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RESEARCH ARTICLE

Effects of the components of conservation agriculture on the profitability of rice (*Oryza sativa* L.) in the Eastern Gangetic Plain of Bangladesh

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Abstract: A two year longer on-farm research on conservation agriculture was conducted at Bhangnamari area of Bangladesh during November-June in 2014-15 and 2015-16 to evaluate the performance of non-puddled rice cultivation under increased crop residue retention. The rice variety *BRRI dhan28* was transplanted under puddled conventional tillage (CT) vs. non-puddled strip tillage (ST) with 50% standing residue (R_{50}) vs. conventional no-residue (R0) practice. The treatments were arranged in a randomized complete block design with four replications. There were no significant yield differences between tillage practices and residue levels in 2014-15. But in the following year, ST yielded 9% more grain compared to CT leading to 22% higher BCR. Retention of 50% residue increased yield by 3% over no-residue, which contributed to 10% higher benefit-cost ratio (BCR). Results of this two year on-farm study confirmed that the ST combined with 50% residue retention yielded the highest grain yield (5.81 t ha^{-1}) which contributed to produce the highest BCR (1.06).
Keywords: benefit cost ratio, conventional tillage, crop residues, non-puddled, strip tillage, yield

1. Introduction

Cultivation of rice (*Oryza sativa* L.) through transplanting the seedlings in puddled soil is the most common method in Bangladesh. In this method 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 plowing, cross plowing and laddering in standing water. However, this traditional puddling system is labor, fuel, time and capital consuming (Islam et al., 2015). Nowadays most of the tillage operations for puddling soil in the country 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., 2009). Moreover, puddling produces a hard setting soil when dry which makes land preparation difficult for the following crops. 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 (Alam et al., 2019).

Adoption of one of the components of conservation agriculture like the minimum tillage non-puddled transplanting might be an alternative to puddled transplanting to overcome these destructive impacts as this technology has potential to allow saving in labour, energy, water and time during rice establishment as well as improving soil fertility (Islam et al., 2012). Concerning the soil health, another component of conservation agriculture 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 & Goh, 1999). 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 (Sharma et al., 2011). 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. Therefore, the present study was conducted to examine the performance of rice using non-puddled transplanting in the form of strip tillage system with the retention increased level of the previously cultivated summer rice straw.

2. Materials and Methods

2.1. Experimental site and season

The experiment had conducted on a farmer's field of Bhangnamari under Mymensingh district of Bangladesh (24.75° N and of 90.50° E) during the November-June in 2014-15 and 2015-16 years.

2.2. Edaphic and climatic condition

This experimental area belongs to the Old Brahmaputra Floodplain, which is characterized by dark grey non-calcareous alluvium soils belong to the *Sonatala* series. Soil characteristics are presented in Table 1.

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The research site was characterized by high temperature, high humidity and heavy monsoon rainfall with occasional gusty wind during April-September and low precipitation with moderately low temperature during October - March. Monthly minimum and maximum temperature, relative humidity, rainfall and sunshine hours of 2014 - 2016 the maximum temperature varies from 32.3 - 33.5°C during April-June while January was the coldest month. About 95% rainfall was received during April-September. The rest of rainfall was very unevenly distributed and mostly uncertain. Sunshine hours differed much in December and January.

2.3. Experimental treatments and design

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 summer rice straw residues *viz*., no-residue (R_0) and 50% standing residue (R_{50}). The treatments was laid out in randomized complete block design with four replications using unit plots of 9 m × 5 m.

2.4. Planting operation

The 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., 2015). Thirty-five day-old seedlings of rice var. *BRRI dhan28* were transplanted. A spacing of 25 cm × 15 cm was maintained for both CT and ST with 2 or 3 seedlings $hill^{-1}$. In the no-residue treatment, planting was done without retaining residues of summer rice crop. In 50% residue practice previous summer rice was harvested keeping 50% plant standing in the respective plots.

2.5. Cultural operations

The recommended dose of nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) was applied. The N in the form of urea was applied @ 80 kg ha^{-1}. A basal dose of phosphorus (22 kg ha^{-1}) from triple super phosphate, potassium (35 kg ha^{-1}) from muriate of potash and sulfur (11 kg ha^{-1}) from gypsum was applied. The entire amount of P, K, and S was broadcasted before transplanting. The N was applied in three equal installments at 15, 30 and 45 DAT. Three irrigations were applied at 20, 55 and 80 DAT. Adequate plant protection measures were taken throughout the crop growing season as per the recommendations.

2.6. Measurements

Yield contributing characters as of Table 2 have transcribed from randomly selected ten hills before harvest. Harvesting had done at maturity when 80% of grains became golden yellow. The crops were harvested from the central 3 m × 1 m area from 3 spots of each plot and weighed. The weight of 1000 grains and yield was calculated at 14% moisture content. Finally, the grain yield had converted to t ha^{-1}.

The economics of crop production was estimated following the partial budgeting system. The variable costs were calculated based on labor requirement for sowing, transplanting, weeding, harvesting and threshing, irrigation, fertilization, and all other input costs like seed, residues, fertilizer, irrigation, etc. The gross return was calculated based on the market price of grain and byproducts. The gross benefit was calculated by deducting the variable cost from the gross recovery. The benefit-cost ratio (BCR) was calculated by computing the raio of gross income to total costs of production.

2.7. Data analysis

Data were subjected to analysis of variance where; treatment means were separated by the Duncans' Multiple Range Test at P<0.05. The statistical package program *STAR* was used to analyze all data.

3. Results and Discussion

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 2014-15. Whereas in 2015-16, 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). The ST plus 50% residue retained produced the highest BCR which largely resulted from the highest grain yield. The highest grain yield might be attributed to the highest number of productive tillers m^{-2} and grains $panicle^{-1}$, and the lowest numbers of sterile tillers m^{-2}. The CT or ST with 50% residue yielded the higher values of these parameters compared to no-residues. 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.

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 favoured 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 favourable 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 winter crop.

Moreover, the crop yield increase in ST 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) whofound 20% higher maize yield in ST 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

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how conservation tillage practices increase crop yield by improving soil quality and sustainability in non-puddled strip tillage practices as also reported by Mvumi et al. (2017). Some research findings also concluded no yield differences between ST and CT. Haque et al. (2017) 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 & 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 summer rice 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. 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 Harrington & Erenstein (2005) 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 microorganisms, which could increase nitrozen supply to the crops. Straw residues for controlling weeds in different crops have suggested by (Govaerts et al., 2007) who concluded the crop residues restrict weed growth and thus retards crop-weed competition and better environment for crops producing the higher yield.

Partial economic analysis of this study 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 US$ 190.80 while ST required US$ 35.80. Thus, ST saved around 68% of the cost for land preparation. This estimation is in line with (Bell et al., 2018) estimating 70% savings in land preparation in ST over CT since the lowest land preparation cost was recorded in ST (US$ 32.54 ha^{-1}) while the higher land preparation cost was incurred in CT (US$110.29 ha^{-1}). Islam et al. (2015) 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 fuel and labour 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 practising 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.

4. Conclusion

Based on this two-year study, we can conclude that non-puddled rice transplanting with the retention of 50% 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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Author Contributions

M.H. helped with design of field evaluation trials, data recording and analysis, and led the manuscript writing. M.B. and M.R. supervised the research. A.H and R.B. revised manuscript critically for important critical content. E.H. led the design and fabrication of planters.

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Table 1. The properties of soil at 0-15 cm depth of the experimental field

Parameters	**Values**
Sand (%)	25.2
Silt (%)	72.0
Clay (%)	2.8
Textural class	Silty loam
pH	6.71
Organic matter (%)	0.93
Total nitrogen (%)	0.13
Available sulphur (mg kg^{-1})	13.9
Available phosphorus (mg kg^{-1})	16.3
Exchangeable potassium (mg kg^{-1})	0.28

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Table 2. Combined effect of tillage practice and residue levels on yield contributing characters, yield and BCR of rice

Tillage practice	Residue levels	Plant height (cm)	Productive tillers m^{-2} (no.)	Sterile tillers m^{-2} (no.)	Panicle length (cm)	Grains $panicle^{-1}$ (no.)	Sterile spikelets $panicle^{-1}$ (no.)	1000-grain weight (gm)	Grain yield (t ha^{-1})	Benefit-Cost Ratio
2014-15										
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
2015-16										
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

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

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CONFLICTS OF INTEREST

"The authors declare no conflict of interest".