

Influence of unpudded transplanting on rice (*Oryza sativa* L.) retained residue of previous mustard

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Abstract

On-farm research was conducted at Gouripur sub-district under Mymensingh district of Bangladesh during *boro* (mid November-June) season in 2013-14 and 2014-15 to evaluate the performance of unpudded rice cultivation with 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 two levels of mustard residues, *i.e.*, no residue (R_0) and 50% residue (R_{50}). The experiment had 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 higher grains (5.72 t ha^{-1}), which was about 9.36 % higher compared to CT. The higher grain yield in ST, leading to 22.23% higher BCR compared to CT. Retention of 50% residue increased by 3.15 % yield compared to no-residue, which contributed to 10.58 % higher benefit-cost ratio (BCR). The ST combine with 50 % residue retention yielded the highest grain yield (5.81 t ha^{-1}) which credited to obtain the highest BCR (1.06).

Keywords: unpudded, strip tillage, crop residues, yield

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Introduction

Most of the farmers in the Asian continent cultivate rice (*Oryza sativa* L.) seedlings by transplanting in puddled soil for comfortable crop establishment. Lands had prepared by single 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 labour, fuel, time and capital consuming (Islam *et al.*, 2014). Nowadays most of the tillage operations for puddling soil in Bangladesh are done by power tiller and is detrimental to physical soil conditions through destroying soil aggregates, breaking capillary pores, and dispersing the soils (Miah *et al.*, 2002). Cloddy soil structure with less soil moisture and inadequate seed-soil contact resulted from the puddling 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). It also reduces soil organic carbon at a double rate, thus decreases soil fertility has losses of irrigation water and damages the ecological environment (Sayre and Hoobs, 2004). Adoption of minimum tillage unpudded transplanting might be an excellent alternative to puddled transplanting to overcome these destructive issues, as it is using widely for many crops around the world (Singh *et al.*, 2014). This technology has potentials to allow saving in labour, energy, water and time during rice establishment as well as improves soil fertility (Islam *et al.*, 2012). Concerning the soil health, another agronomic option is the retaining the residues of previously cultivated crops are a significant factor for crop production through their effects on soil physical, chemical and biological functions as well as water and soil quality and increase crop yield (Kumar and Goh, 2000). Residue practice 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 had done on puddle transplanting, but there is limited information on unpudded rice transplanting with crop residue retention under Bangladesh condition. Therefore, the present study had conducted to examine the performance of rice to the unpudded transplanting system with the retention of crop residues.

Materials and Methods

The experiment had conducted at farmer's field of Durbachara, Gouripur, Mymensingh, Bangladesh (the latitude of 24.75° N and the longitude of 90.50° E) (Fig. 1) during *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 and these soils are mostly sandy loam under Sonatala series (Brammer, 1996). Soil characteristics had presented in Table 1. Climatic (rainfall and thermal condition) data were collected from the nearest weather station and illustrated in Fig. 2. The treatments were: (i) puddled condition conventional tillage (CT) and (ii) unpudded condition strip tillage (ST) and two levels of crop residue *viz.*, no residue (R_0) and 50% residue (R_{50}). The treatments had laid out in randomized complete block design with four replications using unit plots of 9 m \times 5 m. In tillage practice, CT consisted of two passes primary tillage by two-wheeler tractor (2 WT) and exposed to the sun for two days followed by inundating whole plot and puddling by 2WT with two passes to complete land preparation. The ST had done by a versatile multi-crop planter in a single pass operation before flooding the field. Three days before ST, pre-plant glyphosate herbicide had applied @ 75 ml 10 L⁻¹ water. After ST, the land had inundated with 3-5 cm standing water one day before transplanting operation for making the soil soft enough to transplant seedlings (Islam *et al.*, 2014). Thirty-five days old seedlings of rice var. BRRI dhan28 had transplanted. Fertilizers have applied according to the recommendation of BRRI (2014). A spacing of 25 cm \times 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 \times 3 m each, and then data had recorded. Grain yield had adjusted to 14% moisture content. Data were subjected to ANOVA using STAR software and means were separated by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

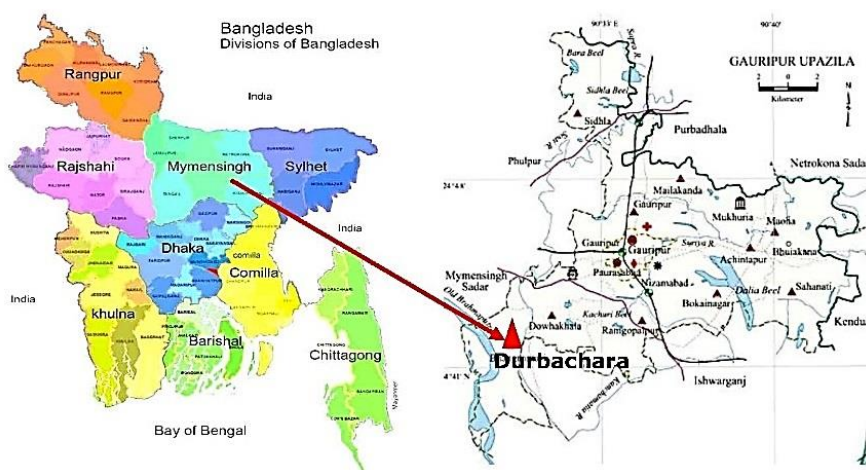


Figure 1. Map of Bangladesh showing the site of on-farm experiment

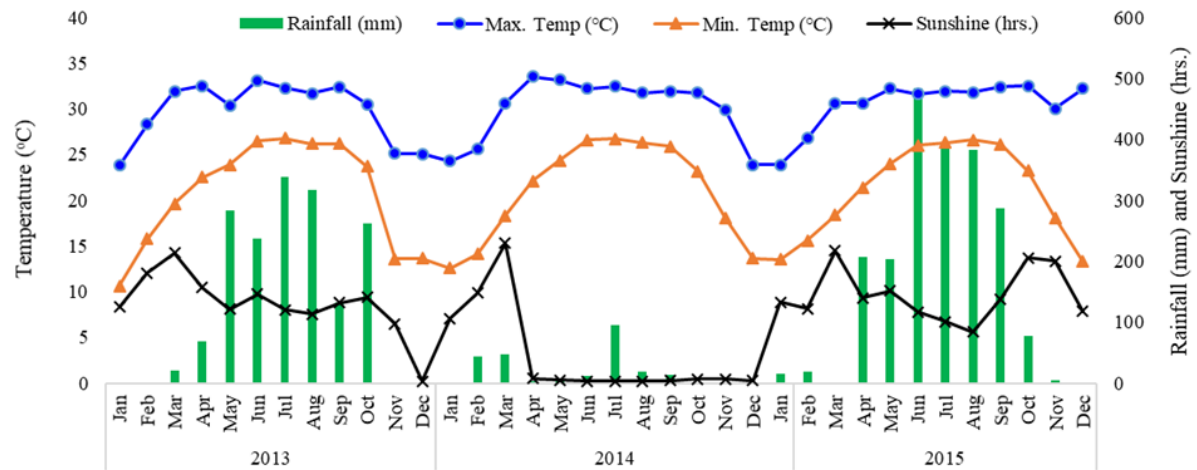


Figure 2. Monthly average temperature, rainfall, relative humidity and sunshine hours of the experimental site in 2013-2015

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.	p ^H	:	6.71
ii.	Organic matter (%)	:	0.93
iii.	Total matter (%)	:	0.13
iv.	Available sulphur (ppm)	:	13.9
v.	Available phosphorus (ppm)	:	16.3
vi.	Exchangeable potassium (ppm)	:	0.28

Results

Effect of tillage practice on yield contributing characters, yield and the benefit-cost ratio (BCR) of rice

In 2013-14, although none of the parameters except the BCR, varied significantly due to tillage practices but in 2014-15 yield contributing characters were significantly affected except the plant height, panicle length, and the weight of thousand-grains (Table 2). The highest and lowest numbers of effective and non-effective tillers m⁻², respectively as well as the highest and lowest numbers of grains and sterile spikelets panicle⁻¹, respectively, were recorded from

the ST which attributed to higher yield (9.36 % higher in 2014-15) in ST than CT. The higher yield in ST might have credited the higher BCR (22.23 % higher) compared to CT during this time (Table 2).

Table 2. Effect of tillage practice on yield contributing characters and yield of rice

Tillage practices	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 panicle ⁻¹	1000 grain weight (gm)	Grain yield (t ha ⁻¹)	Benefit-Cost Ratio
2013-14									
CT	110.4	209	44	24	159	47	30	5.20	0.72b
ST	109.9	211	44	25	157	49	31	5.17	0.88a
LSD _(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.13
CV (%)	2.74	12.6	11.7	2.4	3.47	2.27	1.32	0.34	4.72
2014-15									
CT	107.3	361b	70a	23.9	114b	41	21.9	5.23b	0.81b
ST	105.6	382a	56b	24.4	126a	40	23.0	5.72a	0.99a
LSD _(0.05)	NS	4.59	3.00	NS	8.29	NS	NS	0.09	0.03
CV (%)	4.60	1.20	5.68	3.84	5.14	8.88	6.83	2.10	1.24

In a column, the figure with similar letter do not differ significantly whereas dissimilar letter differs significantly
CT= Conventional tillage, ST= Strip tillage, CV=Co-efficient of variance

Effect of residue levels on yield contributing characters, yield and the benefit-cost ratio (BCR) of rice

During the first year of experimentation, there was no significant effect of residues on the yield and yield attributes of rice. But in the second year, retention of 50% residue improved the numbers of effective tiller m⁻² and the numbers of grain panicle⁻¹ while declined the numbers of non-effective tiller m⁻² and the numbers of sterile spikelets panicle⁻¹, compared to no-residue (Table 3). Retention of 50% residue yielded around 3.15 % higher rice which attributed to earning 10.58 % higher BCR in 2014-15 (Table 3).

Table 3. Effect residue level on yield contributing characters and yield of rice

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 panicle ⁻¹	1000 grain weight (gm)	Grain yield (t ha ⁻¹)	Benefit-Cost Ratio
2013-14									
R ₀	110.6	208	44	24.6	160	53	29.90	5.20	0.76
R ₅₀	109.5	209	43	24.5	159	54	29.88	5.19	0.79
LSD _(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	2.74	12.67	11.71	2.40	3.47	2.27	1.32	0.34	4.72
2014-15									
R ₀	104.9	368b	56b	24.4	115b	41	22.7	5.39b	0.85b
R ₅₀	106.3	376a	69a	24.5	130a	40	22.9	5.56a	0.94a
LSD _(0.05)	NS	2.65	1.73	NS	4.78	NS	NS	0.05	0.018
CV (%)	4.60	1.20	5.68	3.84	5.14	8.88	6.83	2.10	1.24

In a column, the figure with similar letter do not differ significantly whereas dissimilar letter differs significantly
CT= Conventional tillage, ST= Strip tillage, CV= Co-efficient of variance

Combination effect of tillage practice and residue levels on yield characters, yield and the benefit-cost ratio (BCR) of rice

Combination of tillage practice and residue level exerted significant effect only on BCR while the rest of the parameters did not vary significantly 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 4). Strip tillage retained 50% residue produced the highest BCR which might have credited from the highest grain yield. The highest grain yield might have attributed from 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 residue yielded the higher values of these parameters compared to no-residues. CT without residue produced the lowest grain yield, consequently the lowest BCR. Also, about 5.19 % higher yield had found in 2014-15 than 2013-14.

Table 4. Combination effect of tillage practice and residue level on yield contributing characters and yield of rice

Tillage practice	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 panicle ⁻¹	1000 grain weight (gm)	Grain yield (t ha ⁻¹)	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

In a column, the figure with similar letter do not differ significantly whereas dissimilar letter differs significantly

CT= Conventional tillage, ST= Strip tillage, CV= Co-efficient of variance

Discussion

Effect on the yield of rice

The higher yield in ST might have attributed from the changes in soil properties viz. the higher porosity and better soil moisture conservation in ST favoured the more robust root growth and nutrient uptake resulted in increasing grain yield. These results agree Huang *et al.* (2012) stating that minimum tillage (MT) unpadding condition provides more favourable soil physical environment for better crop growth than CT. Pittelkow *et al.* (2015) about Qi *et al.* (2011) also reported that higher and more stable crop yields in MT than CT. In CT, heavy grinding of the

surface soil by 2 WT forms hardpan by exerting massive pressure. Hence, leading to loss of structure and fusing the cultivated layer resulting in the disruption of the soil pores.

On the other hand, crop yield increase in MT might have occurred from the improved soil structure and stability. They were moreover facilitating better water holding capacity and drainage that reduces the extremes of waterlogging and drought (Holland, 2004), ultimately improving soil fertility by sequestering organic carbon in farmland soils (Zheng *et al.*, 2014). 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 unpaddded strip tillage practices as also clinched 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 unpaddded 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 unpaddded 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 had found in the 2013-14 year.

In this study, retention of 50 % of crop residues increased the grain yield of rice by about 3.15% over no-residue. Research finding of Shrivastav *et al.* (2015) confirm this stating residue converts to mineralized nutrients which causes sufficient crop growth and facilitates higher yield over no-residue. Kaschuk *et al.* (2010) in support 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 be utilized by the crops, consequently results in the higher yield. Straw residues for controlling weeds in different crops have suggested by Devasinghe *et al.* (2011), and Hossain *et al.* (2016) concluded residues prevent weed growth and thus retards crop weed completions. Hence, the crop is grown stronger and favoured to higher yield.

In this study, 5.19 % higher yield in the 2014-15 year than 2013-14 might be due to the variation of monthly average temperature, rainfall, relative humidity and sunshine hours of the experimental site during 2013-2015 (Fig. 2). Such interpretations of all climatic parameters during various phonological stages of rice *viz.*, germination to transplanting, tillering, and anthesis to physiological maturity exerted definite stresses on the growth and development of rice. Such pressures might have influenced to vary the yield in two consecutive years by controlling the variation of yield attributes such as the number of effective and non-tillers m⁻² and grains and sterile spikelets panicle⁻¹ (Safdar *et al.*, 2013).

Effect on the benefit-cost ratio (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 from the variation in grain yield and cost required for rice cultivation. One hector land preparation in CT required US\$ 190.80 while ST required US\$ 35.80. Thus, ST saved around 68% cost for land preparation. This estimation is in line with Haque *et al.* (2016) estimating 70% savings in land preparation in ST over CT showing the lowest land preparation cost had recorded in ST (US\$ 32.54 ha⁻¹) while the maximum land preparation cost had incurred in CT (US\$110.29 ha⁻¹). Islam *et al.* (2014) estimated 49 % savings from land preparation in ST over CT. Savings in ST might have happened due to the more significant number of tillage passes and fuel consumption for land preparation in CT.

On the other hand, ST reduced fuel and labour requirements during land preparation. About 10.58 % higher profit in 50% residue might have occurred solely from 3.15% higher grain yield than no-residue. Therefore, the study claimed that rice cultivation through practising unpadded strip tillage with the retention of 50% crop residue could achieve a higher profit compared to existing conventional tillage of rice cultivation in Bangladesh.

Conclusion

Based on the result of this study, we can conclude that unpadded rice transplanting with the retention of crop residues may be an excellent alternative to existing conventional tillage operation and farmers are likely to be benefited through adopting this practice.

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