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Mechanical Transplanting of Hybrid Rice for Sustainable Food Security

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Abstract

Now-a-days, different hybrid and high yielding rice varieties are available in Bangladesh which has higher yield potential over conventional high yielding varieties. Transplanting of hybrid rice variety with mechanical transplanter is a challenge to maintain the seedling density and precision planting. This study was conducted to determine the performance of rice transplanter in puddled and unpuddled soil conditions for hybrid rice variety and to compare the yield parameters with traditional manual transplanting in *Boro*-2018 at Bangladesh Agricultural University. Hybrid rice seed Moyna (HTM303) was used for transplanting. Seed rate per tray was maintained as 120 g and seedling per hill was adjusted to 2-3 nos. Transplanting was conducted by an ACI Daedong DP 480 model rice transplanter that possessed an effective field capacity, fuel consumption and efficiency of 0.17 ha/h, 4.61 l/ha and 70.20%, respectively in puddled soil condition whereas in unpuddled condition the parameters were 0.16 ha/h, 4.8 l/ha, 67.48%, respectively. Missing hill percentage were observed 6.3% with a floating hill of 5.46% in puddled soil whereas in unpuddled soil the parameters were found 6.1% and 7.36%, respectively. Plant heights were recorded as 14.79 cm and 15.72 cm in puddled and unpuddled soil, respectively at the day of transplanting and at the day of harvesting, plant heights were 91.66 cm and 86.19 cm, respectively with tiller per hill of 24 and 18 nos., respectively. The average panicle lengths of plants were found 25.11 cm and 23.61 cm in puddled and unpuddled soil, respectively where in manual transplanting, it was 23.17cm. The yields of mechanically transplanted rice in puddled and unpuddled soil conditions were 5.60 ton/ha and 5.21 ton/ha, respectively where manually transplanted field had a yield of 4.22 ton/ha. Results reveal that mechanical transplanting of hybrid rice was found possible in both puddled and unpuddled soil conditions than manual transplanting without compromising yield.

Introduction

Globally, paddy is the second most significant cereal crop in terms of production area and the staple food for nearly half of the world's seven billion people (Li *et al.,* 2011; Juraimi *et al.,* 2013). In Asia, more than 90 percent of paddy is consumed where it is staple food for majority of the population, including the region's 560 million hungry people (Mohanty, 2013). With a production of 34.6 million tons, Bangladesh ranks the fourth position among major paddy growing countries of Asia (FAO, 2017) where Agriculture possesses a contribution to GDP of about 13.41% in FY 2016-17 (BBS, 2018). In 2015-16, the area under paddy cultivation is 74.85 percent and average yield of paddy in Bangladesh was around 4.61 tons per hectare (BBS, 2018), which is much below than the highest country average (6.5 t/ha) (IRRI, 2014).

Bangladesh will require about 44.6 million tons of paddies for the year 2050 (Kabir *et al.,* 2015). During this time entire paddy area will also shrivel to 10.28 million hectares. Rice yield, therefore, needs to be increased from the present 3.073 to 4.3 t/ha. Of the 13.7 million ha of arable land, paddy is grown on 10.28 million ha (75%) producing 94% of total food grain requirement. This is not adequate to feed the nation where 1.5 million tones annual shortage of food grain exists (Sattar, 2000). To achieve complete self-sufficiency in food grain production, the paddy yield needs to be increased without interruption by making full use of the available technologies. To do so, it is necessary to use quality input in the rice production system and postharvest loss reduction.

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Variety of paddy is one of the most vital factors for healthier production of rice. Now-a-days, a number of hybrid and high yielding rice varieties are on hand in Bangladesh which have more yield prospective than conventional inbred varieties (Akbar, 2004). Hybrid rice occupies more than 20 percent yield advantage over improved inbred varieties (Hari Prassad, 2014). Salam *et al.* (2012) reported that the gross margin of Hybrid rice was found 29% higher compared to that of inbred rice. Cropping area of hybrid rice only during the *Boro* season has been amplified 9.77% and yield of hybrid rice increased 0.25% from the previous year. With the increase in land area for hybrid cultivation, the land area for inbred and HYV varieties are decreasing as 0.93 % and 0.29% respectively (BBS, 2016). To meet up the emergent food consumption for the upward population, the cultivation of hybrid varieties of rice is an obligation, and it has been introduced to our farmers.

Mechanization leads to on-time agricultural practices that ensure uniformity and accuracy in production. In rice cultivation, labor deficiency and high labor wages are also major problems both in transplanting and harvesting period. It is projected that the overall labor requirement for rice production per hectare of land was 156.2 man-days of which seedling raising and transplanting consumes 28.24% of the total labor requirement (Rahman, 1997). Singh *et al.* (1985) reported that manual transplanting takes about 250-300 man-hours/ha and it is approximately 25% of the total labor requirement for the crop production. The yield loss due to delayed planting was recorded as 60.0, 55.4 and 9.0 kg per ha/day in the *Boro, Aman* and *Aus* seasons, respectively (Satter, 1999). From year 2000 to 2010, the share of hired labor in agriculture decreased from 19.4 percent to 15.5 percent (Emran *et al.,* 2018) due to accretive urbanization and industrialization. The maximum yield is again a function of transplanting time. In these circumstances, to meet up the crisis of labors in transplanting season, to minimize the total production costs of cultivation to ensure in time operations and to increase the production per hector mechanical rice transplanting is needed (Rabbani *et al.,* 2018).

As day-to-day farmers are moving to hybrid rice cultivation and the decreasing scenario of the labor availability in agriculture is most concerning, the mechanical transplanting of hybrid rice pretends its importance now a day to gear up the growing hybrid production to meet up the challenge of food security. So, the study was carried out with the objective of evaluating mechanical transplanting performance of hybrid rice in different soil conditions compared to traditional transplanting based on the agronomic and yield parameters.

Materials and Methods

The experiment was conducted in *Boro* (December 2017-April 2018) season at the experimental field of Department of Farm Power and Machinery, Bangladesh Agricultural University farm, Mymensingh, Bangladesh. Seedling was raised at the workshop of Farm power and machinery department.

Seedling raising

Seedling was raised with Hybrid rice seed, Moyna (HTM303) of Laal Teer Seed Company Ltd. Seedling was grown on plastic tray maintaining the seed rate 120g per tray (Sarkar *et al.,* 2019) and was covered with polythene due to cold weather. For traditional transplanting, seedling was also grown in traditional method using same seed and conditions. Sufficient irrigation was provided during seedling raising period for proper development of the seedlings. Tray making process was broadcasting on trays by hand. Tray preparation and seedlings are shown in Figure 1 and Figure 2, respectively.

Figure 1. Tray preparation

Figure 2. Seedling on tray

Seedling transplanting

Seedling was transplanted in field using Daedong DP-480 rice transplanter. Unpuddled field was prepared by weed treatment using herbicide, and after herbicide application, the field was flooded with standing water for 72 hours. The puddled field was prepared with a 2-wheel tractor (2WT). For conventional transplanting, a field was also prepared by puddling with 2WT and transplanting was done by hand following traditional rice transplanting method. General features of the rice transplanter are shown in Table 1.

Table 1. General features of the transplanter

Attribute	Description	DP 480
Dimensions	Length × width × height (mm)	2385×1530×870
	Overall weight (kg)	160
Engine	Type	4-strocke, air-cooled, gasoline
	Output kW/rpm	3/1800
Traveling Section	Forward & Reverse	2 speeds and 1 speed
Transplanting Section	Number of rows	4
	Row to row distance (mm)	300
	Plant to plant distance (mm)	110,130,150
	Transplanting speed (m/s)	0.6 to 1.0

Performance of rice transplanter

Machine performance

The machine performance of the transplanter was measured as an appraisal of transplanting speed, theoretical field capacity, actual field capacity, field efficiency, time of operation and fuel consumption in puddled and unpuddled soil condition.

Transplanting speed

Transplanting speed was recorded from the time required for the transplanter to travel a distance before a turn in the field. The speed of transplanting can be computed using equation 1 (Kepner *et al.,* 1978).

$$S=\frac{D}{t}\times 3.6 \qquad (1)$$

Where, S = Transplanting speed (Km/h), D = Distance of travel (m) and t = Time required to cover the distance D (s).

Theoretical field capacity

Theoretical field capacity is the rate of field coverage that would be obtained if the machine performs its function 100% of the time at the rated forward speed and always covers 100% of its rated width. Theoretical Field capacity was calculated by equation 2 (Kepner *et al.,* 1978).

$$C_0=\frac{W\times S}{C} \qquad (2)$$

Where, C_0 = Theoretical field capacity (ha/h), w = Operating width of the transplanter (m), S = Transplanting speed (Km/ h) and C = Constant, 10.

Actual field capacity

It is the ratio of actual area of field coverage by the machine to the total time during operation. Equation 3 was used for determining actual field capacity (Kepner *et al.,* 1978).

$$C=\frac{A}{T} \qquad (3)$$

Where, C= Actual field capacity (ha/h), A= Total transplanted area (ha) and T= Total operating time required for transplanting (h).

Field efficiency

It was obtained from the ratio of effective field capacity and the theoretical field capacity of a machine under field conditions and the theoretical maximum output which was calculated by equation 4 (Kepner *et al.,* 1978).

$$e=\frac{C}{C_0}\times 100 \qquad (4)$$

Where e = Field efficiency (%), C = Actual field capacity (ha/h) and C_0= Theoretical field capacity (ha/h).

Fuel consumption

Before starting to field operation the fuel tank of transplanter was filled with fuel. The total operating time was also recorded and after the completion of field operation the fuel tank of machine was refilled, and the amount of refill was recorded.

Time of operation

Time of operation was recorded from a video of the total operation and turning time, idle time, loading time and operation time was recorded using Multimedia Player, "Daum Potplayer".

Field performance of the transplanter

Percent missing hills

The ratio of total number of hills without seedlings to the total number of hills expressed in percentage as missing hill percentage and it can be calculated by the following equation

$$H_{pm}=\frac{H_m}{H_t}\times 100 \qquad (5)$$

Where H_{pm}= Percent missing hills (%), H_m= Total number of missing hills in the sampling area and H_t= Total number of hills in the sampling area.

Tiller per hill

Three randomly selected hills from different position of each $1m^2$ selected areas was counted for estimation of plants per hill.

Percent floating hills

It is the ratio of the number of floating hills after transplanting to the total number of hills expressed in percentage and it can be calculated by the following equation:

$$H_{pf}=\frac{H_f}{H_t}\times 100 \quad (6)$$

Where H_{pf} = Percent floating hills (%), H_f = Total number of floating hills in the sampling area and H_t = Total number of hills in the sampling area.

Yield performance

Yield performance parameters were recorded as a measure of grain yield, no. of grain per plant, panicle length, grain-straw ratio, and no. of tiller per hill at the time of harvesting. The data was compared with traditionally transplanted hybrid rice. Grain yield was measured at 14% moisture content using John Deer digital moisture meter (Moisture Check PLUS™, SW08120). The weight of grain was measured by a digital weight machine and the moisture content was measured at the same time. The moisture content (MC) of grain in dry basis from wet basis was calculated by the following equation (Bala, 2016):

$$\%M=\frac{100\times m}{100-m} \quad (7)$$

Where M= moisture content in dry basis (%) and m= moisture content in wet basis (%).

The weight of grain in any moisture content (D.B) was calculated by equation 8 (Bala, 2016).

$$W_f=W_i\times\frac{100-M_i}{100-M_f} \quad (8)$$

Where, W_f=final weight of grain at 14% MC (g), W_i = initial weight of grain (g), M_i= initial MC (%) and M_f = final MC (%).

Grain-straw ratio and panicle length

Straw grain ratio was calculated by dividing grain yield with respect to straw yield. The grain and straw yield were measured in kilogram per ha. Panicle length of the rice plant was measured as an average of three readings from three randomly selected plots from each treatment.

Results and Discussion

Machine performance of transplanter

Table 2 shows the machine performance of Daedong DP-480 Transplanter. It gives a clear scenario that the performance of the rice transplanter is not same in two different soil conditions. The soil hardness and vegetation caused the difference in operational parameters though the transplanter was the same. Transplanter in unpuddled condition possessed a lower field capacity and higher fuel consumption than in puddled condition.

Table 2. Machine performance of the transplanter

Parameters	Values	
Soil condition	Puddled	Unpuddled
Area covered, ha	0.03	0.028
Time required, min	10.40	10.84
Forward speed, km/h	2.06	1.92
Machine width, m	1.20	1.20
Theoretical field capacity, ha/h	0.25	0.23
Actual field capacity, ha/h	0.17	0.16
Field efficiency (%)	70.20	67.40
Fuel consumption (l/ha)	4.61	4.80

Time of operation

The time required for the mechanical transplanting in puddled soil was 31min 13s and operational time in unpuddled land was 29min 31s. This operational time also includes turning time, loading-unloading time, and idle time. Figure 3(a) and (b) are the graphical representations of comparative time distribution of mechanical transplanting in puddled and unpuddled soil, respectively. In Figure 3, a 2% of total operational time in puddled soil was used as idle time where in unpuddled condition it took 11% of total time. The reason of the dissimilarity was clogging of mud and vegetation with picker and other moving parts of the transplanter.

Missing and floating hill percentages

The missing hill percentage in puddled soil and unpuddled soil was found 6.37% and 6.1%, respectively where floating hill was 5.46% and 7.36% for the two soil types. Floating hill is a function of soil compaction and standing water level. The standing water level was quite high in unpuddled soil that caused the high floating hill percentage in unpuddled field. Figure 4 and Figure 5 shows the comparative missing hill and floating hill percentages in two soil conditions, respectively.

Growth parameters

The growth parameters include the growth by length and no. of tiller per hill at an interval of 20 days. The comparison of regular growth and no. of tiller per hill and plant height of mechanically transplanted rice in puddled and unpuddled condition to traditionally transplanted rice for *Boro* season is shown in Figure 6 and Figure 7, respectively.

It was observed that the plant growth in unpuddled soil was lower than that of puddled soil. The fig.6 shows that the number of tillers per hill in puddled soil was increased more rapidly than unpuddled land. At the time of harvesting, the number of tillers/hill in unpuddled soil became 18 on average but in puddled soil, the number became 24 on average. Both the figures (Figures 6 and 7) reveal that the mechanically transplanted rice in both puddled and unpuddled soil gave the more satisfactory result than the traditional field.

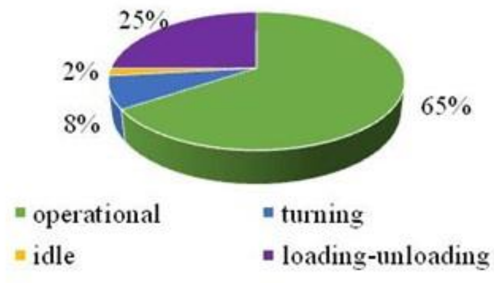

Figure 3a. Comparative operational time distribution (puddled condition)

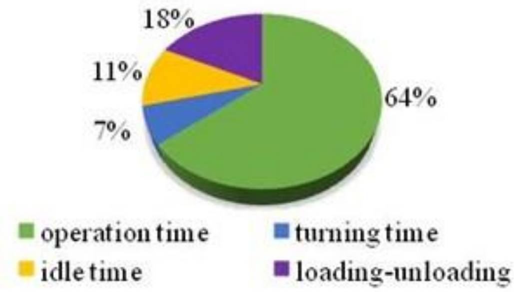

Figure 3b. Comparative operational time distribution (unpuddled condition)

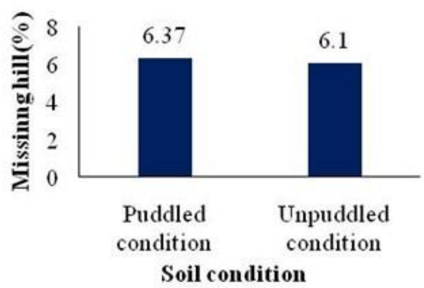

Figure 4. Missing hill (%) in puddled and unpuddled soil

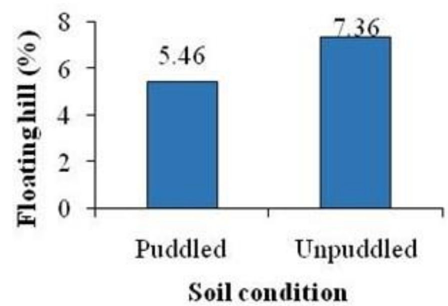

Figure 5. Floating hill (%) in puddled and unpuddled soil

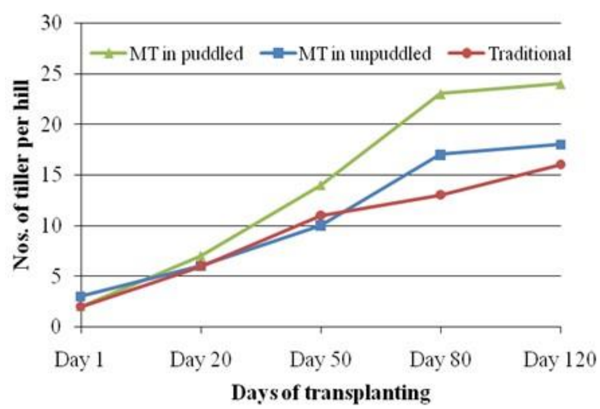

Figure 6. Comparative tiller nos./hill vs. time. *MT=mechanical Transplanting

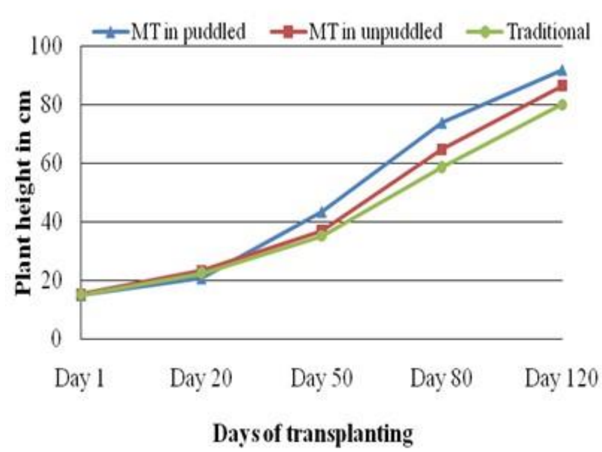

Figure 7. Comparative height vs. time. *MT=Mechanical Transplanting

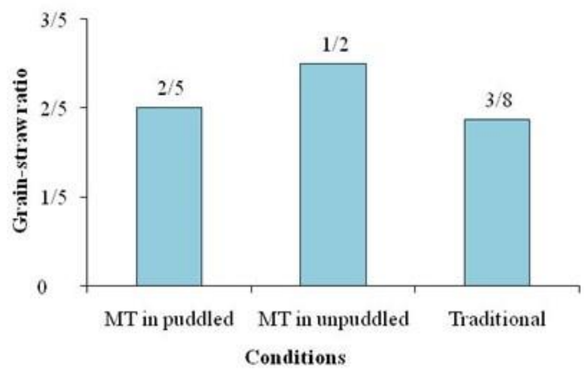

Figure 8. Comparative straw-grain ratio (by weight). *MT=Mechanical Transplanting

Grain yield

The yield of mechanically transplanted rice in puddled and unpuddled soil condition was 5.60 Ton/ha and 5.21 Ton/ha, respectively where the manually transplanted field provides a yield of 4.22 Ton/ha. The yield result shows that mechanical transplanting gives more yield than traditional practice as in-line transplanting and timely operation was possible in mechanical transplanting. Barua *et al.* (2001) compared mechanically transplanted inbred variety rice with manually transplanted rice and found an average yield of 4.71 t/ha for mechanically transplanted rice. Average yield in manually transplanted paddy was recorded 4.20 t/ha.

Grain-straw ratio

Grain- straw ratio shows the result of grain yield over straw. This study reveals that the ratio is higher in mechanical transplanting in puddled and unpuddled soil than traditional practice. Figure 8 shows the comparative grain-straw ratio of mechanical transplanting in puddled and unpuddled soil and traditional practice of rice transplanting.

Comparative panicle length

The average panicle length of mechanically transplanted plants in puddled and unpuddled soil was found 25.11 cm and 23.61 cm where in manual transplanting, it was 23.17cm.

Conclusion

The experimental evaluation of machine transplanting of hybrid rice shows that machine transplanting performs better in terms of agronomic and yield parameters than manual transplanting. However, missing hill and floating hill of the transplanter in unpuddled condition were 4.26% lower and 25.8% higher, respectively than the same transplanter in puddled condition. The fuel consumption of the transplanter was 3.95% lower in the puddled condition than in unpuddled condition. Though seedling requirement per hill was higher than prescribed amount in both puddled and unpuddled conditions, but the higher growth and yield of hybrid variety rice were observed in machine transplanting than manual. Machine transplanting of hybrid rice could be a viable option for reducing transplanting time and increasing production of hybrid variety rice for ensuring food security in Bangladesh. In future, intervention is needed to reduce floating hill percentage in unpuddled condition.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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