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PERFORMANCE STUDY OF A WALKING TYPE 4-ROW MECHANICAL RICE TRANSPLANTER

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ABSTRACT

A study was carried out at Bangladesh Rice Research Institute, Regional Station, Rangpur along with laboratory test and farmers field in Fulgachi, Lalmonirhat for field test during Aman season with BRRI dhan52 to identify the effect of plant spacing of transplanter on grain yield. Three levels of plant spacing (30 cm×13 cm, 30 cm×15 cm, 30 cm×17 cm), seedling density setting (Middle, Middle+1 and Middle+2) and RCBD with 9 plots were used for the purpose. In field experiment, three plant spacing and Middle+2 seedling density setting was used. In this walking type self-propelled rice transplanter, the field capacity, field efficiency and fuel consumption of the transplanter were 0.134 ha hr^{-1}, 68 % and 3.71 L ha^{-1}, respectively. Labor requirement for mechanical and manual transplanting were 6.75 man ha/hr and 223 men hour per hectare respectively. Cost of mechanical transplanting was Tk. 3291 per hectare as compared to Tk.13000 per hectare in case of manual transplanting. If the usage of this machine per year decreases, the operating cost per hectare will increase. From breakeven analysis with mechanical and manual operating cost, it was found that transplanter should use at least 11 hectares per year to minimize the operation cost per hectare. For 17 cm, 15 cm and 13 cm plant spacing, number of tray requirement were 218, 270 and 277 per hectare, respectively. Number of seedling tray saved for 17 cm and 15 cm spacing were 21 % and 2.53 % compared with 13 cm spacing. In 30 cm×17 cm spacing, minimum number of seedlings required maximum no. of tray saved. Grain yield in different spacing (30 cm×13 cm, 30 cm ×15 cm, 30 cm ×17 cm) and manual transplanting were 4.43, 4.97, 5.23, 4.13 t ha^{-1}, respectively. Results showed that, highest grain yield among plant spacing was found 5.23 t ha^{-1} from 30 cm×17 cm.

Keywords: Plant spacing, grain yield, rice transplanter, tray seedlings, walking type, economic feasibility

INTRODUCTION

Rice *(Oryza Sativa)* is the staple food for a large portion of the world's population including Bangladesh. Rice is the staple food of about 166.3 million people of Bangladesh (BBS 2022)It provides nearly 48 % of rural employment, 61.83 % percent of her population lives in the villages and agriculture is the major occupation of the people (BBS 2022). Total irrigated area under different crops in the country is about 55,56,614 hectares (64.72 % of net cultivation) of which transplanted rice (Aus, Aman, and Boro) area is about 462,268 hectares (BBS 2022) and total area, production and per hectare yield of rice is 10.5 million hectares, 25 million tons and 2.87 tons/ha, respectively (BRKB 2020). Rice covers most of the cropping area in Bangladesh which is mostly a labor-intensive crop and requires hardship through a small, low-cost transplanter can be a best solution to this problem (Rahaman *et al.* 2022). Singh *et al.* (1985) reported that transplanting takes about 250–300 man-hours per hectare which is roughly 25 % of the total labor requirement of the crop. Traditional rice transplanting caused several health problems to labors such as backache, skin disease etc. (BRRI 2013). In case of transplanting at 2.5 cm water level, maximum yield was obtained primarily due to highest number of hills per sq. meter, followed by increased number of productive tillers per plant and number of fertile grains per panicle (Saleem *et al.* 2015). Marumkar *et al.* (2014) examined 10 different village in Kharif season with self-propelled four row MAHINDRA Model and found field capacity, field efficiency and fuel consumption 0.1 ha h^{-1}, 65 % and 10 L ha^{-1}, respectively and mechanical cost Rs 1500 ha^{-1} as compared to Rs 5000 ha^{-1} for manual transplanting in India. Karthik *et al.* (2018) and Manjunatha *et al. (*2009) also satisfied with transplanter for cultivating 28-hectare field with minimum labor. Saha *et al.* (2021) reviewed Divulging technical skill, confirming timely accessibility and boosting custom hiring may be some of the practical solutions. Islam *et al.* (2016) found the growing cost for mat type seedling for mechanical transplanter was 53 % and traditional seedbed was 34 % and mechanical transplanting reduced 1.8 percent input cost than hand transplanting in crop cultivation. Hossen *et al.* (2018) evaluated Walking type (Model-DP480) and riding type (S3-680) rice transplanter in different locations for 2011-2013. Hossen *et al.* (2022) evaluated multiple field problems and tried to find out solutions to make transplanters more user-friendly and cost-effective in Bangladesh. Transplanting may also allow crop intensification as the crop is in the main field for minimum time (IRRI 2003). Bangura *et al.* (2018) designed a transplanter fitted with seedlings number counting device. By mechanical rice transplanters, transplanting can be done in accurate spacing in rows and no need of additional land for seedling preparation. Alogaidi *et al.* (2009) were reported that plant spacing of 20 cm × 20 cm was better than those of 15 cm ×15 cm under normal soil for rice productivity. Munnaf *et al.* (2014) conducted a study with Kukje transplanter and found field efficiency and planting efficiency of the transplanter were 83.33 % and 95 %, respectively. Shaikh *et al.* (2021) were conducted an experiment at three different locations during the dry season (Boro) to determine the best seeding density and found 150-160 g per tray was suitable. Total number of lands are decreasing due to urbanization and mans' are towards the town creating labor and experienced manpower scarcity. Main objective of the study was to evaluate the performance of Korean DP-480 four row type rice transplanters in respect of spacing, adjustment of seedling density setting to optimize number of seedlings, to estimate the fuel consumption and field capacity of transplanter and to estimate the break-even point of transplanter.

MATERIALS AND METHODOLOGY

Specification of Transplanter: Machine specification was: Made in Korea**;** Engine Model DP-480; Engine hp 3(1.5kw)**;** Type of Machine**:** Mechanically operated, Field Capacity**:** 1.5 bigha per hr; Fuel**:** Petrol, Tray requirement**:** 4, No. of seedling per hill**:** 2 to 7, No of picker**:** 4, Workability**:** 33 acres (From Machine manual).

Figure 1. Mechanical rice transplanter (Model DP-480) and Seedlings tray with mate.

Location and duration: The experiment site was located at the regional station, BRRI**,** Rangpur for laboratory test and for field test at fulgachi, Lalmonirhat during aman season (June to November, 2019). Soil of the field was sandy clay loam soil, low in organic matter content and its general low fertility level and under sub-tropical climate that was characterized by high temperature. Seeds of BRRI dhan52 were collected from the BRRI office, Rangpur.

Experimental design and treatments

Mechanically operated tray type test along with RCBD design replicated on nine plots.

For laboratory test: Space setting: T_1 = 13 cm; T_2 = 15 cm; T_3 = 17 cm;

Seedling density setting: Middle; Middle + 1; Middle + 2;

For field test: Space setting: T_1=13 cm; T_2=15 cm; T_3=17 cm; Seedling density setting: Middle+2.

Preparation of plot and seeds for sowing: Seeds were immersed in water with bucket for 24 hours and then kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours. Calculation for the germination percentage by the following formula, $\text{Germination}(\%) = \frac{\text{Number seeds germinated}}{\text{Number seeds on tray}} \times 100$

A piece of high land was selected in the Regional Station, BRRI, Rangpur for raising seedlings. The experiment was laid out in a randomized complete block design (RCBD). The size of the individual plot was 10 m × 6.5 m and total numbers of plots were 9. Then the sprouted seeds were sown in the nursery bed. For mechanical Transplanter, seedlings were grown in a tray which size 58 cm × 29 cm.

Land preparation: For aman season, the age of seedling of tray must be range at 13 to 18 days. The prepared land was 2.5 cm water depth to avoid floating of seedling and 11 cm puddling depth. For manual and Mechanical transplanting land preparation was remain same. The transplanter was operated by running length wise with 3 spacing and setting seedling density with Middle, Middle+1, Middle+2. For field test, Middle+2 density was used.The number of seedling number per hill, number of missed hills, hill to hill distance was noted.

Preparation for mechanical rice transplanter: At first carefully fulfilled 4 chamber of rice transplanter with 4 tray seedlings. Observations on speed of operation, depth of placement of seedlings, time taken for turning, time taken for loading of seedling mat on to the transplanter, total time taken for transplanting, total area covered, width of coverage and quantity of fuel consumed for the operation were recorded. Using the above information, the following parameters were computed for mechanical transplanter:

Theoretical field capacity: Theoretical field capacity, $C_{th} = \frac{SW}{10}$ ha hr^{-1}, Where, C_{th}= Field efficiency, %; S= forward speed, (km h^{-1}); W=width of equipment (m).
Actual field capacity: Actual field capacity, $C_{eff} = \frac{A}{T}$ ha hr^{-1}, where, C_{eff} = Actual field capacity, (ha hr^{-1}); A= total area, (ha); T=Total time, (hr).

Field efficiency: Field efficiency $= \frac{C_{eff}}{C_{th}} \times 100$, Where, C_{eff} = Actual field capacity, (ha hr^{-1}); C_{th}= Theoretical field capacity, (ha hr^{-1}).

Cost of mechanical transplanting: Cost of mechanical transplanting per hectare was worked out after taking into consideration the fixed cost, labor cost, fuel cost, field capacity of the equipment and usage of the equipment in terms of hectares per year and was compared with the manual transplanting.

Regulation of irrigation: The flood irrigation was applied in field to maintain a constant level of standing water up to 6 cm in early stage to enhance tillering and 10 to 12 cm in later stage to discourage late tillering. 48 days after transplanting, transplantations water management is the most complicated variable in System of Rice intensification (SRI) technique. The rice roots were not allowed to grow in a hypoxic, anaerobic condition caused by continuous flooding and saturated soil. Starting form panicle initiation, a thin layer of water (2 to 3 cm) was kept on the plots.

Data collections: Observations were regularly made and the field looked nice with normal green plants. From each unit plot 10 m^2 area (excluding Border hills) was selected randomly. Threshing was done by pedal thresher. The panicles were threshed, grains were dried and processed and the yield was recorded after adjusting its moisture content to 14% by using the following formula:
$\%\text{ Moisture content} = \frac{(\text{Fresh weight} - \text{Oven dry weight})}{\text{Fresh weight}} \times 100$
So adjusted yield at 14% moisture content = $\frac{(100 - \% MC)}{86} \times W,$ Where, W=Fresh weight of grain.

Statistical analysis: Statistical analysis was done by using software Statistix 9.0. Least significant difference was used to compare the means.

Cost calculation for fuel and labor
Fuel, F (Tk/ha) = $\frac{\text{Fuel consumed (lit/day)} \times \text{price(Tk/lit)}}{\text{Area covered (ha/day)}}$ and

Labor, L (Tk/ha) $= \frac{\text{Sum of wages of laborers (Tk/day)}}{\text{Area covered (ha/day)}}$

RESULTS AND DISCUSSION

Spacing adjustment in laboratory test

In mechanical transplanter, line to line spacing in machine was fixed at 30 cm whereas, plant to plant spacing was varied. Plant to plant spacing was set 13, 15 and 17 cm. In figure 2, effect of spacing (13 cm) at seedling density setting "Middle" position was shown in 1st figure. Maximum percentage of seedling density was found at 14–16 cm and maximum spacing was found in 73 % when plant to plant spacing was set in 13 cm Spacing. Due to slippage 3 % spacing were found

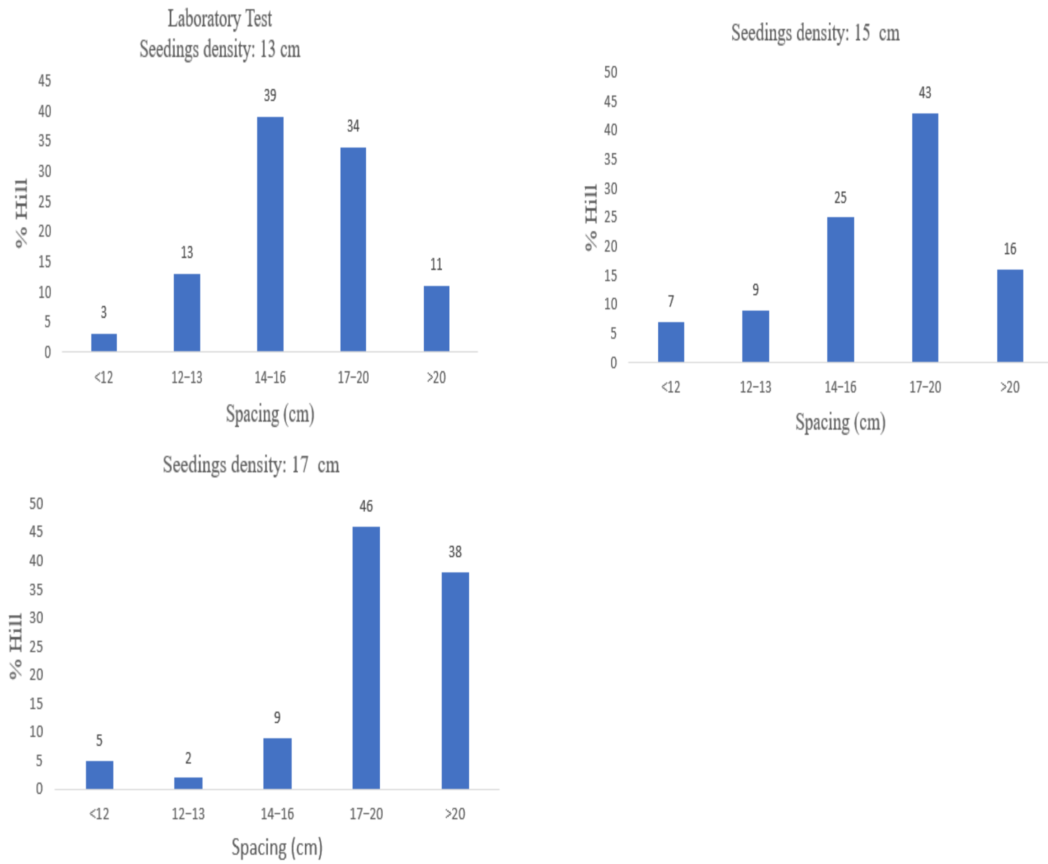

Figure 2. Effect of plant to plant spacing 13, 15 and 17 cm on seedling density setting "Middle" position, "Middle+1" and "Middle+2" position under laboratory condition.

and 84 % spacing were found for skidding. 2nd figure showed the effect on plant spacing 15 cm at seedling density setting "Middle+1" position. Plant to plant spacing obtained within 18-19 cm and maximum spacing found in 68 %. Due to slippage, 7 % spacing were found and 84 % spacing were found for skidding. In 3rd figure, the effect of 17 cm at seedling density setting "Middle+2" position was shown and maximum 84 % was found at 19-20 cm or greater than 21 cm spacing. Due to slippage 5 % spacing were found and 93 % spacing were found for skidding test.

Seedling density adjustment in laboratory test

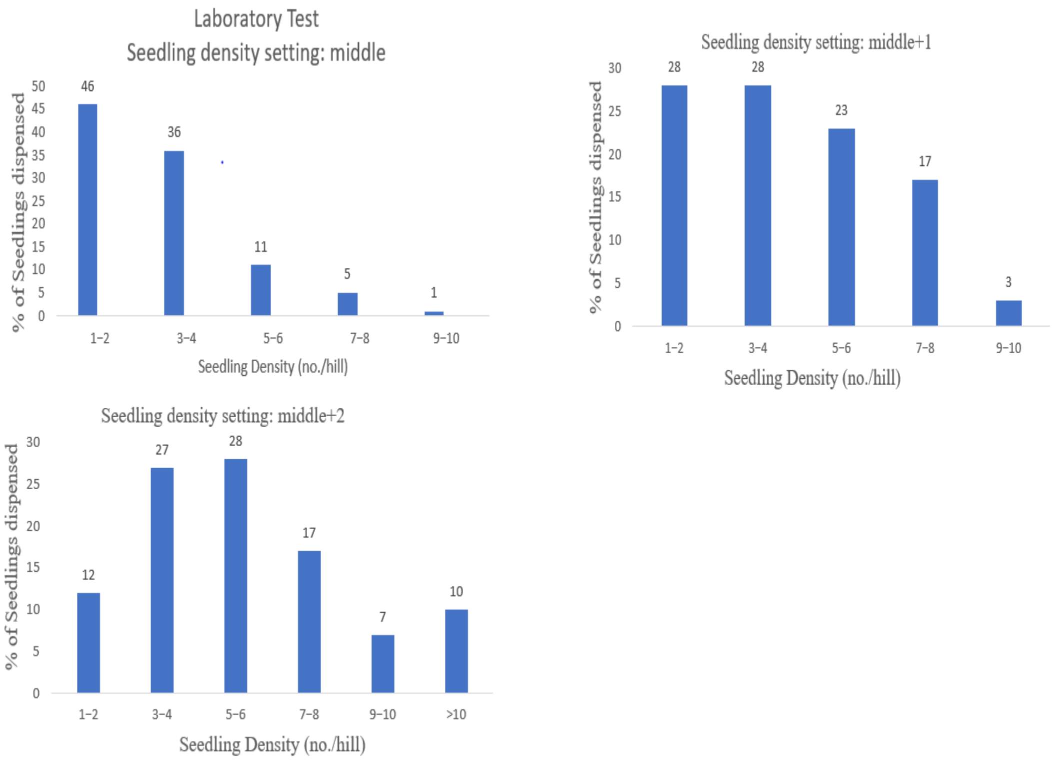

Figure 3. Effect of number of seedlings dispensed on seedling density (no./hill) at density setting “Middle”, **“**Middle+1" and “Middle+2" position for 13, 15 and 17 cm plant spacing under laboratory condition.

In figure 3, 1st figure explained the effect of seedlings dispense on seedling density (no/hill) setting at “Middle" position in 13 cm plant to plant spacing showing minimum (1-4) number of seedlings dispensed in 82 % hills. More than 5 number of seedlings dispensed in 17 % hills. In 2nd figure, effect on seedling density setting “Middle+1" position in 15 cm spacing was shown. Minimum (1-4) number of seedlings dispensed per hill was 56 % and maximum dispensed in 43 %. Effect on seedling density setting “Middle+2" position in 17 cm spacing was shown in 3rd figure. Seedlings dispensed per hill which was 39 % and maximum seedling dispensed per hill obtained (5-6).

Spacing adjustment under field test

In practical situation, most of the place’s plant to plant spacing was not consistent and sometimes higher and lower than 17 cm. Effect of plant spacing (13 cm) at seedling density setting “Middle+2” position was shown in 1st figure in figure 4, where maximum areas covered at 12-16 cm spacing. Maximum spacing was found in 67 %. Due to slippage, 6 % spacing were found and 55 % spacing were found for skidding. Again, in 2nd figure, effect on spacing (15 cm) at seedling

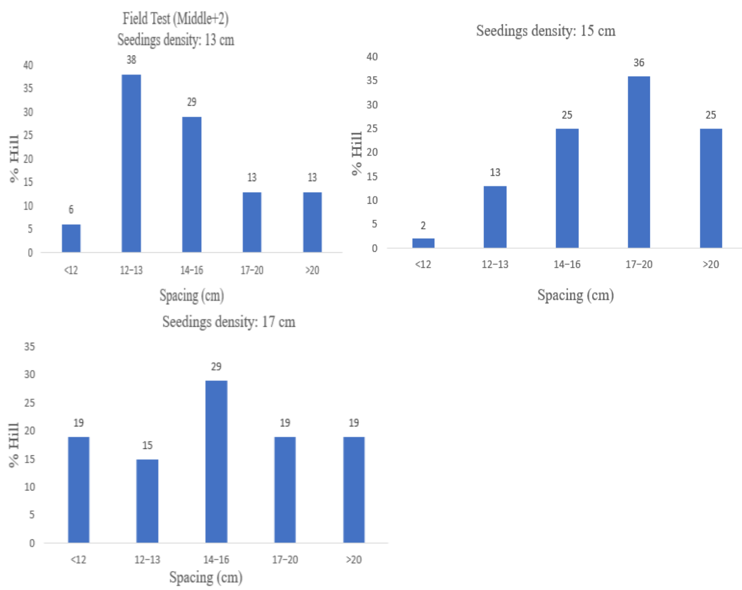

Figure 4. Effect of plant spacing 13, 15 and 17 cm at seedling density setting “Middle+2” position under field condition.density setting “Middle+2” position was showed and maximum area covered at 16-19 cm spacing or greater than 19 cm spacing almost 25 %. Maximum spacing was found in 86 %. Due to slippage, 2 % spacing were found in less than 14 cm and 86 % spacing were found for skidding. Effect of spacing (17 cm) at seedling density setting “Middle+2” position under field was shown in 3rd figure 4. 29 % maximum spacing was found and 38 % spacing were found for skidding and 34 % spacing due to slippage.

Seedling density adjustment in field test

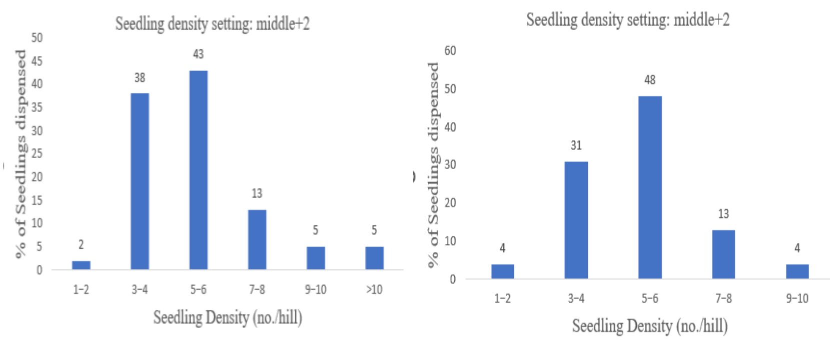

Figure 5. Effect of number of seedlings dispensed on seedling density (no./hill) at seedling density setting “Middle+2" position for 13, 15 1nd 17 cm spacing under field test.

1st figure, effect of seedlings dispensed on seedling density no./hill at "Middle+2" position in 15 cm spacing was shown. Minimum (1-4) number of seedlings dispensed per hill which was 38 % and maximum (5-6) number of seedlings dispersed per hill was 42 %. Effect on seedling density setting in 13 cm spacing (2nd figure) showed that minimum (1-4) number of seedlings dispensed per hill which was 40%. Maximum (5-6) number of seedlings dispensed per hill which was 43%. It depends on seedling emergence and germination percentage of seeding. In 3rd figure, effect on seedling density setting in 17 cm spacing was shown. Minimum (1-4) number of seedlings dispensed per hill was 35% and maximum (5-6) number 48%.

Table 1. Comparative inputs for mechanical transplanting and traditional transplanting

Parameter	Mechanical transplanting	Manual transplanting
Variety	BRRI dhan52	BRRI dhan52
Seed rate	12.5 kg dry seed/ha	37.5 kg/ha
Seedling raising technique	Plastic tray method	Traditional seedbed
Age of seedling	14 days	25 days
Soil type	Sandy clay loam soil	Sandy clay loam soil
Plant height	16.60 cm	30 cm
Depth of placement	4.8 cm	5.5 cm
Row to row distance	30 cm	30 cm
Plant to plant distance	13 cm, 15 cm, 17 cm	13 cm, 15 cm, 17 cm

Table 2. Yield and yield contribution character

Location	Treatment	Grain yield, t ha^{-1}	Panical no./m^2	Panical length, cm	Grain no./m^2
Rangpur	Mechanical transplanting	4.43 a	237.53 a	21.20 a	21512 b
Lalmonirhat	Manual transplanting	4.13 b	222.57 b	20.33 b	25350 a
CV, %		6.25	16.22	5.57	15.25
LSD $_{0.05}$	L	0.22	38.05	1.05	3063
	T	0.22	NS	1.05	NS

Seeding tray requirement

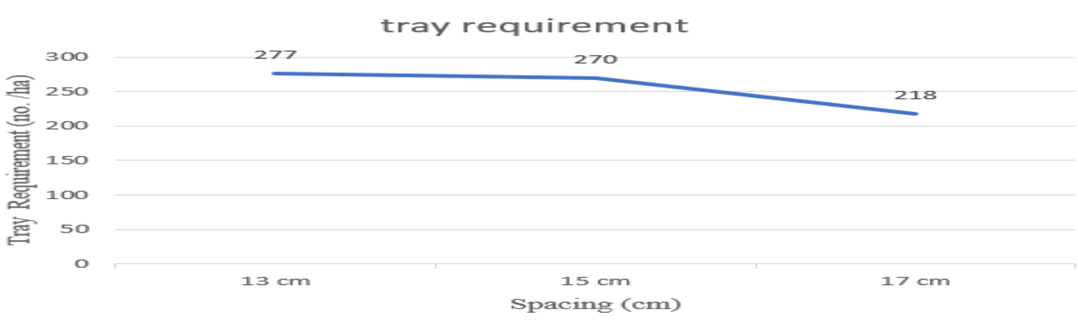

Figure 6. Effect of spacing on required tray, number per hectare.

Seedling tray requirement depend on plant-to-plant space setting. Figure 6 showed that seedling tray requirement decreases with the increase in plant-to-plant space setting. Tray requirement for 17 cm, 15 cm and 13cm spacing were 218, 270 and 277 no./ha, respectively. At least 21 percent seedling tray can be saved for space setting 17 cm which reduced the cost of seed and seedling tray preparation.

Effect of plant spacing on yield performance of mechanically transplanted rice

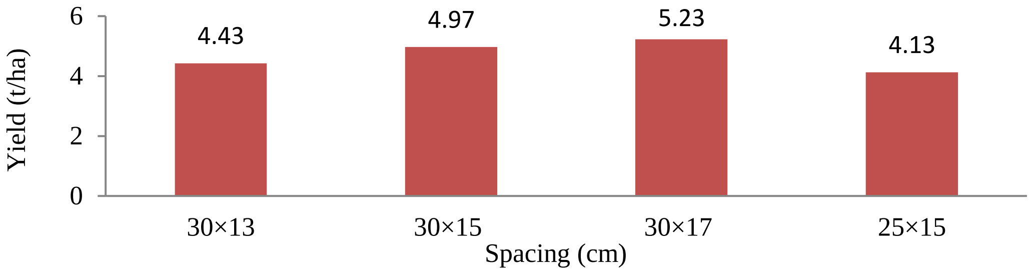

Figure 7. Effect of plant spacing on yield performance compared with manual transplanting.

The average yield of three plot for mechanical transplanting was 5.23 t/ha, 4.97 t/ha, 4.43 t/ha at 17 cm, 15 cm, 13 cm, respectively and for manual transplanting 4.13 t/ha. Maximum yield obtained at 17 cm spacing compared with other spacing. Pest attacked in closer spacing (13 cm) plot due to lack of good aeration and light interception. The yield performance of BRRI dhan52 was more in mechanically transplanted rice compared to manual transplanting.

Labor requirement: Labor requirement for mechanical rice transplanting obtained in 6.75 hour per hectare. For manual transplanting obtained in 223 man-hour per hectare which was less in mechanical transplanting.

Fuel consumption: Fuel consumption of walking type mechanical transplanter obtained 3.71 liter per hectare.

Field capacity: Field capacity of mechanical transplanter obtained 0.134 hectare per hour.

Break even analysis

Break even analysis of transplanter (figure 7) means that the mechanical rice transplanter should be operated on at least 1ha per year to produce break even outcome with neither loss nor profit

with 13000 Tk./ha yearly

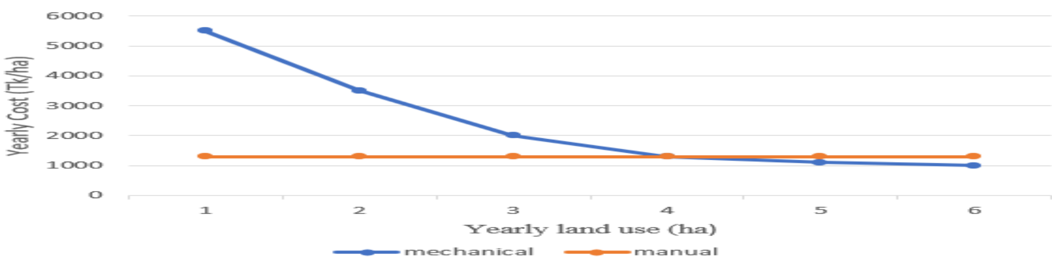

Figure 7. Break even analysis for mechanical and manual transplanting

CONCLUSION

Rice transplanter is a new technology in Bangladesh which is not adopted yet due to various machine limitations like pricing, seedlings preparation, tray availability, lack of skilled manpower, etc. 17 cm spacing was found most economical for this rice transplanter model. In Bangladesh, rice is the main cereal crop and almost 90% done with hand broadcasting which takes lots of time and manpower. Due to rapid industrialization, manpower is decreasing day by day. So its high time to adopt these new technologies to overcome existing and upcoming problems.

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