villages. Sixty (60) farmers were selected purposively for this study. Among these 60 farmers, 30 farmers participated in the farmers field school (FFS) and rest 30 farmers did not participate in the FFS. Considering the size of the actual population was huge, selecting this sample size of 60 was arbitrary [36]. When deciding the sample size, the study budget, time, and data quality were also taken into account [37]. Data was collected in a face-to-face interaction using a structured questionnaire between April 2021 to June 2021.

Measurement of the variables and analysis of data

Farmers' knowledge regarding integrated soil fertility management was the dependent variable of this study. Farmers' knowledge was measured based on their responses to the selected questions. For this purpose, twelve aspects such as knowledge on integrated soil fertility management related concept, soil health, soil testing, Balanced nutrient supply, Tillage, Irrigation , Weeding , Crop residue management, Soil erosion , Crop rotation , Cropping pattern and Best practices were considered. Each respondent was asked to answer 16 selected questions from these aspects. These 16 questions were selected based on literature review and informal discussion with farmers of the study area (prior to data collection). A total of 35 marks were assigned against these questions and the score was assigned for each question based on the importance, difficulty and depth of the knowledge. The researcher gave marks to each of the question according to the correctness of responses of the respondents. The range of the overall knowledge score for all aspects is from 0 to 35 where "0" indicated no knowledge and "35" indicated the highest knowledge on soil fertility management. The independent variables in this study included age, education, size of the household, experience in farming, size of the farm, annual family income, exposure to extension media, and training received. The respondents' age, education, household size, and annual family income were classified using the most commonly used classification in Bangladesh [38,39]. Farm size of the respondents was classified based on Department of Agricultural Extension (DAE) farm land classification. Other variables such as farming and training experience, and exposure to extension media were classified based on observed and possible range.

Multiple regression analysis (both enter and stepwise methods) was used to identify factors affecting the knowledge of farmers on soil fertility management. Once insignificant variables have been eliminated from the model, stepwise regression analysis assists in quantifying the individual contributions of factor variables [40]. The equation is as follows (Equation 1).

$$y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where, y_i = problems in getting agricultural extension services, β_0 = constant, X_1= age, X_2= education, X_3 = household size, X_4 = farming experience, X_5 = farm size, X_6 = annual family income, X_7 = exposure to extension media, X_8 = training received.

The problems faced by the farmers were assessed using a 4-point rating scale. To ascertain the problem rating, the problem-facing index (PFI) was calculated. The weights assigned to each cell on the scale, which varied from 3 for high frequency to 2 for medium frequency to 1 for low frequency to

0 for not at all, were multiplied by the frequency counts of each cell for each problem. Equation 2 was used to calculate PFI for each of the eight problems that were chosen. The equation is as follows [41].

$$\text{PFI} = (\text{Ph}\times 3) + (\text{Pm}\times 2) + (\text{Pl}\times 1) + (\text{Pn}\times 0) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where; PFI = Problem Facing Index, Ph = number of farmers with high problems, Pm = number of farmers with medium problems, Pl = number of farmers with low problems, and Pn = Number of farmers with no problem.

In this study, both descriptive and inferential statistics were utilized to elucidate the data. The analysis of the data was performed using the Statistical Package for Social Science (SPSS) version 25.

RESULTS AND DISCUSSION

Socio-economic characteristics of the farmers

Table 1 provides a simple overview of the socioeconomic traits of the respondents. It shows that the majority of respondents in both the FFS and Non-FFS categories were middle-aged (36–50) at 75% and 53%, respectively, while only 15% of FFS respondents and 47% of Non-FFS respondents were older (>50). There was a very small proportion of young people. This is most likely may be due to the fact that younger people are becoming more and more interested in non-agricultural and educational pursuits. The results resemble those of Hasibuan et al. [42]; Uddin et al. [43,38].

Table 1. Socio-Economic Characteristics of the Respondents

Characteristics (Measuring Unit)	**Category**	**Non-FFS farmers**			**FFS farmers**		
		%	**Mean**	**SD**	**%**	**Mean**	**SD**
Age (Years)	Young (18-35)	0	49.6	7.3	10	44.14	5.88
	Middle aged (36-50)	53			75		
	Old (above 50)	47			15		
Education (Years of schooling)	No schooling (0)	27	5.1	3.68	4	9.5	4.01
	Primary (1-5)	33			18		
	Secondary (6-10)	36			39		
	Above secondary (>10)	4			39		
Household	Small (upto 4)	17			21		

Size (No. of members)	Medium (5-6)	43	6.3	1.78	42	5.8	1.5
	Large (above 6)	40			37		
Farming Experience (Years)	Up to 11 years	0	28.46	8.21	8	22.35	8.08
	Medium (12-23)	37			50		
	High (24-35)	63			42		
Farm size (Hectares)	Landless (upto 0.02)	0	1.06	0.41	0	1.01	0.435
	Marginal (0.021-0.2)	14			0		
	Small (0.21-0.99)	46			54		
	Medium (1-2.99)	40			46		
	Large (3 and more)	0			0		
Annual family income ('000' Tk.)	Low (250-350)	30	417.56	100.2	33	421.3	109.5
	Medium (351-450)	30			25		
	High (more than 450)	40			42		
Exposure to extension Media (Scale score)	Low (9-16)	57	15.7	4.05	0	25.14	3.82
	Medium (17-24)	43			50		
	High (25-31)	0			50		
Training Received (Days)	No training (0)	33	4.70	4.02	7	9.10	4.93
	Short (1-6)	24			28		
	Medium (7-14)	43			50		
	High (more than 14)	0			15		

Source: Field Survey, 2021

The majority of Non-FFS participants (69%) had primary to secondary level education, according to data on their educational qualifications, 4% of the participants had above secondary education, and 27% had no education. Conversely majority of the FFS participants had (78%) secondary to above secondary level education, 18% of the participants had primary education, and only 4% had no education. The findings are consistent with those of Moumeni-Helali and Ahmadpour [44], who discovered that farmers engaging in the FFS had a Diploma and an associate degree, whereas framers who did not participate in the FFS had a primary and a secondary level of education. Average household size of FFS and Non-FFS farmers were 5.8 and 6.3 respectively which is higher than the national average of 4.06 [45]. The FFS farmers had an average of 22.35 years of experience, and the

Non-FFS farmers had an average of 28.46 years of experience. With regard to farming experience, the majority of FFS farmers (50%) had medium farming experience, followed by 42% had high experience, and 8% by low farming experience. However, none of the non-FFS farmers had low farming experience, with the majority (50%) having high farming experience and the remainder (37%), having medium farming experience.

The average farm size for both FFS and non-FFS farmers was larger than the national average of 0.6 hectares, with an average of 1.01 and 1.06 ha, respectively [38]. The mean annual income of the Non- FFS farmers was 0.417 million Bangladeshi taka (4920 US dollars), while the mean annual income of the FFS farmers was 0.421 million BDT (4967 US dollars).

Both mean incomes were higher than the national average of 0.142056 million Bangladeshi taka (1675 USD) [39]. The extension media contact levels of FFS farmers were found to be medium to high, while those of Non-FFS farmers were low to medium. According to the study, Non-FFS farmers received training for an average of only five days, whereas FFS farmers received training for nine days on average.

Farmers' knowledge on integrated soil fertility management

The observed score of farmers' knowledge ranged from 7 to 28. The findings revealed that the majority of non-FFS farmers (66.66 percent) had low knowledge on soil fertility management, followed by medium-level knowledge (33.33%), and no one had higher level of knowledge. Conversely, majority (60%) of the FFS farmers possessed a higher level of Knowledge on soil fertility management, 40% FFS farmers had a medium level, and none of them had low level of knowledge.. The results are consistent with those of Moumeni-Helali and Ahmadpour [44]. The mean difference suggests that the FFS improved the farmers' level of knowledge who attended. Similar findings were observed in the studies conducted by Diab [46]; Red et al. [47]; Van den Berg et al. [48].

Table 2. Knowledge on Integrated Soil Fertility Management

Possible Range	Observed Range	Categories	Non-FFS farmers			FFS farmers			Mean Difference
			%	Mean	SD	%	Mean	SD	
		Low (7-14)	66.66			0			

0-35	7-28	Medium (15-21)	33.33	12.53	3.83	40	23.8	2.68	11.27
		High (more than 21)	0			60			

Source: Field Survey, 2021

Fertilizer use pattern of the farmers

Table 3 indicates the fertilizer usage pattern of the respondents. The majority (70%) of the non-FFS farmers were found to use a high level of fertilizers. Only 13% were found in the low fertilizer usage category. On the contrary, almost half of the FFS farmers belong to the medium usage category, whereas 33.4% were found to be using a higher level of fertilizer. The negative mean difference indicates that FFS motivated the farmers in reducing fertilizer usage which is further indicated by lower means of FSS farmers compared to non-FFS farmers. Victor et al. [49]; van Huis and Yajima [50] had similar findings regarding fertilizer use by FFS attending and non-attending farmers.

Table 3. Fertilizer Use Pattern of the Respondents

Possible Range	Observed Range	Categories	Non-FFS farmers			FFS farmers			Mean difference
			%	Mean	SD	%	Mean	SD	
0-16	4-16	Low (4-8)	13	12.3	1.91	17	11.64	3.66	-0.66
		Medium (9-12)	27			49.6			
		High (more than 12)	70			33.4			

Source: Field Survey, 2021

Manure use pattern of the farmers

Manure application not only increases aggregate stability and soil porosity [51] and decreases bulk density [52] but also improves the soil biochemical properties [53]. That is why manure usage is one of the prime concerns of FFS. This study reveals that only 11 percent of the FFS farmers use manure to a high level while 45 percent have medium level usage, and 44 percent were found to have a low level of manure usage. On the other hand, the majority (76.66%) of the non-FFS farmers were in the low usage category, followed by medium manure usage by 23.33 percent. None was found to be in the high manure usage category. Thus, though the manure usage was less frequent than the fertilizer use, the mean difference represents that FFS farmers used manure more than the non-FFS ones. Phillips et al. [54] had identical findings in their study.

Table 4. Manure Use Pattern of the Respondents

Possible Range	Observed Range	Categories	Non-FFS farmers			FFS farmers			Mean difference
			%	Mean	SD	%	Mean	SD	
0-14	0-8	Low (0-3)	76.66	2.1	1.65	44	3.42	1.34	1.32
		Medium (4-6)	23.33			45			
		High (more than 6)	0			11			

Source: Field Survey, 2021

Factors affecting the knowledge of farmers' on integrated soil fertility management

Multiple linear regression analysis was used to identify the influential factors and their contribution to predicting the focus variable, i.e., farmers' knowledge on soil fertility management.

Non-FFS farmers

The results of the regression analysis (Table 5) revealed that all the explanatory variables, such as age, education, household size, farming experience, farm size, annual family income, exposure to extension media and training received significantly influence knowledge on soil fertility management (Adjusted R^2 = 0.91) and these variables contributed for 91% of the variation of farmers' knowledge collectively. Among them, farm size (t=2.209; $p < 0.05$), annual family income (t=3.677; $p < 0.01$), and training (t=5.809; $p < 0.01$) had substantial impact on farmers' knowledge of soil fertility management. The Variance Inflating Factors (VIF) used to detect multi-collinearity among independent variables were less than 10, indicating that multi-collinearity was not a major problem in the model.

Table 5: Summary of Multiple Regression Explaining Farmers' Knowledge on Integrated Soil Fertility Management (Non-FFS Farmers)

Model	B	Std. Error	Beta	t	*P*-Value	Collinearity Statistics	
						Tolerance	VIF
(Constant)	10.228	3.013		3.394	0.003		
Age	0.002	0.078	0.003	0.023	0.982	0.125	8.022
Education	-0.053	0.070	-0.051	-0.747	0.463	0.615	1.625
Household size	-0.070	0.143	-0.033	-0.493	0.627	0.639	1.564
Farming experience	-0.035	0.064	-0.074	-0.542	0.594	0.152	6.599
Farm size	2.604	1.179	0.283	2.209	0.038	0.172	5.824
Annual family income	0.008	0.002	0.210	3.677	0.001	0.870	1.150
Exposure to extension media	0.076	0.054	0.080	1.410	0.173	0.870	1.150
Training received	0.697	0.120	0.732	5.809	0.000	0.178	5.625
F (8, 21)					41.61***		
$R^2 = 0.941$, Adjusted $R^2 = 0.91$							

*Note. * = p < 0.10; ** = p < 0.05; *** = p < 0.01*

Results showed that farmers' knowledge of integrated soil fertility management was significantly increased with the increase of their farm size, indicating that if farm size changes by 1 unit (one number), then knowledge of soil fertility management changes by 0.283 units.

Farm size is a significant determinant in developing world, exerting a direct impact on educational facilities and other physical infrastructure crucial for fostering farming skills, information acquisition, and enhanced communication capabilities [34]. Agricultural farmers with more large farms engage in the year-round cultivation of diverse crop varieties. They are consequently more concerned about soil fertility. The same finding was discovered by Farouque and Takeya [34]; Chikowo et al. [55].

Results also indicated that farmers with more annual family income positively influenced the knowledge level of the non-FFS, indicating that if annual family income received score changes by 1 unit (one number) then the knowledge changes by 0.210. Findings showed that farmers' having more family income had a substantial positive impact on the knowledge of soil fertility management. Farmers with higher income are capable of maintaining year-round crop cultivation, hence increasing their opportunities to use knowledge pertaining to soil fertility management. Similar results were also discovered by Roy [56]; Danso-Abbeam et al. [57] in their study the annual income had a positive influence on knowledge.

Results also indicated that farmers with more training are more knowledgeable on integrated soil fertility management, indicating that if training received score changes by 1 unit (one number) then the knowledge changes by 0.732. Findings showed that non-FFS farmers' increased exposure to training had a substantial positive impact on the knowledge level of soil fertility management. Training has been identified as an effective method to enhance farmers' knowledge on integrated soil fertility management, according to findings by Kpadonou et al. [58]; Caffaro et al. [59], which support similar conclusions.

A stepwise multiple regression analysis was employed to understand the individual contribution of the explanatory variables in predicting the variation of farmers' knowledge on integrated soil fertility management. Table 6 presents the summary of stepwise multiple regression analysis.

Table 6: Summary of Stepwise Multiple Regression of the Non-FFS Farmers

Model	**Variables Entered**	**Multiple R**	**Multiple R^2**	**Variation Explained (Percent)**	**Significance level**
Constant+ X_8 +	Training (X_8)	0.887	0.88	88	0.000
Constant+ X_8 + X_6	Training+ Annual family income (X_6)	0.906	0.2	1.9	0.000
Constant+ X_8 + X_6+ X_5	Training+ Annual family income+ Farm size (X_5)	0.913	0.06	0.6	0.000

Table 6 shows that these three variables (R^2 = 0.91) account for 91 percent of the variation in the farmers' knowledge on integrated soil fertility management. The findings indicate that training (R^2 = 0.887) was the first in the model that explained the most prominent variation (88%) in farmers knowledge. The results suggest that farmers can gain necessary knowledge regarding soil fertility management through training activity [58,59]. The second variable in the model was the annual family income of the farmers. Annual family income accounted for 1.9 percent of the variation in the focus variable. The model's third aspect was farm size and it explained 0.6 percent variation.

FFS farmers

The results of the regression analysis (Table 7) revealed that all the explanatory variables, such as age, education, household size, farming experience, farm size, annual family income, exposure to extension media and training received significantly influence knowledge on soil fertility management (R^2 = 0.92) and these variables contributed for 92% of the variation of farmers' knowledge collectively. Among them, exposure to extension media (t=2.567; $p < 0.05$), and training (t=4.756; $p < 0.01$) had substantial impact on farmers' knowledge of soil fertility management. The Variance Inflating Factors (VIF) used to detect multi-collinearity among independent variables were less than 10, indicating that multi-collinearity was not a major problem in the model.

Table 7: Summary of Multiple Regression Explaining Farmers' Knowledge on Integrated Soil Fertility Management (FFS Farmers)

Model	B	Std. Error	Beta	t	*P*-Value	Collinearity Statistics	
						Tolerance	VIF
(Constant)	11.884	3.078		3.862	0.001		
Age	0.072	0.076	0.159	0.948	0.355	0.145	6.896
Education	0.008	0.060	0.012	0.137	0.892	0.500	2.001
Household size	-0.064	0.125	-0.036	-0.510	0.616	0.801	1.249
Farming experience	-0.022	0.050	-0.067	-0.441	0.664	0.179	5.597
Farm size	0.594	0.940	0.096	0.633	0.535	0.175	5.717
Annual farm income	0.001	0.004	0.060	0.400	0.694	0.180	5.566
Exposure to extension media	0.216	0.084	0.308	2.567	0.019	0.282	3.548
Training received	0.316	0.066	0.581	4.756	0.000	0.273	3.664
F (8,19)					28.34***		
R^2 = 0.92, Adjusted R^2= 0.89							

*Note. * = p < 0.10; ** = p < 0.05; *** = p < 0.01*

The first significant factor was exposure to extension media (β = 0.308, t = 2.567, p < 0.05). Exposure to extension media is important because if farmers have high extension exposure, they can easily know about integrated soil fertility and nutrient management. These findings are consistent with the findings stated by Tesfahunegn et al. [28].

Extension media contact of farmers had a significant effect on knowledge level of integrated soil fertility management, indicating that if extension media contact of the farmer increases by one unit (one day), knowledge level of integrated soil fertility management increases by 0.308 units. This may suggest that farmers' access to extension media contacts enables them the chance to acquire new agricultural techniques and information, which can substantially enhance their knowledge of integrated soil fertility management [28]. Extension media engagement, particularly through interpersonal and face-to-face modes of communication, provides valuable information for the efficient management of diversified farm activities [60,61,38].

A stepwise multiple regression analysis was employed to understand the individual contribution of the explanatory variables in predicting the variation of farmers' knowledge on integrated soil fertility and nutrient management. Table 8 presents the summary of stepwise multiple regression analysis.

Table 8: Summary of Stepwise Multiple Regression of the FFS farmers

Model	Variables Entered	Multiple R	Multiple R^2	Variation Explained (Percent)	Significance level
Constant+ X_8	Training (X_8)	0.816	0.81	81	0.000
Constant+ X_8 + X_7	Training (X_8) + Exposure to extension media (X_7)	0.894	0.08	8	0.000

Table 8 presents the summary of stepwise multiple regression analysis. Table 8 shows that these two variables (R^2 = 0.89) account for 89 percent of the variation in the farmers' knowledge of integrated soil fertility and nutrient management. The findings indicate that training (R^2 = 0.81) was the first in the model that explained the most prominent variation (81%) in farmers' knowledge. The result is almost similar to the non-FFS farmers. The second variable in the model was exposure to extension media. Exposure to extension media accounted for 8 percent of the variation in the focus variable.

Problems faced by the farmers in practicing integrated soil fertility management

The efficacy and productivity of soil as a medium for plant growth are significantly influenced by the careful management of soil fertility by farmers. In contrast, for agricultural production to increase, use of plant nutrients from both organic and inorganic sources must be enhanced and/or optimized. Consequently, in order to increase agricultural crop production, it is equivalently critical to utilize nutrients from each of these sources [62]. Farmers faced different types of problems while practicing soil fertility management. Table 2 shows the problems respondents experienced while practicing soil fertility management. According to the results, 53.33% of the non-FFS farmers and 46.66% of the FFS farmers had medium level of problem for practicing soil fertility management.

Table 9: Distribution of Farmers Based on Their Problems about Practicing Integrated Soil Fertility Management

Possible Range	Observed Range	Categories	Non-FFS farmers (%)	FFS farmers (%)
0-39	12-33	Low (12-18)	13.33	30.01
		Medium (29-26)	53.33	46.66
		High (more than 27)	33.33	23.33

The problems of Non-FFS farmers were ranked according to the problem-facing index (PFI), and they were then listed in Table 10. According to Table 10's findings, the respondents rated lack of knowledge about soil fertility management as the greatest problem, with problem-facing index (PFI) score of 75. Similar conclusions were reached by De Valença et al. [63].

There were 21 respondents who faced this problem to a high extent out of 30 Non-FFS farmers. Lack of knowledge about the beneficial aspect of combined use of organic manures and fertilizers was the respondents' second major problem, receiving a PFI score of 73. The study's findings showed that among 30 Non-FFS farmers, 20 farmers facing this problem was in higher category, 4 farmers in medium, 4 in low category, and only one respondent had no problem at all. This finding supports Itelima et al. [64]; Srinivasarao et al. [65] which also revealed that Non-FFS farmers had poor knowledge about the beneficial aspect of combined use of organic manures and fertilizers.

Third-ranked problem with a PFI score of 70 was lack of technical knowledge in preparing organic manure and its role in maintaining soil fertility and enhancing crop productivity.

Table 10: Rank Order of the Problems Faced by the Non-FFS Farmers

Problems	Extent of problems				PFI	Rank order
	High	Medium	Low	Not at all		
Lack of knowledge about integrated soil fertility management	21	4	4	1	75	1
Lack of knowledge about the beneficial aspect of	20	4	5	1	73	2

combined use of organic manures and fertilizers						
Lack of technical knowledge in preparing organic manure and its role in maintaining soil fertility and enhancing crop productivity	19	4	5	2	70	3
Limited training opportunity about appropriate techniques of soil fertility and nutrient management for crop production	17	5	5	3	66	4
Lack of knowledge about the beneficial aspect of legume and cover crops	15	5	7	3	62	5
Limited initiative by the extension department to motivate farmers about use of ISF and NM system	14	5	6	5	58	6
Lack of knowledge about the beneficial aspect of crop rotational and crop residue management	13	6	4	7	55	7
Limited demonstration plots emphasizing balanced fertilization	11	5	7	7	50	8
Unavailability and unstable market price of fertilizers during crop season	9	4	9	8	44	9
Scarcity of lands for cultivating green manure crops	8	3	9	10	39	10
Use of cow dung and crop residues for cooking due to shortage of bio-fuel	6	3	8	13	32	11
Financial inability to buy fertilizers in time	4	3	8	15	26	12
Lack of availability of raw materials for preparing organic manure	2	2	10	16	20	13

Notes: high = 3, medium = 2, low = 1 and not at all = 0; PFI = Problems Facing Index, Source: Field survey, 2021

The problems of FFS farmers were ranked according to the problem-facing index (PFI), and they were then listed in Table 11. According to Table 11's findings, the respondents rated unavailability and the unstable market price of fertilizers during the crop season as the greatest problem, scoring it at 72 on the problem-facing index (PFI). This finding concurs the conclusions drawn by Olaniyan [66]; Shah et al. [67], which stated that constraints in accessing markets and unavailability were the challenges associated with fertilizer utilization throughout the growing season. Financial inability to buy fertilizers in time (PFI-71) was ranked second problem.

Additionally, the issue was documented in the research conducted by Mgbenka et al. [68]; Nina et al. [69], which indicated that financial constraints restrict farmers in many global locations from purchasing fertilizers necessary for cultivating crops. Third-ranked problem with a PFI score of 69 was 'scarcity of lands for cultivating green manure crops'. Grard et al. [70]; Xu et al. [71] also found similar findings.

Table 11: Rank Order of the Problems Faced by the FFS Farmers

Problems	**Extent of problems**				**PFI**	**Rank order**
	High	Medium	Low	Not at all		
Unavailability and the unstable market price of fertilizers during the crop season	20	4	4	2	72	1
Financial inability to buy fertilizers in time	21	2	4	3	71	2
Scarcity of lands for cultivating green manure crops	19	4	4	3	69	3
Lack of availability of raw materials for preparing organic manure	18	4	4	4	66	4
Limited demonstration plots emphasizing balanced fertilization	18	3	2	7	62	5
Limited initiative by the extension department to motivate farmers about the use of ISF and NM system	16	3	4	7	58	6
Use of cow dung and crop residues for cooking due to shortage of bio-fuel	17	3	4	6	54	7
Lack of technical knowledge in preparing organic manure and its role in maintaining soil fertility and enhancing crop productivity	14	2	3	11	49	8
Limited training opportunity about appropriate techniques of soil fertility and nutrient management	12	3	3	12	45	9

for crop production						
Lack of knowledge about the beneficial aspect of legume and cover crops	10	2	6	12	40	10
Lack of knowledge about the beneficial aspect of crop rotational and crop residue management	8	2	6	14	34	11
Lack of knowledge about the beneficial aspect of combined use of organic manures and fertilizers	5	2	8	15	27	12
Lack of knowledge about integrated soil fertility management	3	2	8	17	21	13

Notes: high = 3, medium = 2, low = 1 and not at all = 0; PFI = Problems Facing Index, Source: Field survey, 2021

CONCLUSIONS

This paper has analyzed farmers' knowledge on integrated soil fertility management and to identify the variables affecting their knowledge level. Based on the results of the study, the following conclusions were drawn:

First, there were substantial variations between Non-FFS and FFS farmers regarding knowledge on integrated soil fertility management. The study's analyses showed that most FFS farmers had high to medium levels of knowledge, whereas non-FFS farmers had low to medium levels of knowledge on Integrated Soil fertility management. Therefore, it can be concluded that the level of knowledge of the Non-FFS farmers on the mentioned issue was not satisfactory. There is scope to improve the farmers' knowledge on soil fertility management through training, and intensive group-based participator approaches like FFS.

Second, there were several factors that influence the knowledge of farmers on integrated soil fertility management. For the Non-FFS famers farm size, annual family income, and training; and for FFS farmers, exposure to extension media and training significantly influence the knowledge level of the farmers on integrated soil fertility management. Analysis shows that these factors explained 91% variation (for Non-FFS) and 89% variation (for FFS) in the farmers' knowledge on integrated soil fertility management. Therefore, decision-makers and pertinent authorities should emphasize the factors while implementing policy measures into operation in this regard.

Third, Additionally, there were notable differences between FFS and non-FFS farmers in terms of the problems they experienced while practicing integrated soil fertility management.

The analysis reveals that Non-FFS farmers faced several problems and among them major three problems included lack of knowledge about soil fertility management, lack of knowledge about the beneficial aspect of combined use of organic manures and fertilizers, and lack of technical knowledge in preparing organic manure and its role in maintaining soil fertility and enhancing crop productivity.

On the contrary, FFS farmers also faced some problems while practicing integrated soil fertility management and among them major three problems included unavailability and the unstable market price of fertilizers during the crop season, financial inability to buy fertilizers in time, and scarcity of lands for cultivating green manure crops.

To tackle these challenges face by the Non-FFS farmers, various governmental and non-governmental organizations can play active role to increase awareness and knowledge of farmers on integrated soil fertility management by implementing suitable measures, such as offering technical education, training and group based extension activities like FFS.

RECOMMENDATIONS FOR FURTHER STUDIES

There is huge opportunity to pursue further research related to this issue. Some of them are

listed below:

- Three specifically chosen villages—Vobokhali, Churkhai, and Narayanpur—within the Vobokhali union under the Mymensingh sadar Upazila were the sites of the current study. To generalize the results, similar research might be done across the country.
- This study investigated the influence of eight selected characteristics of the farmers. Further study may be conducted considering other characteristics of the farmers and the situational factors.

Consent

1. Respondent participation:

a) Voluntary participation and informed consent: Participants consents were obtained without outside pressure or constraints on individual freedom of action.

b) Formally well informed: A statement of letter that describes the study and the researcher and formally requests participation.

c) Informants are informed about recording during conducting interview.

d) Respect for the values and motives of others: Respect for the individuals and institutions values and views that are being studied.

e) Anonymity and confidentiality: Personal data of the respondents were collected anonymously and confidentially.

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