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Exploring rice residue management practices focusing environmental pollution and soil health in six major rice growing upazilas of Mymensingh district in Bangladesh

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Abstract

The study was conducted in the six major rice growing upazilas under the district of Mymensingh of Bangladesh during the period from January to December 2018. The purpose of the study was to find out the present status of rice residue management practices focusing on the environmental pollution and soil health. The data were collected from randomly selected 300 respondents with the help of pre-designed respective questionnaire to serve the objectives of the study. The results indicated that most of the respondents were illiterate and they have lack of knowledge on environmental pollution and soil health. About 54.33% of the respondents (163) managed their rice residues by incorporation, about 2.3% of respondent (7) open burning and 43.33% of the respondents (130) collected for other use as cattle feeding, cooking fuel, animal bedding, roofs of house making etc. There was a good sign for the environment as a few number of respondents used their rice residues as burning. About 33.66% of the respondents (95) reported that burning is harmful for environment, create breathing problems, 48.33% of the respondents (145) have no idea about this and 9.33% of the respondents (28) said burning produce toxic gas. About 47.66% of the respondents (143) had given opinion to increase soil fertility, 15% of the respondents (45) said increases soil productivity, 13.3% of the respondents (41) said reduce chemical fertilizer using and 9% of the respondents (27) said decrease soil erosion. Some of the respondents said that, rice residue incorporation in soil saves money (5.66%), easy to apply (18.66%), eco-friendly (3.66) and have no idea about it (72%). About 55% respondents were satisfied in existing residues management system whereas 45% have given negative responses. Management of rice residues have faced the problem as lack of available labors (48%), costly (9%), lack of storing place (25.66%), lack of modern technology (12.66%). Most (70.66%) of the respondents (212) were collected information of residue management and environment pollution by the television and radio programmes. Finally, it can be said that, with the highest production of rice in our country, a huge number of residues are also produced. Rice residues may cause environmental pollutions and soil health degradation. Proper management is needed to overcome this environmental pollution as well as soil health degradation through enhancing suitable and environment friendly residue management practices.

Key words: Rice residue, management practices, environmental pollution, soil health

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Introduction

Bangladesh is an agriculture based country. Among the agricultural sector in crop production rice (*Oryza sativa* L.) is the most important crop of the country from the perspectives of production volume, value, cultivated land coverage and employment generation (BBS, 2017). Rice contributes to 70% of agricultural GDP. Bangladesh is now the fourth largest rice producer after China, India and Indonesia (FAO, 2016). Rice residue comprises 70 percent of the total yearly crop residue produced in Bangladesh (ASB, 2008). Since Bangladesh is also a climate vulnerable and other natural disasters oriented country so that there are huge research works conducted on climate vulnerability (Haque *et al*., 2019; Afrin *et al.*, 2017), mostly on rice production and its related to rainfall (Rokonuzzaman *et al*., 2019), drought, flood, storm etc. Over half of the world's population depends on rice as a staple food (Muthayya *et al*., 2014). For every ton of rough grain harvested, approximately 1.35 tons of rice straw is produced – around one billion tons per annum in total (Kadam *et al*., 2000). This makes rice straw the third-largest agricultural residue globally (Abbasi and Abbasi, 2010).

Rice residues are the materials left in an agricultural field after the crop harvested (stalks, stems, leaves and seed pods). Normally, these are either harvested as fuel, animal bedding or are burnt in the field. Left on the soil surface, crop residue serves as a mulch to decrease soil temperature and maintain higher soil moisture as well as reduce carbon emission in the atmosphere (Wilhelm *et al*., 2004). In addition, these can be used as animal fodder. Moreover, these residues also contain chemical residues which can be harmful for human/animal health and also cause for air pollution. Little research conducted on residue of chemicals in different crops, fruits, and vegetables in Bangladesh (Islam *et al.*, 2020; Yeasmin *et al.*, 2019; Islam *et al.*, 2015a,b). It is also one of the important task for future research era in Bangladesh. However, it is a great challenge for the agriculturists to manage rice residues effectively and efficiently in order to enhance crop production. In order to manage rice residue in the field, farmers in Bangladesh have three options: (a) burn residue in the field, (b) incorporate residue into the field, and (c) remove residue from the field, either for burning along with cow-dung or for feeding cattle herds.

Organic matter is essential to maintain the soil's capacity to regulate the availability of macro- and micro-nutrients (Alexander, 1976). More recently, SOM has become viewed as a potential source of atmospheric CO_2. Therefore, conserving or increasing its content in the soil is justified not only from an agricultural perspective but also from an environmental point of view (Elliot *et al*., 1994). Organic matter plays a key role in maintaining the fertility of acid soils since the clay mineral is mainly kaolinite (Bationo *et al.*, 1991). In many agricultural systems crop residues can be returned to the soil beneficially, but not in the intensive flooded rice systems that predominate in Asia, where 87% of global rice production is located (USDA, 2015). Thus rice straw is often burnt in the fields, resulting in airborne emissions that are hazardous to human and ecosystem health (Korenga *et al*., 2001). Miah *et al.* (2019) reported on environmental health related hazardous elements produced from burning in household products where rice residues were burnt in rural areas.

Burning of rice residue results in loss of the C and N sequestered in the biomass, it pollutes the air and contributes to global warming by CO_2 evolution. Rotations with legumes that are efficient in fixing atmospheric N_2 and in returning N to the soil through crop-residue incorporation have been widely studied elsewhere (Rembon, 1997). Epidemiological studies show that the contamination of air quality increases adverse health impacts (Ostro *et al.* 1995). In Bangladesh different research group worked on rice residues and its impact in air pollution, like-atmospheric contents of PM (Hasan *et al.*, 2020), air

pollution caused by rice straw burning in rural areas (Sarker *et al.*, 2018), metals contamination in agricultural fields which would burnt after rice residue management (Das *et al*. 2019), perception, awareness and health impact of air pollution in rural areas studied by a group (Islam, 2018) where buring of rice residues mentioned, a combined impact of brick kilns and rice residues burning in field- a major issue for air pollution (Islam *et al.*, 2017) etc. Many of the components of agricultural smoke cause health problem because of crop residues burning. Another common approach is mulching, which releases large quantities of methane – a potent greenhouse gas (Liu, 2016). Also the anatomical features of plants affected by dusts created from rice residues burn into the field, the roadside plant's anatomy observation data was reported by a group of researcher in Bangladesh (Mitu *et al.*, 2019).

So there is a need to adopt ways and means to manage this valuable resource. In this article, crop residue potential particularly of rice crop, its management practices and reduced tillage options and soil properties associated with rice residue management etc. are discussed. There is lack of information on the management of crop residues in Bangladesh as well as Mymensingh region. The main objectives of this study are to explore various practices of rice residue in the field, to assess the impact of rice residue practice on the succeeding crop productivity and to suggest better options for the efficient management of rice residue considering soil health and environmental pollution.

Materials and Methods

The methodology for this study includes site selection, observation and field level data collection through inventory, questionnaire survey and interviews in formal and non-formal ways.

Study area: The study was conducted in Mymensingh district including six upazilas (Mymensingh Sadar, Phulpur, Haluaghat, Gouripur, Ishwarganj, Muktagacha) (Figure 1). The Mymensingh town, which was earlier Nasirabad is situated on the bank of the old Brahmaputra.

Figure 1. Map showing the study area of Mymensingh district.

Preliminary field investigation: Preliminary information was attainted about the study area by preliminary investigation. During the period, the aim, scope and objectives of study were carefully maintained.

Development of survey schedule: In order to collect relevant information, a survey schedule was prepared in Bengali on perception of respondents for managing rice residues in the field considering soil health and environmental pollution. There total 300 respondents 50 for each upazila were participated in the interview (Table 1). Before finalizing the schedule, it was pre-tested for judging the suitability of schedules to respondents and necessary correction, modification and alterations were done accordingly.

Period of data collection: The study was conducted using the stratified random sampling technique over a period of 5 months, from January 2018 to May 2018. On site sampling was started from January 2018 and the primary data collection was finished by the end of April 2018.

Method of data collection: Collection of data for farm management study involves compromises and the judgement of the analyst in selecting data collection methods within the limits impose by the resources available for the work. As far as data collection tools were concerned, the conduction of the research involved the use of semi-structured questionnaire with certain and some additional questions.

Table 1. Study area and numbers of respondents**.**

Name of upazila	No. of respondents
Haluaghat	50
Muktagachha	50
Gauripur	50
Ishwarganj	50
MymensinghSadar	50
Phulpur	50
Total	**300**

Collection of data: The data were collected from randomly selected farmers of the selected areas from pre-prepared questionnaire interviewed. The study was conducted at different villages of Mymensingh district where farmers have been following crop residue practices. FGD, Field surveys and key informant interviews (KII) were followed to collect primary data. For secondary data information from GOs and NGOs and different reports, publications, notifications, etc. relevant to this study were also collected.

Analysis of data: After completion of the field survey, the information obtained from all of the respondents were coded, compiled and transferred to a master sheet for tabulation and statistical analysis. Basic statistics such as number and percentage distribution were used for analysis. A number of graphs were also used and the relationship between two variables was also investigated.

Results and Discussion

The results of the respondents' knowledge on rice residue management practices in Mymensingh region focusing on environmental pollution and soil health have been discussed under the following sub-headings.

Characteristics of the rice grower respondents

In the study there were four selected characteristics of rice grower viz. age, level of education, family member, and farm size. The composite findings of the selected characteristics of the respondents are presented in Table 2 and have been discussed in subsequent sections.

Age: The respondents were from different age groups; for the purpose of analysis, they were classified into three groups, these were ranges from 15-25 years, 26 to 40 years, and above 41 years. It was observed that among 300 farmers, most of them were in the range of 25-40 years and the lowest range of 15-25 years (Table 2).

Education level of the respondents: During the study, questions were asked about the level of education of the respondents. It was clustered into five categories and the rates were 36%, 25.66%, 21%, 13.66% and 3.6% for illiterate, primary, secondary, higher secondary, graduate and above respectively. The highest level of education among the respondents was up to illiterate level. Only 3.6% of the respondents completed their graduation in the study area (Table 2). During the Focus Group Discussion, they have mentioned that earlier there were few educational institutions and poor communication system. However, after the industrialization of this area road communication system has developed significantly.

Categories of farms: Out of 300 rice growers participated in the field study, maximum 35.33% of them (105) were medium farmers, whereas 24.66% farmers (74) were under small category, 22.33% of them (67) are marginal farmers and the lowest proportion 18% of respondents (53) were under large farmer's category (Table 2). Rice is the main crop of the respondents. Besides, winter vegetable, potato and wheat are more prominent crop cultivated by the respondents.

Family size: The family size was found small, medium and large group based in the number of persons. In small family there were family members 4 or below (24.33%), in medium above 4 but not more than 6 persons (60.66%), and in large above 6 persons (15%) respectively (Table 2).

Table 2. Classification of the respondents according to their selected characteristics.

Characteristics	Scoring system	Category	Number (N=300)	Percent
Age	Years	Young (15-25)	39	13.00
		Middle-aged (26-40)	200	66.66
		Old (>40)	61	20.33
Level of education	Level of Schooling	Illiterate	108	36.00
		Primary	77	25.66
		Secondary	63	21.00
		Higher Secondary	41	13.66
		Graduate & above	11	03.66
Family member	Numbers	Small (1-4)	73	24.33
		Medium (5-6)	182	60.66
		Large (above 6)	45	15.00
Farm category	Acre	Marginal (0.05-1.49)	67	22.33
		Small (1.50-2.49)	74	24.66
		Medium (2.50-7.49)	106	35.33
		Large (above 7.50)	53	17.66

Source: Field survey, 2018

Respondents perception on rice residue

Procedure of utilizing rice residue: According to the opinion from the 300 respondents, most (54.33%) of them (162) incorporate the rice residue in the field, collect for using as cooking fuel (23%), use as animal feed (16%). Small numbers (4.33%) of the respondents (13) collected rice residue for selling purpose. A very small amount (2.33%) of the rice residue was burnt in the field. It was a good sign for the environment to escape from air and so other chemicals in smoke pollution (Table 3).

Due to growing repeated cereal crops, soil fertility and crop productivity are reducing over the time. Crop residue practice is suggested for the purpose of preserving and enhancing productivity (Wilhelm *et al.* 2004).

Reason for incorporation/burn: From the opinion of respondents, a large number of them (130) have no knowledge why they incorporated rice residues in the fields. About 22.66% of the respondents (68) said rice residues increase soil organic matter (Figure 2).

Table 3. Distribution on the procedure of utilizing rice residue in study sites.

Procedure of utilizing rice residue	Number of respondents [N=300]	% response
Use for animal feed	48	16
Cooking fuel	96	23
Incorporation in the field	162	54.33
Burning at the field	7	2.33
For sale	13	4.33

The above table indicates similar result with the survey result of Powlson *et al.* (2008) which showed that greater savings in carbon emissions and climate change mitigation can be obtained by removing the

straw and using it for energy generation. Most of these respondents reported that an improvement in crop productivity and soil fertility is the result of residue incorporation in the field.

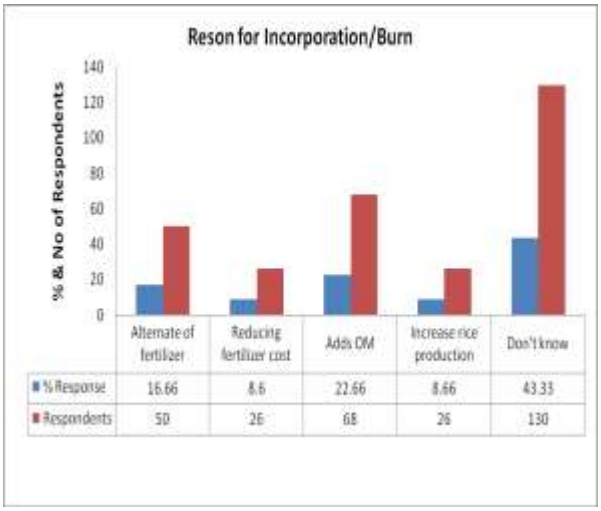

Figure 2. Reason for incorporation/burn of rice residue by the respondents from the study areas.

Management system of rice residue by respondents: Out of 300, the maximum (54.4%) respondents incorporated their rice residue as management, 43.33% use rice residue for the purpose like cow meal, cooking fuel and so many. A very less number of respondents burn (2.33%) their rice residue as management system and it was an important part of environment pollution issue. Among this rice residue management system, about half of the respondents use lower part and whole the residue for incorporation, burn and other use purposes respectively. In management system, a large share (72.04) of the respondents used whole the residue in other use purposes (Figure 3).

The results found from the study by the opinion of the respondents, in Mymensingh a very few respondents burn their rice residue and it is a good indicator for the environment. The smoke of residue burning has various chemical component including heavy metals and all those are hazardous pollutants for the environment. In Bangladesh, farmers use rice residues mainly as cattle feed.

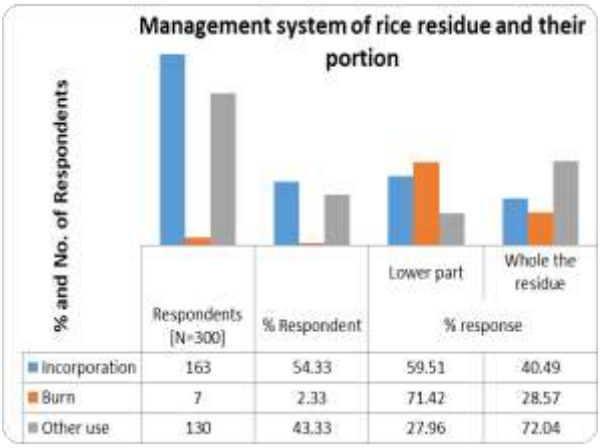

Figure 3. Distribution of respondents on different management practices of rice residues in study areas**.**

Operational tool for incorporation: Out of 300 respondents of the six upazila in Mymensingh district, about 55% of the respondents incorporate the rice residue as management policies. They used various tools for the incorporation of rice residue in the rice fields. Operation in incorporation of rice residue most of them (106) used disc plough as operational tool, whereas 17.33% used country plough, 2.33% burn (7) and 1.66% incorporate their (5) residue as irrigation respectively. Rest of 43.33% respondents (130) didn't use incorporation as the management of rice residue in their rice fields (Table 4).

Table 4. Operational tool for incorporation.

Operational tool for incorporation	Number of respondents [N=300]	% response
Country plough	52	17.33
Disc plough	106	35.33
Complete burning	7	2.33
Irrigation	5	1.66
Harrow	0	0
Don't use	130	43.33

Rice residue burning harmful for environment: According to the respondents in the study area, they

had no idea (48.33%) about the harmful effect of rice residue burning in the rice field as residue management because most of the respondents were illiterate. The knowledge of environmental issue was unknown to them. They only said that when burning it produces smoke (33.66%), heat (10%), reduces moisture (1.66) of the soil. Some of them said that, burning of rice residue in the rice field also reduces the organic matter (6.33%) and ruins (2%) the surface layer of the soil (Table 5).

Table 5. Residue burning harmful for environment.

Residue burning harmful for environment	Number of respondents [N=300]	% response
Produce smoke	95	33.66
Reduce OM	19	6.3
Produce excessive heat to soil	30	10
Ruins the litter layer	6	2
Reduce soil moisture	5	1.66
No idea	145	48.30

Field burning of crop residue converts a great deal of nutrients to gaseous form, which is then lost from the site. For example, some of the carbons contained in the crop residue is lost if it is burnt in the field (Ghimire, 2007). Moreover, the burning of residue gives rise to emissions of Heavy Metals (HM) and dioxin (Webb *et al.*, 2009). While a study by Brady and Weil (2002) has shown that crop residue burning in the field emits large quantities of CO, CO_2, particulate matter and volatile hydrocarbons into the air, EIA (2008) has found that it emits methane and nitrous oxide which cause pollution and climate change.

Health hazards of burning of rice residue: In this study area, a little (2.33%) number of respondents (7 out of 300) practiced burning of rice residue. Among them 31.66% told that, it creates breathing problems, produces toxic gas (9.33%), feel discomfort (14%) and had no idea (45%) respectively (Figure 4).

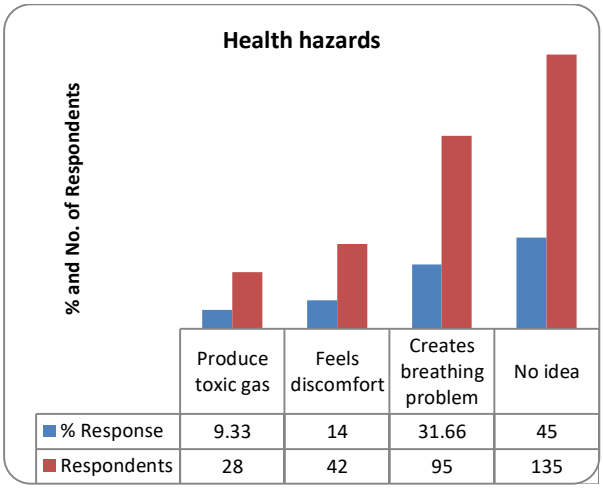

Figure 4. Opinion of respondents about health hazards of burning of rice residue in the study areas.

Stubble burning is not only injurious to human health due to environmental hazards involved with it, the process is also harmful for farmers as several friendly pests are burnt in the fire. Burning of straw emits emission of trace gases like CO_2, CH_4, CO, N_2O, NOX, SO_2 and large amount of particulates which cause air pollution. Thus contributes to respiratory diseases like eye irritation, bronchitis, emphysema, asthma etc.

Residue incorporation to improve soil health: Most (48%) of the respondents (144) have no idea about the benefit of the incorporation of rice residues in the field. About 30.66% of the respondents (92) said, it increases soil fertility, increase productivity 15% of respondents (45), reduce chemical fertilizer using only 3.33% of respondents (10), balances soil temperature 1% of the respondents (3) and improve soil moisture 2% of the respondents (6) respectively (Table 6).

The results from the respondents were not very satisfactory and the knowledge about management and benefits of incorporation of rice residues in the soil need to be increased among the respondents**.**

The incorporation of crop residues in the field is beneficial in recycling nutrients, but sometimes leads to temporary immobilization of nutrients (e.g. Nitrogen) thus increasing C:N ratio. But field

incorporation of residue is more advantageous and beneficial than field burning or removal (Mandal *et al.*, 2004). The study of Singh *et al.* (2001) shows that, the grain yield of wheat and following rice have not been adversely affected by in situ incorporation of rice straw in soil 10, 20, or 40 days before wheat sowing. It does not even show residual effect on succeeding rice crop.

Table 6. Residue incorporation improve soil health.

Residue incorporation improve soil health	Number of respondents [N=300]	% response
Increase soil fertility	92	30.66
Increase soil productivity	45	15
Reduced chemical fertilizer using	10	3.33
Balances soil temperature	3	1
Improve soil moisture	6	2
No idea	144	48

Management of rice residue affect soil health: The respondents were divided in various group in their answer regarding their opinion on soil health of rice residues management. A large number (50.66%) of the respondents (152) said it was very well for soil health whereas 30% of the respondents (90) said somewhat well. About 4.66% of the respondents (14) said as extremely well. There also found, 11.33% of respondents (34) said it was not so well for soil health of the present rice residue management system (Table 7).

The retention of plant residues on the soil surface has frequently been associated with an increased incidence of crop diseases (De Boer *et al.* 1993). It can further exacerbate soil-borne diseases in no-till systems because of the lack of soil disturbance.

Rice residue as fertilizer improving soil health: According to the opinion of the 300 respondents during study period, most of the respondents answer that, rice residue make soil fertile (47.66%). Many of respondents said that residues were used as compost fertilizers (25%) and a small number (13.66%) of them said that, it had reduced the use of chemical fertilizers used. Some respondents told that rice residue decrease soil erosion (9%), improve moisture (4.66%).

The return of residues to the soil has immense potential for providing plant nutrients (Nepal, 2007) because it increases the N, P, K and C supplies to the soil (Bird *et al.*, 2001; Sharma and Prasad, 2008;), which in turn lead to a reduction in fertilizer dependency for crop production (Bird *et al.*, 2001).

Table 7. Management of rice residue affects soil health.

Management of rice residue affect soil health	Number of respondents [N=300]	% response
Extremely well	14	4.66
Not so well	34	11.33
Very well	152	50.66
Not at all well	10	3.33
Somewhat well	90	30

Rice residue is better than chemical fertilizer using: Some of the respondents said that, rice residue was better than chemical fertilizers using. Chemical fertilizers have so many side effects on soil as well as environment. Chemical fertilizers also pollute the environment. Rice residue use in soil saves money (5.66%), easy to apply (18.66%), eco-friendly (3.66%) and have no idea (72%) about it (Table 8).

Use of organic residues has been shown to enhance nutrient cycling, improve nutrient use efficiency, and increase productivity in rain-fed lowland rice systems. Available on-farm residues include rice straw, rice hulls, and farmyard manure (FYM). Straw accounts for approximately 60% of aboveground biomass and is probably the most abundant on-farm residue available.

Table 8. Rice residue is better than using chemical fertilizer.

Rice residue is better than using chemical fertilizer	Number of respondents [N=300]	% response
Saves money	17	5.66
Easy to apply	55	18.66
It's eco-friendly	11	3.66
No idea	216	72

Effectiveness of existing management of rice residue: In the view of effectiveness of existing management system of rice residue, a large number of the respondents were given positive response and a small number of respondents given negative response. About 55% respondents were satisfied in existing residues management system whereas 45% have given negative response (Figure 5).

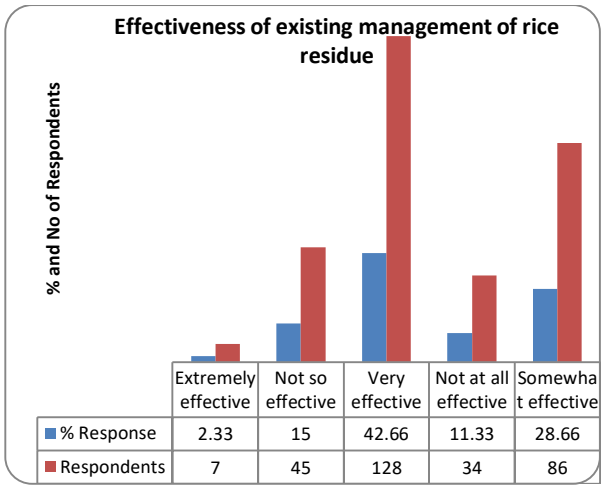

Figure 5. Effectiveness of existing management of rice residue by the respondents from the study areas.

Satisfaction of existing rice residue management system: During the study period, a common question was drawn to all the respondents about their satisfaction of existing rice residue management system. According to the answer of the 300 respondents, about 55% of the respondents (165) had given positive answer whereas 45% of the respondents (135) negative answer (Table 9).

Table 9. Satisfaction of respondents on existing rice residue management system.

Reponses of the respondents	Number of the respondents [N=300]	% Response
Yes	165	55
No	135	45

Problems of rice residue management: Major problem identified during field survey was lack of labors (48%) to management of rice residue. Moreover, lack of storage place (25.66%), lack of modern technology (12.66%) and costly (9%) management of rice residues to the respondents respectively (Table 10). There are also lacking of knowledge about the management system and lack of awareness about environmental issues.

Table 10. Problems related to rice residue management in the study areas.

Problems of rice residue management	Number of respondents [N=300]	% response
Labors not available	144	48
Costly to manage	27	9
Lack of storing place	77	25.66
Waste by animals	6	2
Lack of modern technology	38	12.66
Wets in water	8	2.66

In our country, most of the farmers are poor and illiterate. They have no ability to manage rice residues by appointing laborer after harvesting of rice from the fields, because it is very much costly for the farmers. There are also lacking of knowledge about the

management system and lack of awareness about environmental issues.

Primary source of environmental information: The main source of knowledge about rice residues management in the rural is TV and radio. Maximum (70.66%) respondents (212) collect information from TV and radio. Newspaper and magazine (15%) were other sources to the respondents (45) about the information of environment. This amount was very small as most of the respondents were illiterate and small number of literate respondents didn't read newspaper daily.

Conclusion

This study determined options of rice residue in Mymensingh and the options available for respondents to manage their rice residue. Major utilization options of rice residue were identified which are: animal feed, cooking fuel, incorporation with tillage for organic fertilizer and mulching and burning in the rice fields. Respondents' perceptions about the use of rice residues were mostly adding organic matter to the rice field followed by mulching and feeding animal. The recycling of resources among rice retention has the great potential to return a considerable amount of plant nutrients to the soil in the rice based production systems. Thus, proper management of rice residues for the maintenance of soil fertility cannot be overstressed. The sampled respondents were reported that they were benefited from retention of rice residues by improving soil quality, soil moisture, etc.; and farmers used fewer amounts of fertilizer, irrigation water, etc. for the succeeding rice production.

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