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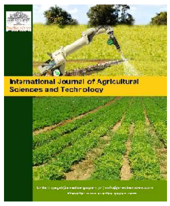

Research Paper

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Influence of non-puddled transplanting and residues of previous mustard on rice (*Oryza sativa* L.)

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Abstract

On-farm research was conducted at Gouripur sub-district under Mymensingh district of Bangladesh during the *boro* (mid November-June) season in 2013-14 and 2014-15 to evaluate the performance of non-puddled rice cultivation with and without crop residue retention. The rice var. *BRRI dhan28* was transplanted by two tillage practices, *viz.*, puddled conventional tillage (CT) and non-puddled strip tillage (ST) and at two levels of mustard residues, i.e., no-residue (R_0) and 50% residue (R_{50}). The experiment was designed in a randomized complete block design with four replications. There were no significant yield differences between tillage practices and residue levels in 2013-14. But in the following year, ST yielded 9% more grain compared to CT leading to 22% higher Benefit-Cost Ratio (BCR). Retention of 50% residue increased yield by 3% compared to no-residue, which contributed to 10% higher BCR. The ST combined with 50% residue retention yielded the highest grain yield (5.81 t ha^{-1}) which contributed to fetch the highest BCR (1.06).

Keywords: *Crop residues, Non-puddled, Strip tillage, Yield*

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1. Introduction

Most of the rice (*Oryza sativa* L.) farmers in the Asian continent establish seedlings by transplanting in puddled soil. Lands is prepared by one or two passes in dry condition followed by exposure to the sun for a couple of days. Then after inundation, the final field is prepared by ploughing, cross ploughing and laddering in standing water. However, this traditional puddling method is labor, fuel, time and capital consuming (Islam *et al.*, 2014). Nowadays most of the tillage

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operations for puddling soil in Bangladesh are done by power tiller which is detrimental to physical soil conditions through destroying soil aggregates, breaking capillary pores, and dispersing the soils (Miah *et al.*, 2002). Moreover, puddling produces a hard setting soil when dry which makes land preparation difficult for the following crops (Islam *et al.* 2012). Not only that, puddled rice transplanting consumes about 20-40% of the total water required for raising a crop, and it also promotes the formation of hardpan (Singh *et al.*, 2014). Furthermore, it reduces soil organic carbon which apart from decreasing soil fertility accelerates the losses of irrigation water and damage to the environment (Sayre and Hobbs, 2004). Adoption of minimum tillage and non-puddled transplanting might be an alternative to puddled transplanting to overcome these destructive impacts (Singh *et al.*, 2014). This technology has potential to allow saving in labor, energy, water and time during rice establishment as well as improving soil fertility (Islam *et al.*, 2012). Concerning the soil health, another agronomic option is the retaining the residues of previously cultivated crops for their effects on soil physical, chemical and biological functions as well as water and soil quality and on crop yield (Kumar and Goh, 2000). Residue retention maintains soil micro-organisms and microbial activity which can also lead to weed suppression by the biological agents leading to increase crop yield (Shrivastav *et al.*, 2015). Considerable research work was done on puddled transplanting, but there is limited information on non-puddled rice transplanting with crop residue retention under Bangladesh conditions (Haque *et al*. 2016; Haque and Bell, 2019). Therefore, the present study was conducted to examine the performance of rice using non-puddled transplanting system with the retention of mustard residues.

2. Materials and methods

The experiment had conducted on a farmer's field of Durbachara, Gouripur, Mymensingh, Bangladesh (the latitude of 24.75° N and the longitude of 90.50° E) (Figure 1) during the *boro* (mid November-June) season in 2013-14 and 2014-15. This experimental area belongs to the Old Brahmaputra Floodplain, which is characterized by dark grey non-calcareous alluvium soils belonging to the *Sonatala* series. Soil characteristics are presented in Table 1. Climatic (rainfall and thermal condition) data were collected from the nearest weather station and illustrated in Figure 2. The treatments were: (i) puddled soil condition following conventional tillage (CT) and (ii) non-puddled soil condition using strip tillage (ST) and; two levels of mustard residues, *viz*., no-residue (R_0) and 50% residue (R_{50}). The treatments were laid out in randomized complete block design with four replications using unit plots of 9 m × 5 m. In tillage practice, CT consisted of two passes of primary rotary tillage by two-wheeler tractor (2 WT) and exposure to the sun for two days followed by inundation of the whole plot and puddling by 2WT with two passes to complete land preparation. The ST was done by a Versatile Multi-crop Planter (Haque *et al.*, 2016) in a single pass operation before flooding the field. Three days before ST, pre-plant glyphosate herbicide was applied @ 75 ml 10 L^{-1} water. After ST, the land had inundated with 3-5 cm standing water for one day before transplanting to allow the disturbed strip to soft enough to transplant seedlings (Islam *et al.*, 2014). Thirty-five day-old seedlings of rice var. *BRRI dhan28* were transplanted. Fertilizers have applied according to the

Figure 1: Map of Bangladesh showing the site of on-farm experiment

Table 1: The morphological, physical and chemical properties of soil (0-15 cm) of the experimental field			
A. Morphological characteristics			
i.	Soil Tract	:	Old Brahmaputra Alluvium
ii.	Soil Series	:	Sonatola Series
iii.	Parent materials	:	Old Brahmaputra River Borne Deposit
B. Physical characteristics of soil			
i.	Sand (2.00-0.50 mm)	:	25.2%
ii.	Silt (0.5-0.002 mm)	:	72.0%
iii.	Clay (< 0.002 mm)	:	2.8%
iv.	Textural class	:	Silty loam
C. Chemical characteristics of soil			
i.	pH	:	6.71
ii.	Organic matter (%)	:	0.93
iii.	Total nitrogen (%)	:	0.13
iv.	Available sulphur (mg kg^{-1})	:	13.9
v.	Available phosphorus (mg kg^{-1})	:	16.3
vi.	Exchangeable potassium (cmol kg^{-1})	:	0.28

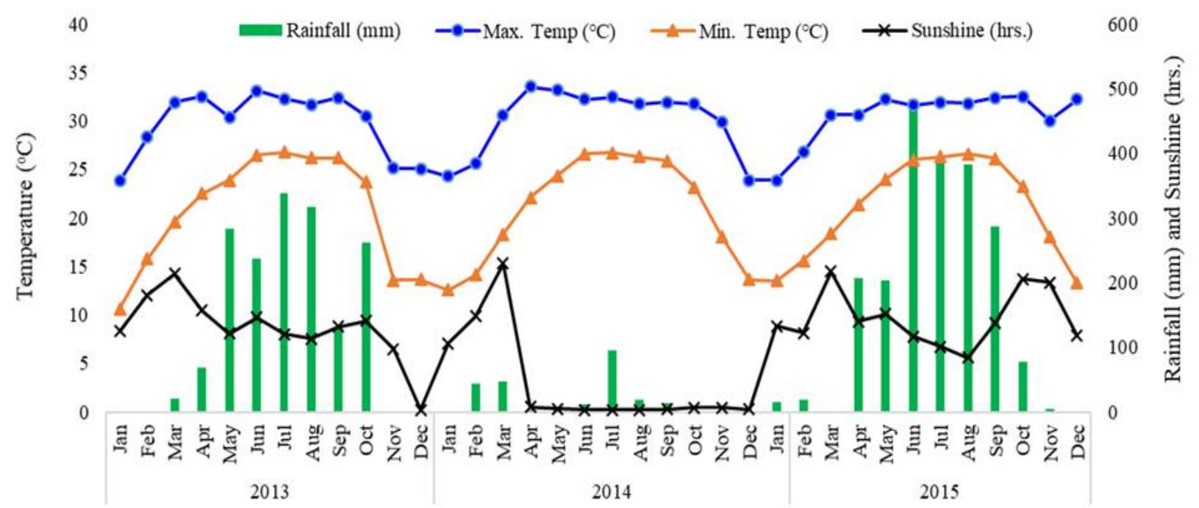

Figure 2: Monthly average temperature, total rainfall, relative humidity and sunshine hours of the experimental site in 2013-2015

recommendation of BRRI (2014). A spacing of 25 cm × 15 cm was maintained for both CT and ST with 2 or 3 seedlings $hill^{-1}$. The crops were harvested at maturity from 3 m × 3 m in each plot, and then data were recorded. Grain yield was adjusted to 14% moisture content. Data were subjected to two-way ANOVA using *STAR* software and means were separated by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

3. Results

3.1. Combined effect of tillage practices and residue levels on yield attributes, yield and the Benefit-Cost Ratio (BCR) of rice

Combination of tillage practice and residue levels exerted significant ($p \leq 0.05$) effect only on BCR while the rest of the parameters did not vary significantly ($p > 0.05$) during 2013-14. Whereas in 2014-15, a combination of treatments had a significant impact on all the parameters except plant height, panicle length, number of sterile spikelets panicle^{-1} and weight of thousand grain (Table 2). ST plus 50% residue produced the highest BCR which largely resulted from the highest grain yield. The highest grain yield might be attributed to the highest number of effective tillers m^{-2} and grains panicle^{-1}, and the lowest numbers of non-effective tillers m^{-2}. CT or ST with 50% residue yielded the higher values of these parameters compared to no-residue. CT without residue produced the lowest grain yield and BCR. Compared to CT and no-resdue, ST and 50% residue increased the grain yield and BCR by 9% and 22%, and 3% and 10%, respectively.

Table 2: Combined effect of tillage practice and residue levels on yield contributing characters and yield of rice

Tillage practices	Residue levels	Plant height (cm)	No. of effective tillers m^{-2}	No. of non-effective tillers m^{-2}	Panicle length (cm)	No. of grains panicle^{-1}	No. of sterile spikelets	1000 grain weight panicle^{-1}	Grain yield (t ha^{-1}) (gm)	Benefit-Cost Ratio
2013-14										
CT	R_0	109.3	207	45	24.2	162	53	29.5	5.21	0.73b
	R_{50}	111.5	211	43	24.6	158	54	29.2	5.19	0.71b
ST	R_0	110.8	209	43	24.6	158	53	29.8	5.20	0.80a
	R_{50}	109.1	207	44	24.5	160	55	30.3	5.20	0.88a
$LSD_{(0.05)}$		NS	NS	NS	NS	NS	NS	NS	NS	0.18
CV (%)		2.74	12.67	11.71	2.40	3.47	2.27	1.32	0.34	4.72
2014-15										
CT	R_0	108.3	359c	84a	24.3	100c	41	21.6	5.17d	0.78bc
	R_{50}	106.3	363c	70b	24.5	121b	39	22.2	5.29c	0.83c
ST	R_0	104.2	376b	53c	24.4	129ab	41	22.9	5.60b	0.92b
	R_{50}	106.3	388a	41d	24.2	139a	40	23.0	5.81a	1.06a
$LSD_{(0.05)}$		NS	6.50	4.25	NS	11.72	NS	NS	0.13	0.045
CV (%)		4.60	1.20	5.68	3.84	5.14	8.88	6.83	2.10	1.24

Note: In a column, the means with similar letters do not differ significantly at $p < 0.05$; CT = Conventional tillage, ST = Strip tillage, R_0 = No-residue, R_{50} = 50% residue, LSD = Least Significant Difference, and CV = Co-efficient of variance.

4. Discussion

4.1. Effect on the yield of rice

The higher yield in ST might have attributed to the changes in soil properties, *viz.*, the higher porosity and better soil moisture conservation in ST favored the more robust root growth and nutrient uptake resulted in increasing grain yield. These benefits however were evident in the second year but not in first year suggesting that they require at least a year to develop. These results agree Huang *et al.* (2012) who stated that minimum tillage (MT) non-puddled condition provides more favorable soil physical environment for better crop growth than CT. Pittelkow *et al.* (2015) and Qi *et al.* (2011) also reported that higher and more stable crop yields in MT than CT. In CT, heavy smearing of the sub-surface soil by rotary tillage forms a hardpan. Loss of structure, soil degradation and disruption of the soil pores are likely to hamper root growth especially in *Rabi* season (winter) crop.

On the other hand, crop yield increase in MT might have occurred from the improved soil structure and stability. They may facilitate better water holding capacity and drainage that reduces the extremes of water logging and drought (Holland, 2004), ultimately improving soil fertility by sequestering organic carbon in farmland soils (Alam *et al*., 2019). This finding supports the research result of Liu *et al.* (2010) who found 20% higher maize yield in MT than CT due to increase of soil organic carbon, soil total nitrogen and soil total phosphorus by 25, 18 and 7%, respectively. These results have implications for understanding how conservation tillage practices increase crop yield by improving soil quality and sustainability in non-puddled strip tillage practices as also reported by Hossain *et al. (*2016) and Mvumi *et al*. (2017). Some research findings also concluded no yield differences between ST and CT. Haque *et al*. (2016) found the similar grain yield of rice in non-puddled ST transplanting and CT, which confirms the earlier findings of Hossain *et al.* (2015) who also found no yield penalty of wheat and rice between ST and CT. In another study, Sharma *et al*. (2011) also reported similar rice yield in non-puddled transplanting to the CT. Wiatrak *et al.* (2005) found identical cotton yield in ST and CT while Al-Kaisi and Licht (2004) found the similar corn and soybean yield in ST, NT and CT. The finding of these studies confirms the result of the present study where no significant yield loss was found in the first year of the experiment.

In this study, retention of 50% of mustard residues increased the grain yield of rice by about 120-210 kg ha^{-1} over no-residue. Research finding of Shrivastav *et al*. (2015) confirm that standing residue converts to mineralized nutrients which causes sufficient crop growth and facilitates higher yield over no-residue. Kaschuk *et al.* (2010) and Qin *et al.* (2010) concluded straw residue retention directly increases the input of organic matter and nutrients into the soil, in turn improving soil nutrient availability for crop growth and better yield over no-residue. The earlier study of Thomas *et al*. (2007) and Govaerts *et al*. (2007) also found the benefits of residue retention on crop yield. Improved soil fertility and water availability might occur from the supplies of organic matter from straw residue for heterotrophic N fixing micro-organisms, which could increase nitrozen supply to the crops. Straw residues for controlling weeds in different crops was suggested by Devasinghe *et al.* (2011), and Hossain *et al.* (2016) concluded residues restrict weed growth and thus retards crop-weed competition.

4.2. Effect on the BCR of rice

Partial economic analysis disclosed that among the treatments ST with 50% residue earned the highest profit. Variation in BCR might have attributed to the variation in grain yield and cost required for rice cultivation. One hectare of land preparation in CT required $190.80 while ST required $35.80. Thus, ST saved around 68% of the cost for land preparation. This estimation is in line with Haque *et al.* (2016) estimating 70% savings in land preparation in ST over CT since the lowest land preparation cost was recorded in ST ($32.54 ha^{-1}) while the higher land preparation cost was incurred in CT ($110.29 ha^{-1}). Islam *et al.* (2014) estimated 49% savings from land preparation in ST over CT. Savings in ST might attributed to the fewer tillage passes and lower fuel consumption for land preparation than in CT. In addition to that, ST reduced labor requirements during land preparation. About 10% higher profit after retaining 50% residue might have occurred solely from 3% higher grain yield than no-residue. Therefore, the two year study confirmed that rice cultivation through practicing non-puddled strip tillage with the retention of 50% crop residue could achieve a higher profit compared to existing conventional tillage of rice cultivation in both years and higher yield in the second year of the experiment.

5. Conclusion

Based on this two-year study, we can conclude that non-puddled rice transplanting with the retention of crop residues was a profitable alternative to existing conventional tillage operation and farmers are likely to be benefited by increased profit through adopting this practice.

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