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Performance of non-puddled transplanted *boro* rice following mustard in a reduced rate of phosphorous and potassium fertilizer in Northern Bangladesh

Md. Abu Abdullah Miajy [1], M. Jahangir Alam [2], Md. Hazrat Ali [3], Sharif Ahmed [1*]

[1] *International Rice Research Institute, Bangladesh.*

[2] *Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jessore, Bangladesh.*

[3] *Krishi Gobeshona Foundation, AIC Building (3rd Floor), BARC Campus Farmgate, Dhaka-1215, Bangladesh.*

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[*] Corresponding Author;
E. Mail: s.ahmed@irri.org

ABSTRACT

Boro rice production in Bangladesh, which almost completely depends on irrigation water, is becoming less profitable and less sustainable because of the high cost of cultivation and the inefficient use of inputs such as water, labor, fertilizer, and energy. Shifting from puddled to non-puddled *boro* rice after a mustard crop may help advance the *boro* transplanting early, reducing the tilling cost and improving the soil fertility by less disturbance of the soil. The non-puddled *boro* transplanting, including zero tillage or reduced tillage, has not been practiced by farmers yet. Therefore, we conducted an experiment in twelve farmers' fields in northwestern Bangladesh to evaluate the performance of different non-puddled tillage operation and fertilizer management on *boro* rice production. The experiment tested three tillage systems (zero till, one pass till, and two passes till) and three level of fertilizer management (recommended N,P,K,S; reduced 50% P, and reduced 50% K) in a split-plot design. Zero-till produced the similar crop yield to the one or two pass till which was 5.9 t ha^{-1} and this yield was similar to the yield potentiality of the used cultivar. Fertilizer management recommended doses of N,P,K,S produced the maximum yield (6.1 t ha^{-1}) and reduced 50% K fertilizer has the similar yield (6.0 t ha^{-1}) to the recommended dose. The profitability was similar among all non-puddled tillage systems. The recommended N,P,K,S fertilizer, and reduce 50% K have similar net profit and the benefit-cost ratio (BCR); however, reduced 50% P had lower net profit and BCR than the recommended N,P,K,S fertilizer, and reduce 50% K.

1. Introduction

The most dominant cropping pattern in Bangladesh is *aman* (wet season rice) – fallow –*boro* (dry season rice) which occupied around 22% of the country area (Elahi et al., 2001). Both seasons rice are mostly grown by transplanting the seedlings into the puddled soil. For puddling, generally, lands are prepared by 3-4 times plowing and cross plowing operations followed by levelling in standing water. Puddling is beneficial to easy manual transplanting operation and seedling establishment, controlling weeds and creating anaerobic conditions which enhance nutrient availability (Sharma and Bhagat, 1993); however, continuous puddling in the same field adversely affect soil properties for upland crops grown in a rotation with rice (Sharma et al., 2003; Tripathi et al., 2005). Furthermore, puddling and transplanting is cost intensive operation in terms of fuel consumption, labor and machinery wear, and tear, and account for about 30-40% of the cost of *boro* production (Alam et al., 2017, Rashid et al., 2009). Puddling operations needed huge water which is accounted for 10-30% of the total irrigation water required for rice cultivation (Alam et al., 2017; Aslam et al., 2002). Adoption of non-puddled transplanting may be a good alternative to soil puddling which has the potential to achieve savings in labor, energy, water and time during rice establishment (Islam et al., 2014. It is reported from many previous studies that puddling of the soil is not essential for rice establishment by transplanting (Ahmed et al., 2002; Rashid et al., 2018). In Bangladesh, Haque et al. (2016) achieved similar or higher rice yields and lowered cost of production with manual transplanting into a non-puddled sandy loam soil. The minimum tillage is expected over time to alleviate degraded soil structure, particularly in rice –based cropping soils that experience annual soil puddling and intensive tillage. However, minimum tillage over time may weaken the plow pan and in turn, alter water balance in the rice-based systems. This implication of a change of water balance may be detrimental for rice but beneficial for following crops and for groundwater recharge.

Intensification and diversification in cropping systems in Bangladesh have been increasing from last decades to meet up food demand of growing population and increasing farm profit (Ahmed et al. 2016). However, the growing labor shortages and irrigation cost are likely to adversely affect the intensification and productivity of the rice-based cropping systems in Bangladesh (Ahmed et al., 2014). After developing the short duration *aman* varieties, the *aman*-mustard-*boro* cropping pattern is becoming popular in Bangladesh especially in the northern area (Islam et al., 2014). Following a mustard crop after *aman*, the fields have few weeds and good soil tilth because of dry tillage for the mustard crop and may be in a suitable condition for rice to be transplanted with reduced or no tillage. Transplanting into non-puddled soil could save time and reduce land preparation costs without hampering the yield (Haque et al., 2016; Islam et al., 2014). Farmers usually cultivated a short duration (75 -84 d) mustard between two rice and applied sufficient phosphorus and potassium fertilizer. In addition, huge mustard leaves fall down during the cropping and incorporated into the soil. We assumed that rice in a sequence with mustard may need less phosphorus and potassium fertilizer than recommend dose. Therefore, the aim of the present study was to evaluate the productivity of rice under non-puddled reduced and zero tillage with reduced phosphorus and potassium fertilizer.

2. Materials and methods

2.1. Experimental sites and seasons

On-farm farmers participatory trials were conducted during the *boro* 2014/15 at Khalisha Village in Saidpur Upazila of Nilphamari District, and Sabajpur Village in Rangpur Sadara Upazila of Rangpur District in Northern Bangladesh. The experimental sites belong to the Active Tista Floodplain under the agro-ecological zone, AEZ-2, a region of relatively medium high land (around 72%). The climate of the area is subtropical, with average annual rainfall of 2000 mm, 90% of which falls from June to October. The temperature at the beginning of the boro crop remain very low, therefore, farmers slightly delayed to start *boro* crop than the country average. The general soil type is silty loam to clay loam. The experimental site in each farmer's field had a similar crop management history and uniform soil type. The selected field was under mustard-T. *boro*- T.aman cropping systems at least last three years.

2.2. Experimental design and treatments

The study was conducted in twelve farmers' fields in a split-plot design and each field was considered a replication. The main plot treatments were three levels of dry tillage: zero tillage, single till pass, double till passes and subplot treatments were three fertilizer management levels: recommend fertilizer dose (100% of N,P,K,S), reduced 50% of P (phosphorous fertilizer was 50% of the recommended dose but other fertilizers were recommended dose), reduced 50% of K (potassium fertilizer was 50% of the recommended dose but other fertilizers were recommended dose). Each subplots size was at least 100 m^2. The details of the tillage treatments are as follows:

Zero-tillage (ZT): After the mustard harvest, the land was not plowed. A surface irrigation was applied 2-5 days before transplanting to sock the soil properly, and again irrigation just before/on the day of transplanting, and maintains a depth of 2-3 cm standing water above the surface.

Single tilled pass (STP): The soil was dry tilled using a two-wheel tractor (2WT) to a depth of 5-7 cm in a single pass, and then irrigation was applied at 1-2 days before transplanting to achieve a water depth of 2–3 cm above the surface.

Double tilled pass (DTP): The soil was dry tilled using a 2WT to a depth of 8-10 cm in a double pass, and then irrigation and transplanting operation were followed as similar to STP.

2.3. Crop management

All the treatments in each field were transplanted on the same day. The high yielding semi-dwarf rice cultivar BRRI dhan28 (duration 140 d) was planted in the experiments. Crop management practices were as recommended by BRRI (2011). The seedling nurseries were sown on 31 December to 15 January in 2014. The seedling was manually transplanted on 5 February to 15 February and 45-day old seedlings were transplanted with 2–3 seedlings per hill and 20 cm×20 cm hill spacing. Fertilizer was applied based on a regional recommendation (FRG, 2012). The fertilizer rates were 120, 20, 50, 13, and 2 kg ha^{-1} N, P, K, S and, Zn, respectively, for the recommended fertilizer treatment. The total amounts of P as triple superphosphate, K as muriate of potash, S as gypsum, and Zn as zinc sulfate were broadcast manually prior to the transplanting of ZT, and prior to dry tillage in STP and DTP. Nitrogen as urea was top-dressed uniformly on the surface of the soil by hand in equal three splits at 10-15, 25-35 and 40-50 days after transplanting (DAT) in all the treatments. The main plot was isolated by keeping 75 cm spaced before tilled, and sub-plot was isolated by keeping 50 cm spaced before basal fertilizer application. The isolated spaced was marked by putting stick and thread. The plots were irrigated with water from a shallow tube well when needed and continued until the rice grains reached the hard dough stage. Weeding was done manually by 2-3 times hand weeding and insect and disease management was need-based.

2.4. Observations

The number of tillers was counted on 5 hills taking from a line and at 3 spots in each plot at early tillering (ET), mid-tillering (MT), flowering (FL) and physiological maturity (PM). The crop was harvested when most of the leaves had senesced. Rice grain yield was determined by harvesting an area of 5m^2 (2 m x 2.5 m) from 2 spots of each plot. Grain yield was converted to t ha^{-1} at 14% moisture content. Yield-contributing characters (the number of panicles m^{-2}, the number of grains $panicle^{-1}$) were determined at harvest from three spots taking 3 adjacent hills at each spot.

2.5. Economic analysis

Treatments were evaluated based on total variable cost, gross return, and gross margin. The total variable cost was calculated by taking into account the costs of inputs (seed, fertilizers, and pesticides); costs of human labor for land preparation, irrigation, fertilizer and pesticide application, harvesting, and threshing; and costs of hiring a power tiller for land preparation and an irrigation pump for irrigation. Gross return was calculated from the amount of grain and straw harvested (t ha^{-1}) by its corresponding price at harvest. The market price of paddy was determined during the year of experiment and used for calculation of the gross income. Fixed costs are those costs which do not change with a change in the volume and type of production, such as the rental value of land, depreciation of machinery. Gross margin for each crop was calculated as the difference between total (gross) return and total variable cost. Net return was calculated as the difference between gross return and total cost. The benefit-cost ratio (BCR) was calculated from the gross return divided by the total cost.

2.6. Statistical analysis

Data were analyzed using ANOVA to evaluate the differences between treatments, and the means were separated using least significant differences (LSD) at the 5% level of significance (Crop Stat 7.2; International Rice Research Institute, Philippines).

3. Results and discussion

3.1. Effect of tillage systems and fertilizer management on tiller density

There was no significant interaction between tillage system and fertilizer management on tiller density at any of the crop growth stage. Considered with the individual effect, fertilizer management significantly influenced the tiller density at all growth stage except early tillering; however, there was no effect of tillage systems on tiller density at any growth stage (Figure 1 a,b). The tiller density was gradually increased up to MT stage and later on gradually decreased due to tiller mortality. Among the fertilizer management treatments, the recommended N,P,K,S had the highest tiller density at any growth stage except early tillering. The reduced 50% K at all the crop growth stages had similar tiller density to the recommended N,P,K,S treatment. Although, reduced 50% P had similar tiller density to the recommended N,P,K,S treatment

Table 1. Yield and yield attributes of *boro* rice as influenced by different tillage systems and fertilizer management in northern area of Bangladesh.

Treatments	Panicle density (no. m^{-2})	Filled grain $panicle^{-1}$	Grain yield (t ha^{-1})
Tillage systems (TS)			
2 Pass tillage	321	90	6.02
1 pass tillage	317	89	5.90
Zero tillage	315	87	5.85
Fertilizer management (FM)			
Recommended N,P,K,S	323	92	6.08
Reduced 50%P	309	83	5.57
Reduced 50%K	319	90	5.95
LDS $_{0.05}$			
TS	NS	NS	NS
FM	9.5	5.4	0.2
TS × FM	NS	NS	NS

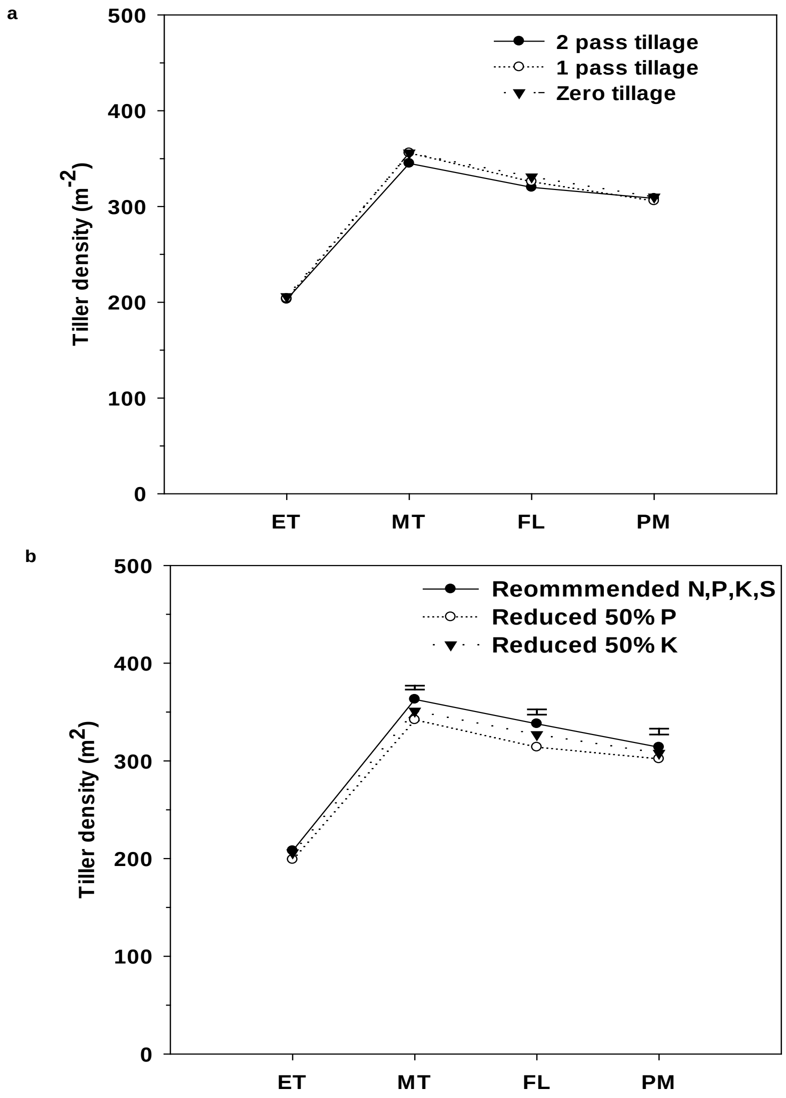

Figure 1. Effect of (a) tillage system and (b) fertilizer management on tiller density of *boro* rice (vertical bars are LDS (p=0.05) for comparing the tillage and fertilizer treatments).

at the early tillering stage but at later stage, it was significantly lower.

3.2 *Effect of tillage systems and fertilizer management on yield and yield components*

There was no significant interaction of tillage system and fertilizer management on crop yield or even any of the yield components (Table 1). The grain yields of rice from non-puddled tilled (one pass and two passes) and without tilled treatments were statistically similar indicating successful cultivation of rice even under non-puddled zero tillage condition. Similar grain yield among the tillage systems was strong evidence from the similar yield components. Although tillage effect was not significant; however, fertilizer management strongly influenced grain yield and yield components (Table 1). The highest grain yield (6.1 t ha^{-1}) was recorded from the recommended N,P,K,S fertilizer and the reduced rate of 50% P fertilizer had significantly lower yield than the recommended

Table 2. Cost of boro rice production (in USD/ha) used in the economic analysis. Average cost was considered.

Items	Quantity ha^{-1}	Unit price (USD)	Tillage options			Fertilizer managements		
			2 pass tillage	1 pass tillage	ZT	Recommended N,P,K,S	Reduced 50% P	Reduced 50%K
Variable costs								
Seedbed	-	-	28	28	28	28	28	28
Seed	40	0.4	16	16	16	16	16	16
Tillage	-	-	38	19	0	38	38	38
Labour (including all operations)	113	3.7	418	418	418	418	418	418
Fertilizer								
Urea (kg)	260	0.2	52	52	52	52	52	52
TSP (kg)	100	0.3	30	30	30	30	15	30
MoP (kg)	100	0.2	20	20	20	20	20	10
Gypsum (kg)	56	0.4	22	22	22	22	22	22
Zinc sulphate (kg)	6	1.8	11	11	11	11	11	11
Irrigation	-	281	281	281	281	281	281	281
Pesticide	1	66	66	66	66	66	66	66
Thershing	1	58	58	58	58	58	58	58
Total variable cost			1040	1021	1002	1040	1025	1030
Fixed cost								
Land rental value	1	228	228	228	228	228	228	228
Total cost			1268	1249	1230	1268	1253	1258

fertilizer. Significantly similar grain yield and yield components of recommended N,P,K,S and reduced 50% K fertilizer indicates that current K fertilizer recommendation for puddled *boro* rice is higher and K dose may curtail in non-puddled (zero or reduced tillage) *boro* cultivation following mustard. Potassium is losses from the soil by leaching, run-off and crop removal (Alfaro et al., 2004). When crop residue is retained in the field, a large amount of potassium is recycled. In mustard, the defoliated leaves are a good source of potassium added into the soil. In addition, it is quite evident that puddling reduces the absorption of potassium (Sing et al., 2004).

Grain yield of the current study indicated that under the non-puddled condition, zero tillage rice following mustard did not hamper the grain yield of rice. The mean grain yield of the current study in zero tillage condition was around 6.0 t ha^{-1} which is similar to the yield potential of the tested variety. In the present study, we do not have the option to compare the yield performance of non-puddled rice with puddled rice but many previous studies reported similar yield in both systems. In Bangladesh, Haque et al. (2016) achieved similar or higher rice yields in non-puddled condition compared to puddle condition when manual

Table 3. Economic analysis of boro rice grown in the experiment of northern Bangladesh in USD (1 USD=82 BDT).

	A. Gross return	B. Total variable cost	C. Total fixed cost	D. Total cost (B+C)	E. Gross margin (A-B)	F. Net return (A-D)	G. BCR (A/D)
Tillage (T)							
2 pass tillage	1468	1040	228	1268	428	200	1.16
1 pass tillage	1439	1021	228	1249	418	190	1.15
Zero tillage	1427	1002	228	1230	425	197	1.16
Fertilizer (F)							
Recommended N.P,K,S	1483	1040	228	1268	443	215	1.17
50% P	1359	1025	228	1253	334	106	1.08
50% K	1449	1030	228	1258	419	191	1.15

*1 ton rice grain price =244 USD

transplanted and soil type was sandy loam. Furthermore, Ahmed et al. (2002) found similar grain yield with manual transplanting of *boro* rice into puddled and non-tilled (zero till, ZT) soil.

3.3 Economics

Boro crop was profitable, with positive gross margin, net return, and BCR>1, regardless of the operation in the analysis (Table 2-3). Gross return in two pass tillage and recommended N,P,K,S was higher than other treatments due to higher grain yield. Gross margin was similar for all tillage treatments and it was due to zero till and one pass till was slightly lower yield than the two pass till but slightly higher tillage cost for two pass till. Among the fertilizer management, the highest gross margin (443 USD ha^{-1}) was observed from the recommended N,P,K,S fertilizer and the lowest (334 USD ha^{-1}) in reduced of 50%P. Net return and BCR were similar for all tillage treatment; however, varied in fertilizer treatments. The recommended N,P,K,S fertilizer and reduce 50% K have similar net profit and BCR. The lowest net profit and BCR were recorded from the reduce 50% P and it was due to lower grain yield than other fertilizer management treatments.

4. Conclusions

The results of the present study show that puddling is not essential for maintaining the yield of *boro* rice transplanted after mustard harvest. Similar yields of rice in non-puddled zero tillage and one or two pass tillage following mustard indicates that farmers can go *boro* rice transplanting immediately after harvest of mustard; however, farmers non-puddled tillage decision would be depended on soil types. If it is found that soil is not suitable for zero tillage transplanting then it is better to use one or two passed dry till. Non-puddled transplanting facilitates rapid and earlier establishment of the *boro* crop which can help to harvest rice before the start of full monsoon rain that may frequently cause yield hamper or completely damage *boro* rice. In addition, non-puddled *boro* rice can save water and tillage cost which is required for puddled rice. If farmers use optimum fertilizer for the mustard crop, they can reduce 50% of K fertilizer of current recommendation for subsequent *boro* crop. In the current study, there was no soil test data and further study is needed to test the different level of potassium fertilizer under non-puddled *boro* rice following mustard.

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