

Evaluation of Mechanical Transplanter in Unpuddled Transplanting of Wet Season Rice in Sandy Loam Soil

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Abstract

Alternate to puddling, unpuddled transplanting is a new concept of rice cultivation. This experiment was conducted to evaluate the performance of mechanical rice transplanter in unpuddled condition under minimum tillage practices in drought prone zone representing sandy loam soil in wet season 2012. Tillage treatments were (i) conventional puddling (CT) in puddled condition and (ii) no tillage (NT) (iii) bed planting (BP) (iv) and strip tillage (ST) in unpuddled condition. Results indicated that unpuddled transplanting saved fuel, time and labour remarkably in land preparation. Mechanical transplanting reduced drudgery of the farmers and ensured timely operation. Transplanting time was higher in unpuddled plot than puddle one. Floating hill was also higher in unpuddled plot due to increase in soil hardness and unable to provide proper anchorage and gripping force to seedlings. Grain yield of unpuddled transplanting was similar to puddled transplanting. Water productivity was the lowest in unpuddled than puddled transplanting. Input cost was higher in conventional puddling than unpuddled transplanting. Mechanical transplanting overcome the constraints of manual transplanting in unpuddled condition. It might be an effective technology in rice production with limited seedling floating (9-17%) in sandy loam soil.

Key words: Bed planting, Strip tillage, Floating hill, Yield

1. Introduction

Transplanting rice in puddled soil is a common practice in lowland rice in the tropics and subtropics of Asia (Cassman and Pingali, 1995). Farmers typically prepare land by two passes of dry tillage followed by exposure to sun for a few days and then inundation of the field, ploughing and harrowing with standing water. Puddling is labour and capital intensive process. Ploughing of puddled soil after rice results in the formation of large clods, having high breaking strength (Sharma and Bhagat, 1993) and very large amounts of energy and time are consumed in producing fine seed beds. Puddling makes land preparation difficult for the following wheat or other winter crops, resulting in cloddy soil structure, loss of soil moisture, delayed planting and inadequate seed-soil contact (Sharma *et al.*, 1995). Continuation of soil puddling for rice transplanting will negate the benefits of minimum tillage in other crops in the rotation as is reported for the rice-wheat system (Sharma *et al.*, 2011). Puddling should preferably be avoided as it is an unfavorable practice for the succeeding upland crops. Sharma *et al.* (1988) revealed that rice grown after minimum tillage produced yields similar to that under conventional puddling with minimized expenses on field preparation. Transplanting rice in unpuddled condition is an emerging issue in crop cultivation. Islam *et al.* (2012) stated that rice grown in unpuddled condition in bed and strip tillage saved fuel, labour and time remarkably and produced yield similar to conventional puddling. Islam *et al.* (2010) mentioned that almost double time was needed to transplant seedling in unpuddled than puddled plot due to poor visibility of strips under muddy flood water caused difficulties for people when transplanting seedlings in the hard surface of untilled soils. Sandy soil may re-gain high strength after wetting much faster than clay soils and this hampered manual transplanting in unpuddled land if it was delayed (White *et al.*, 1997). This problem can be offset by using mechanical transplanter. Moreover, timeliness of transplanting is essential for optimizing the yield and this can only be achieved through mechanical transplanting. A delay in transplanting by one month reduced the yield by 25% and a delay of two months reduced the yield by 70% (Rao and Pradhan, 1973). Optimizing plant density and timeliness of operation in paddy is considered essential for optimizing paddy yield which may be possible if dependence on hired labour is minimized (Chaudhury *et al.*, 2005). For the operation of rice transplanter, the soil flow caused by sinkage is the most critical factor affecting the performance of transplanter. Thus, if the desirable sinkage at which a particular transplanter work effectively is known,

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operator can take quick decision regarding machine operation at any time (Garg *et al.*, 1997). Therefore, the present study was performed to investigate the constraints to operate the mechanical transplanter in unpuddled field and to compare the economics of transplanted rice grown in puddled and unpuddled condition.

2. Materials and Methods

The experiment was conducted at the research farm of Bangladesh Rice Research Institute (BRRI), Regional station, Rajshahi, Bangladesh representing the sandy loam soil during wet season 2012. The study area lies at 24°22'7.73" N and 88°39'33.16" E. Agro-climatic (rainfall, evapotranspiration and thermal condition) data were collected from the BRRI weather station (Fig. 1). Tillage treatments in the experiment were (i) Conventional puddling by 2 wheel tractor (CT) as puddled condition and (ii) No tillage (NT) (iii) Bed formed by Versatile Multi-crop Planter (VMP) in single pass (BP) (iv) Strip tillage by VMP in single pass (ST) as unpuddled condition. The treatments were arranged in a randomized complete block (RCB) design with three replications. Conventional puddling consisted of primary tillage using 2 passes by 2 WT and exposed to sun for two days followed by inundating whole plot and puddling by 2 WT with 2 passes.

Before land preparation, cores of undisturbed soil (0-7.5 cm and 7.5-15 cm layers) were taken with a 7.5 cm long cylinder made from cold rolled steel tubing having a 5.6 cm inside diameter. One end of the cylinder was sharpened to a knife edge. The cylinder was forced into the soil (by pounding on a piece of wood placed over the cylinder when the cylinder could no longer be manually forced into the soil) until the top edge of the cylinder was level with the adjacent ground surface. The core then was removed with a tiling spade, the cutting knife inserted, excess soil trimmed off the bottom edge, and the 0 to 7.5 and 7.5 to 15 cm cores gently placed into separate containers. Soil samples were taken randomly in three places in each plot between rows of crops and top of beds. Weight of wet material of cores was recorded and placed in dry, clean pan and kept in the oven. The material was dried to a constant weight. Constant weight was achieved when two successive periods of drying indicate no change in the weight of the material. Soil samples were oven dried in the laboratory for the calculation of bulk density using methods described by Blake and Hartge, 1986. Hand penetrometer was used to measure the soil penetration resistance (Model: Ejkelkemo, Serial no. 27180909, Netherlands). The apparatus has a mean deviation of + and - 8%. Soil strength was measured from the soil surface to a depth of 15 cm at 2.5 cm depth increments from three points of each plot, with three replications after harvesting rice and maize. Penetrometer readings were taken randomly in three places in subplots between rows of crops and top of bed.

During final land preparation, all cares were taken for uniform leveling of the land. A fertilizer dose of 19 kg P, 33 kg K, 10kg S and 3 kg Zn as triple super phosphate, muriate of potash, gypsum and zinc sulfate, respectively was applied at final land preparation. Fuel consumption was measured by filling the machine's fuel tank twice, before and after each operation.

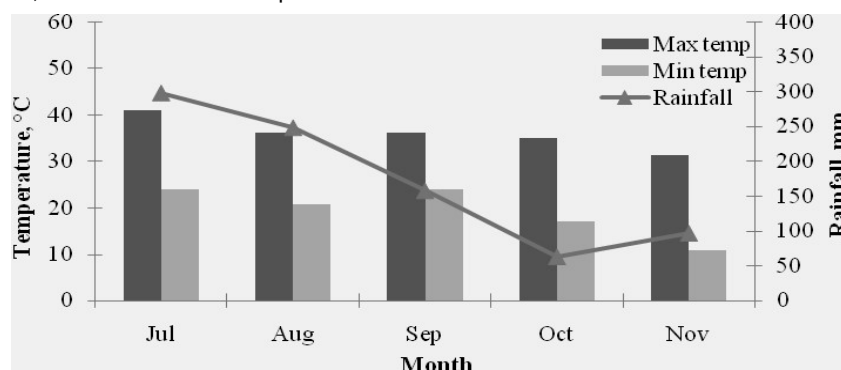


Fig 1. Mean monthly minimum and maximum temperature and rainfall during experimental period

Transplanting was done by using walking type 4-row mechanical transplanter (Model DP-480, made in Korea). Mechanical transplanting required a special method of raising seedlings. Seedlings were raised in tray. Soil was sieved and spread on tray to a depth of 2 cm. Rice seed BR11 was used in this experiment. In each tray, 120 gm seeds were used. Seeds were soaked in 23 June 2012 and seeding on tray was done during 26 June 2012. Sprouted seeds were spread uniformly on the tray, pressed gently and covered with another layer of soil. Water was sprinkled everyday by sprayer until complete emergence of seedlings. Seedlings were ready to transplant at 2-3 leaf stage. Fifteen-day old seedling was transplanted mechanically during 11 July, 2012. Land was inundated before one day of transplanting for maintaining soil softness to transplant seedling in unpuddled plot. The spacing was set as 30 x 14 cm. Water level in the field was kept at 2 cm only to avoid floating of seedlings. Observations on speed of operation, depth of placement of seedlings, number of seedlings per hill, number of missed hills, number of floating hill, total time taken for transplanting, total area covered and quantity of fuel consumed for the operation were recorded.

After seedling establishment, the operations such as fertilizing, weeding, pesticide application and irrigation were performed at the same time and same dose on all plots in order to reduce the significance of differential fertility on crop yield. A knapsack-powered blower (sprayer) was used to apply fertilizer and pesticides. Nitrogen was top-dressed at 60 kg ha⁻¹ as urea in 3 equal splits at 10 days after transplanting (DAT), 30 DAT and panicle initiation (PI) stage. First weeding was done at 25 DAT, urea and weeds were incorporated to the soil. Adequate measures were taken to keep the insect infestation to a minimum. An irrigation frequency was counted to calculate the volume of water required for crop production. The number and duration of operations, the seed, fertilizer and pesticide rates, and the amount of human labour involved in each operation were investigated through field measurements. Water use efficiency was calculated according to Viets (1962) formula. Number of tillers in the selected hills were counted at each growth stage. Based on successive tiller count data, tillering rate and tiller mortality was calculated. No. of panicle per m² was measured. Grain yield was recorded from pre-selected 10 m² land area and adjusted moisture content of 14% moisture level. Border areas of all sides of the plot were excluded to avoid border competition effects. Statistical analysis was done following Gomez and Gomez (1984). Data were analysed by using statistical software Mstat-C. Means were compared with least significant difference (LSD) test.

3. Results and Discussion

3.1 Soil physical properties

Soil bulk density under different tillage treatment was shown in Fig. 2. It was observed that bulk density under no tilled plot was higher than other tillage treatment.

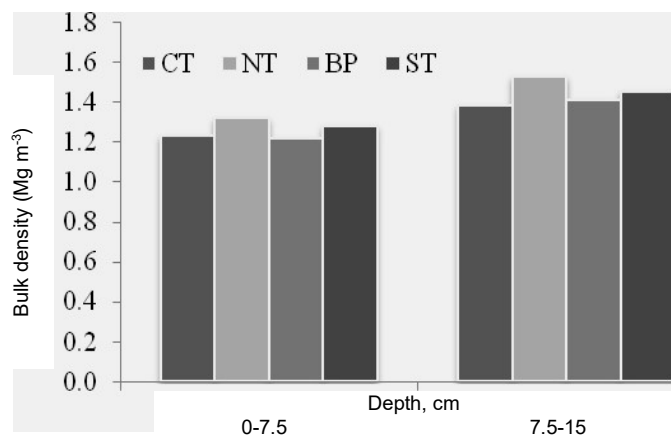


Fig. 2. Soil Bulk density according to soil depth

3.2 Soil penetration resistance

Fig. 3 showed the value of penetration resistance of different tillage plot. Penetration resistance was observed the highest in NT plot compared to other tillage trial plots. In all tillage trial plots, penetration resistance was increased at faster rate with the increase in depth.

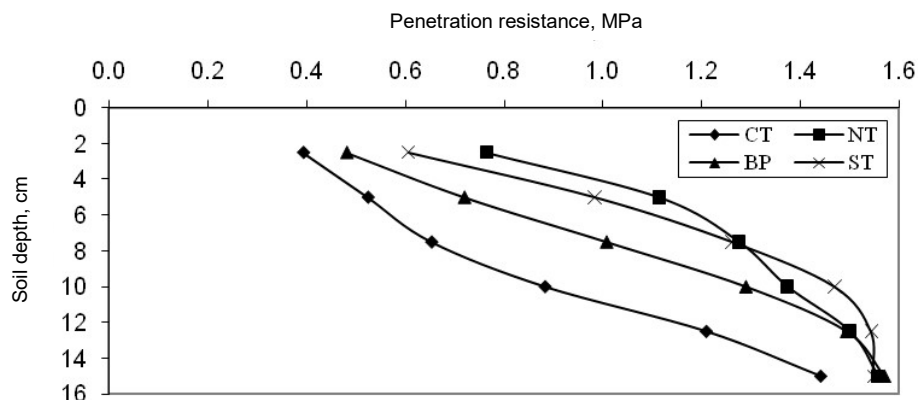


Fig. 3. Soil penetration resistance (MPa)

3.3 Fuel consumption

Tillage treatment showed significant difference in diesel fuel consumption in land preparation (Table 1). Highest fuel was required to prepare the land in CT than other treatments. Unpuddled plot significantly reduced the fuel consumption in land preparation i.e. 45-100% fuel can be saved in land preparation compared to CT. Minimum tillage method indicated fuel saving tillage technology in land preparation.

3.4 Labour requirement in land preparation, transplanting and weeding

Tillage treatment showed significant difference in labour requirement for land preparation (Table 1). Labour requirement for land preparation was highest in CT. BP and ST saved 71% and 83% labour, respectively in land preparation. Tillage treatment gave significant difference in labour requirement for transplanting (Table 1). The greatest time was required for transplanting in BP i.e. almost double the time was needed compared to CT (Table 1). The operator faced difficulties to operate the transplanter for seedling placement on both edge of the bed. It was observed that weeding time in unpuddled and puddled field was statistically similar. It might be due to use of herbicide (glyphosate) before land preparation as mentioned in Natarajan and Kuppaswamy (1999) for transplanted rice.

Table 1. Tillage effect on fuel consumption, labour requirement in land preparation and transplanting and weeding

Tillage options	Fuel consumption (l ha ⁻¹)	Labour requirement (man-hr ha ⁻¹)		
		Land preparation	Transplanting	Weeding
CT	50 a	69 a	3.52 c	344
NT	0 d	0 d	5.28 b	622
BP	27 b	20 b	7.54 a	432
ST	23 c	12 c	5.03 b	429
CV, %	1.90	3.62	10.26	8.01
LSD _{0.05}	0.95	1.81	1.09	NS

3.5 Floating hills

It was observed that the average floating hills were higher in unpuddled than puddled transplanting (Fig. 4). During operation of transplanter in puddle plot, water wave displaced the seedlings which influence the floating hill in CT. The higher floating hills in unpuddled soil were due to poor anchorage of seedlings. In NT and ST, it was due to increased bulk density (Fig. 2) and soil penetration resistance (Fig. 3) compared other tillage plots. In case BP, in some places, picker unable to touch the edge of bed due to uneven shape of BP leading to increased floating hill. Desired depth of planting is very important for proper anchorage of seedling and floating hill may be increased with the decreased in depth of planting. In NT and ST, previous crop residue also hampered the release of seedling from the gripper and proper placement into the soil which ultimately increased the floating hill (16-17%) in those tillage practices. Unpuddled soil increased the hardness and could not provide proper anchorage and gripping force to seedlings resulting higher floating. Floating hills can be minimized with the optimum period of inundation. There is need to quantify the soil bearing capacity to the unpuddled soil. It was observed that unpuddled soil provided sufficient bearing capacity to prevent sinking or floating of transplanter. Gap filling was done after one day of transplanting.

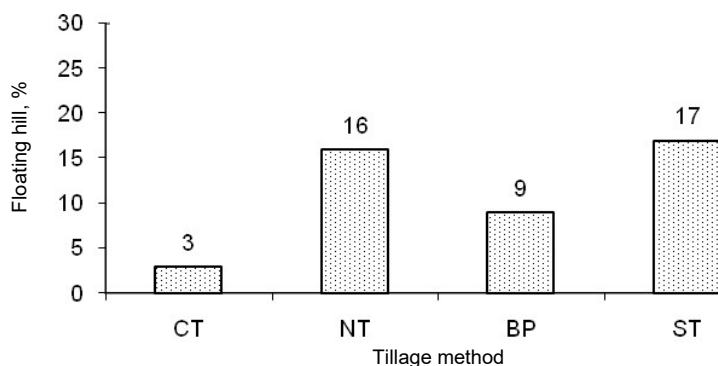


Fig. 4. Floating hills as affected by tillage options

3.6 Plant height

Changes in plant height of transplanted seedling under different tillage practices are shown in Figure 5. During the crop cycle, highest plant height was observed in CT. Although the plant height of conventional and bed planting method over time was similar but significantly differed from strip method. The lowest plant height was found in no-tilled plot probably due to lower root growth and activity in unpuddled soil condition. Plant height followed rapid growth from 42 DAT to 94 DAT. At maturity stage, taller plant was also observed in CT followed by ST, BP and NT.

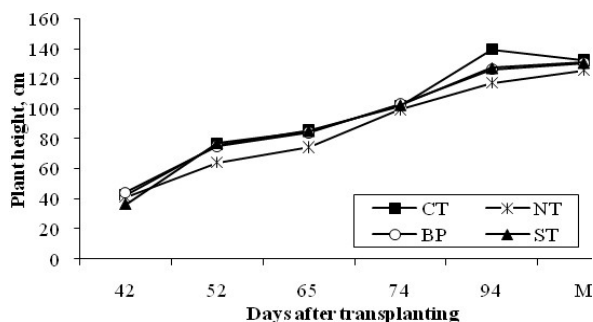


Fig. 5. Effect of tillage on plant height at different days after transplanting

3.7 Tillering pattern

The effect of tillage on tillering pattern of wet season rice is shown in Fig. 4 and 5. Tillage treatment did not influence the plant population throughout the crop cycle. Tillering pattern also behaved similar pattern throughout the production period. Irrespective of the tillage, tillering pattern followed increasing trend upto 40 DAT. In all the treatments, the tiller production sharply increased from 42 DAT and the maximum tillering stage reached in 52 DAT then it was decreased gradually due to tiller mortality (Fig. 6). Strip tillage produced remarkably higher tillers than other treatments although; the difference in tiller production at later stage was not distinguished significantly by tillage options. The result indicated that seedling establishment was equally effective both in puddled and unpuddled soil for tiller production.

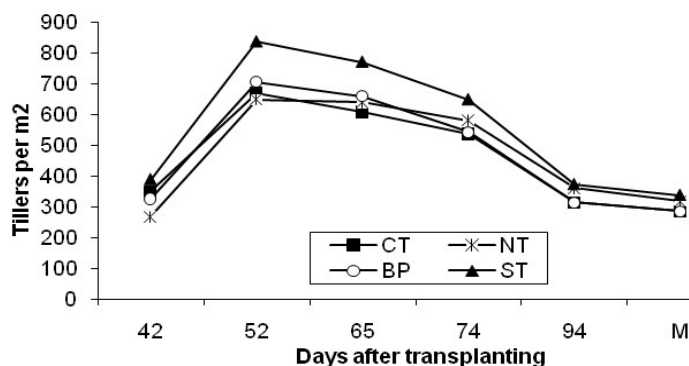


Fig. 6. Effect of tillage on tiller production at different DAT

Fig. 7 showed the stage-wise tiller production under different treatments. ST produced higher tillers at all the studied stages and it was more pronounced at maximum tiller stage and panicle initiation stage. Irrespective of tillage, tiller number was reduced at flowering and maturity stage due to leaf senescence.

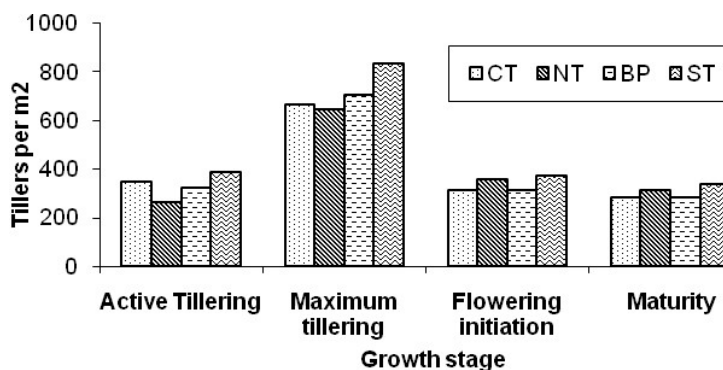


Fig. 7. Effect of tillage on tiller production at different growth stage

3.8 Percent productive tiller production

Among the yield components, productive tillers are very important because the final yield is mainly a function of the number of panicle bearing tillers per unit area. Fig. 8 represented the percent productive tiller at maturity stage under different tillage method. It was reported that although the tiller production was higher, but all the tillers did not produce panicle. At maturity stage, tiller was aborted due to intra competition. Although the plant population under strip method was higher at both maximum tillering and maturity stage but percent productive tiller was lowest in strip method. It might be due to dense population in strip method resulting higher competition within tillers for food and less translocation of assimilates into panicle. Tillage

treatment CT, NT, BP and ST produced 39%, 44%, 37%, 36% productive tiller, respectively. It indicated a high degree of tiller mortality suggesting that rice varieties produce almost double the tillers than they need or can support. Data also indicated that tiller number was negatively correlated with percent productive tiller which was in agreement with Zhong *et al.* (2001).

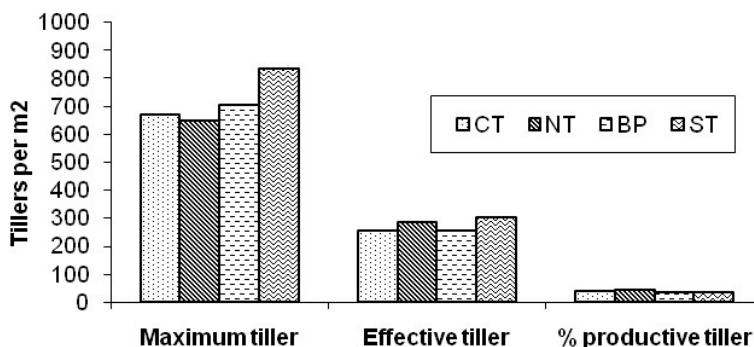


Fig. 8. Tillage effect on maximum tiller and percent productive tiller production

3.9 Water inputs and productivity

Grain yield and water productivity with respect to irrigation plus rainfall are presented in Table 2. The present findings showed that grain yield in unpuddled transplanting of rice was statistically similar to conventional puddling indicating that tillage intensity can be reduced to establish transplanted rice without sacrificing yield. This was coincided with the findings as stated by Islam *et al.* (2010). Total effective rainfall during the growing season (July-December 2012) was 862 mm. Irrigation amounts varied with tillage. Water productivity increased as the tillage passes decreased. Highest water productivity occurred in CT (5.76 kg grain/mm water input), and the lowest was found in NT with a water productivity of 4.94 kg grain/mm water. In this experiment, average grain yield was comparable with all the tillage treatments but water productivity was 14%, 9%, and 8% lower in NT, BP and ST, respectively.

Table 2. Water productivity as affected by average grain yield and water inputs

Tillage options	Average grain yield (kg ha ⁻¹)	Water input (mm ha ⁻¹)			Water productivity (kg grain mm water ⁻¹)
		Irrigation	Rain fall	Total	
CT	5365	70	862	932	5.76
NT	4620	74	862	936	4.94
BP	4886	66	862	928	5.27
ST	4945	67	862	929	5.32
CV, %	8.65	5.81	-	0.43	8.54
LSD _{0.05}	NS	NS	-	NS	NS

3.10 Cost of land preparation and transplanting, weeding and irrigation under different tillage system

Cost of major items in crop production was shown in Table 3. Tillage treatment showed significant effect in land preparation cost. Land preparation cost was the highest in CT due to more labour requirement and fuel usage. Tillage treatment gave significant effect on transplanting cost. BP incurred highest transplanting cost due to difficulties to operate the transplanter on the bed. Weeding and irrigation cost was statistically similar in puddled and unpuddled plot.

Table 3. Cost (Tk ha⁻¹) of land preparation and transplanting, weeding and irrigation under different tillage systems

Tillage	Land preparation	Transplanting	Weeding	Irrigation
CT	9811 a	1087 b	10333	516
NT	0.00 d	1275 b	18676	543
BP	3839 b	1822 a	12967	489
ST	2769 c	1214 b	12877	491
CV, %	1.93	10.13	8.01	5.86
LSD _{0.05}	158	273	NS	NS

In a row, means followed by a common letter(s) are not significantly different at 5 % level by LSD test

3.11 Economic productivity

Input cost was higher in BP and CT due to higher weed infestation. Lowest variable cost was observed in ST and NT. Highest BCR was observed in CT followed by ST, NT and BP. This was due to less variable cost, higher grain and straw yield.

Table 4. Economic productivity of *aman* rice as affected by tillage options

Tillage options	Input cost (Tk ha ⁻¹)	Gross return (Tk ha ⁻¹)	Gross margin (Tk ha ⁻¹)	BCR
CT	69237	108083	38846	1.56
NT	69929	94624	24694	1.35
BP	66990	98475	31485	1.47
ST	65995	99627	33631	1.51

4. Conclusion

Unpuddled transplanting saved fuel remarkably compared to puddle transplanting. In sandy loam soil, unpuddled field could not provide proper anchorage and gripping force to seedlings resulting higher floating hills. Transplanting cost was higher in BP due to difficulties to operate the transplanter on the bed. Water productivity was higher in puddled than unpuddled transplanted rice. Grain yield was statistically similar in puddled and unpuddled transplanting. Transplanting rice under no-tillage condition was less profitable than conventional puddling.

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