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Techno-economic performance of mechanical transplanter for hybrid variety of rice in unpuddled soil

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Abstract

Unpuddled transplanting of rice as a part of conservation agricultural practice has become significant due to its protective behavior for soil properties and economic profitability. Mechanical transplanting in unpuddled soil using hybrid rice variety leads to a high yield with minimum transplanting time and cost, securing soil nutrients. A study was conducted in Bangladesh Agricultural University to evaluate the efficacy of mechanical transplanting of hybrid rice in unpuddled soil considering field and financial performances of rice transplanter. The experiment was conducted during *Boro*-2018 season with a Daedong DP-480 rice transplanter. Hybrid rice seed Moyna (HTM303) of Laal Teer seed company Ltd. was used for transplanting at a seed rate of 120g per tray and seedling per hill was adjusted to 2-3 nos. In unpuddled soil, transplanter possessed an effective field capacity, fuel consumption and efficiency of 0.16 ha/h, 4.8 l/ha and 67.48%, respectively. Transplanting time included an idle time of 11% due to clogging with mud. Missing hill percentage was found as 6.1% with a floating hill of 7.36%. Plant heights were 15.72 cm and 86.19 cm at the day of transplanting and at the day of harvesting, with tiller per hill of 18 nos. The average panicle length of plants was found as 23.6 cm where traditionally transplanted rice has panicles of 21.2 cm average. The yields of mechanically transplanted rice in unpuddled soil condition was 5.21 ton/ha and the yield of mechanical transplanted rice in unpuddled soil was found to be 27.07% higher than traditionally transplanted rice. The BCR and IRR of mechanical transplanting in unpuddled soil was found 1.57 and 55% considering 10% discount factor. The payback period, after which the transplanter will overcome its costs, was found 1.68 years. Financial analysis reveals that mechanical transplanting with this field capacity will be beneficial if the transplanter is used to transplant 19.77 ha annually.

Key words: Machine transplanting, unpuddled soil, financial analysis, BCR, IRR, economic use

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Introduction

Conservation agriculture (CA) is now being practiced in numerous forms over 157 million ha globally (Kassam, 2014) but mostly in large mechanized farms in rainfed and supplementary irrigation areas. There is a little application of CA in rice-based systems which support primarily marginal farms (Johansen et al., 2012). Unpuddled transplanting is a conservation practice that ensures economic maintenance of operational expenditures. Unpuddled transplanting also leads to minimum disturbance in soil texture and thus protects the soil nutrients. Puddling should preferably be avoided as it is an unfavorable practice for the succeeding upland crops. Minimum tillage performs convenience over puddling in a clay loam soil for upholding physical condition and saving field preparation time (Brown and Quantrill 1973). Haque (2009) found that the unpuddled transplanting of rice on bed, strip and single pass shallow tillage practices gives similar yield compared to conventional puddling with additional benefits in fuel and water savings.

The mechanical rice transplanter may experience sinkage and poor wheel traction in puddled soil that decrease its efficiency as other wetland farm machinery. When a mechanical rice transplanter works on puddled soil and encounters a firm surface it performs better. In addition, the puddled surface must possess necessary load bearing capacity to prevent sinkage of the float of the transplanter. Simultaneously, the plow pan must be shallow enough to afford the necessary traction to propel the transplanter. Both traction and load bearing capacity of the transplanter depends on the shear strength of soil (Knight and Freitag, 1962). Therefore, hypothetically unpuddled soil would create more traction and load-bearing capacity compared to puddled soil and thus enhance the efficiency of the mechanical rice transplanter. However, the greater strength of unpuddled soils may limit penetration of the rotary picker and hence reduce the success of seedling establishment. Hence, it was observed that transplanting manually into unpuddled soils increased rice yield in previous studies (Haque, 2009; Haque et al., 2016), there was uncertainty about the performance of a small-scale mechanized transplanter on unpuddled soils and its impact on crop establishment and yield.

Mechanization in rice production has its own advantage of time, labor and cost saving with a high yield. Rice production gives a large amount of cost in seedling transplanting which accommodates about 25% of the total labor requirement (Singh *et al.,* 1985). Mechanization is the ultimate solution of agricultural labor shortage that occurs due to expeditious urbanization. Mechanical transplanting of seedling leads to low cost operation in time and in minimum labor requirement. Mechanical transplanting of hybrid rice complements an additional value in yield as hybrid rice yields 20% higher than inbred varieties (Hari Prasad et al., 2014). 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 varieties pretends its importance now a day to gear up the growing hybrid production to meet up the challenge of food security

The commercial use of mechanized transplanting with small scale machineries has also indicated encouraging possibility since marginal farmers as the ultimate user, have positive interest. However, the performance of commercial transplanting service was observed lower than the recommendable margin because of several restraints that were identified in *Aman* 2014 (Islam et al., 2015). Those constraints pointed a need of formulation of a rigid service business that can cover up the underlying performance of machine in operation at the farmer’s field. The service providing business for rice transplanter thus can include all those crucial issues. However, the willingness of a general user or a marginal service provider to adopt a business relies on his/her motivation that depends on the profitability of that particular business. So, to gear up the service providing business based on mechanical rice transplanting, analysis of its cost and benefit with other financial factors is necessary. Considering these circumstances, the objective of this study is to evaluate the techno-economic performance of mechanical transplanting in unpuddled soil with hybrid rice variety and compare the yield and yield parameters of mechanically transplanted hybrid rice with traditionally transplanted hybrid variety.

Materials and Methods

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

Seedling raising**:** Seedling was raised at the FPMD workshop with hybrid rice seed, Moyna (HTM303) of Laal Teer Seed Company Ltd. Seed rate was maintained 120 gm per tray for hybrid rice (Sarkar *et al*., 2019). Seedling was grown on plastic tray and was covered with polythene due to cold weather. 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 on trays are shown in Figure 1 and 2, respectively.

Figure 1. Tray preparation.

Figure 2. Seedling on tray.

Seedling transplanting**:** Seedling was transplanted in field using Daedong DP480 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. General features of the transplanter is shown in Table 1.

Technical performance of rice transplanter in unpuddled soil**:** The machine performance of the transplanter was measured as a measure of transplanting speed, theoretical field capacity, actual field capacity, field efficiency and fuel consumption in unpuddled soil condition.

Transplanting speed: Transplanting speed was recorded from the time required for the transplanter to travel a distance, D during operation in the field. The speed of transplanting was computed using equation 1 (Kepner, 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, 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, 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, 1978).

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

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

Table 1. General feature of the transplanters.

Attribute	Description	Values
Dimensions	Length × Width × Height (mm)	2385×1530×870
	Overall weight (kg)	160
Engine	Type	4-stroke, 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

***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 refilling fuel was recorded.

***Time of operation*:** The whole procedure of transplanting was recorded by digital camera of Samsung galaxy J2 cell phone. Time of operation and time distribution was recorded from the video clip as a measure of turning time, idle time, loading time and operation time using a Multimedia Player, "Daum Potplayer".

***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:

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

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 area was counted for estimation of plants per hill. Three replications of 1m^2 area was selected randomly from three different positions of the field.

***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:

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

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 penicle, panicle length, straw grain ratio and no. of tiller per hill at the time of harvesting. The yield data of mechanically transplanted rice was compared with secondary data of traditionally transplanted hybrid rice.

Financial performance of rice transplanter in unpuddled soil

Operating cost of transplanter: Transplanter operation cost consists of fixed cost and variable cost. Fixed cost consists of depreciation, interest on invest, taxes, insurance and housing and variable cost has cost items as labor, fuel, oil, repair and maintenance costs.

Fixed cost does not change with level of output. The straight-line method was used for calculating depreciation (Barnard and Nix, 1980). The equation for calculating depreciation is as follows (Hunt, 1977):

$$D = \frac{P\text{-}S}{L} \ldots\ldots(7)$$

Where D = Yearly Depreciation (USD/yr.), P = Purchase price (USD), S = Salvage value (USD) and L = Machine life, assumed as 6 years.

The interest on investment is considered as an important fixed cost item as it is a direct expense item on borrowed capital. The interest on investment is calculated by following formula (Hunt, 1977):

$$I = \frac{P+S}{2} \times i \ldots\ldots(8)$$

Where I= Interest on investment, (USD/yr.) and i = rate of interest (decimal), assumed as 10%

An annual charge equal to 2.5% of the purchase price was considered as the housing and shelter (Hunt, 1977). Shelter cost:

T = 2.5% of P……………………………………….(9)

Total fixed cost per year, FC = (D + I + T)……..…(10)

Variable cost depends on hourly labor cost, fuel, oil, repair and maintenance cost depending on the required working hours for each field operations. The fuel cost is estimated as product of fuel consumption per hour (l) and price per litter of fuel. The lubrication cost is estimated as 15% of fuel cost. Repair and maintenance cost (R & M) are calculated by the following equation (Hunt, 1977):

$$R\ \&\ M = \frac{0.035 \text{ of } P}{\text{yearly use, h}} \ldots\ldots(11)$$

So, the **total variable cost (VC)** = Labor cost + Fuel and lubrication cost + Repair and maintenance cost..(12)

Annual operating cost of Transplanter was divided into fixed cost and variable cost. All calculated fixed cost and variable cost was calculated in USD/ha and then summation of fixed and variable cost was considered as operating cost in USD/ha. Operating cost was calculated as follows:

Operating cost (USD/ha) = Fixed cost +Variable cost…..(13)

***Rent out charge*: ** Rent out charge is the amount that the machine owner pretends to have including his machine operating costs and his profit. The transplanter rent-out cost for an entrepreneur was estimated from the following expression:

Rent out charge = Operating cost + Estimated profit……(14)

Estimated profit is the profit of owner excluding all costs of operation and payments. This amount was estimated based on field data of farmer's daily income.

***Benefit cost ratio (BCR)*:** Benefit cost ratio is the ratio of present worth benefit to present worth cost. The machinery can be said profitable if the BCR is greater than unity. BCR was calculated by the following formula (Barnard and Nix, 1980):

BCR= ∑Present worth Benefit (PWB) / ∑present worth cost (PWC)………………………………………...(15)

***Internal rate of return (IRR)*:** IRR is the value of discount factor when the NPV is zero. The transplanter can be said profitable if the IRR value is greater than the Bank interest rate. The IRR can be computed with the help of this formula (Barnard and Nix, 1980):

IRR= Lower discount rate + {Difference between the discount rate × (Present worth of cash flow at lower discount rate/Absolute difference between the present worth of cash flow at the two discount rates)}…….(16)

***Payback period*:** Payback period is the time within which the initial investment is returned as cash. The payback period can be calculated as following formula (Barnard and Nix, 1980):

Payback period = total initial investment (USD)/Net benefit (USD/yr.)………………………………….(17)

***Economic use of transplanter*:** Rice transplanter can only be used in rice transplanting operation and the time of operation is only 40-50 days in a year. The rest of the year, machine remains idle and there is no use of the transplanter. So, for determining the economic use, a break-even analysis was used to find out the minimum operation area per year. The break-even point of economic use was estimated by equation 18 (Hunt, 1977).

Break even use, $\frac{ha}{yr.} = \frac{\text{FC (USD/yr.)}}{\text{(Total benefit (USD/ha)-VC (USD/ha)}}$..(18)

Where, total benefit = operating cost + estimated profit.

Results and Discussion

***Machine performance of transplanters*:** Table 2 shows the machine performance of Daedong DP-480 Transplanter.

Table 2. Machine performance of transplanter.

Parameters	Values
Machine width (m)	1.20
Area covered (ha)	0.028
Time required (min)	10.84
Forward speed (km/h)	1.92
Fuel consumption (l/h)	4.82
Theoretical field capacity (ha/h)	0.23
Effective field capacity (ha/h)	0.16
Field efficiency (%)	67.40

Time of operation: The time required for the mechanical transplanting in unpuddled land was 29 min 31s with 18 turns and 8 loadings of tray. This operational time also includes turning time, loading time and also idle time. Figure 3 is the graphical representation of the comparative time distribution of mechanical transplanting in unpuddled soil.

In Figure 3, the 11% of total operational time was used as idle time. The reason of this high idle time was clogging of mud and residual vegetation with rotary parts of transplanter.

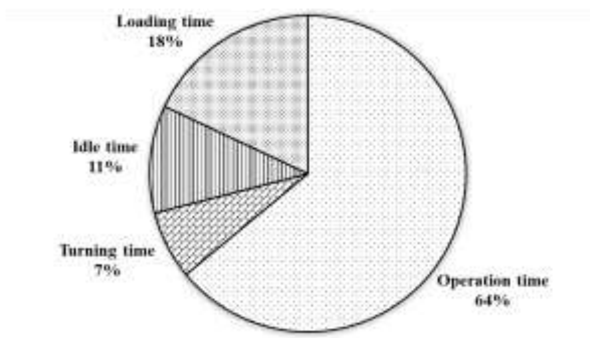

Figure 3. Time distribution of transplanting in unpuddled soil.

***Field Performance result of the transplanter*:** Field performance of the transplanter gives a satisfactory result in transplanting hybrid rice variety. It possessed a lower missing and floating percentage. The test result is shown in Table 3.

Table 3. Field performance of the transplanter.

Parameters	Values
Missing Hill (%)	6.1
Floating Hill (%)	7.36
No. of plant/ hill (nos.)	3-4

Yield result

***Grain yield*:** The yield of mechanically transplanted rice in unpuddled soil condition was 5.21 Ton/ha where the manually transplanted field provides a yield of 4.10 Ton/ha (Islam et al., 2014). The yield of mechanical transplanted rice in unpuddled soil was found to be 27.07% higher than traditional transplanted rice.

***Grain-straw ratio*:** Grain- straw ratio shows the result of grain yield over straw. This study revealed that the ratio is higher in mechanical transplanting in unpuddled soil than traditional practice (Ito, 1975). Figure 4 demonstrates the grain-straw ratio of mechanically transplanted rice in unpuddled soil compared to traditional practice.

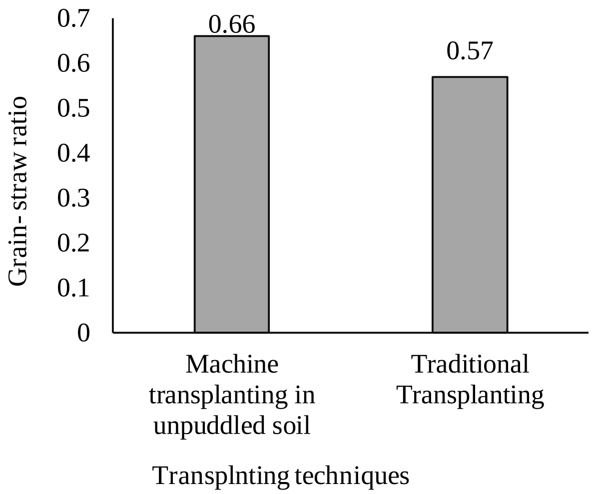

Figure 4. Grain-straw ratio.

***Comparative panicle length and nos. of grain*:** The average panicle length of plants in unpuddled soil condition was 23.6 cm. The comparison of panicle length and nos. of grain per plant of mechanically transplanted rice in unpuddled soil and traditional practice is shown in Figure 5.

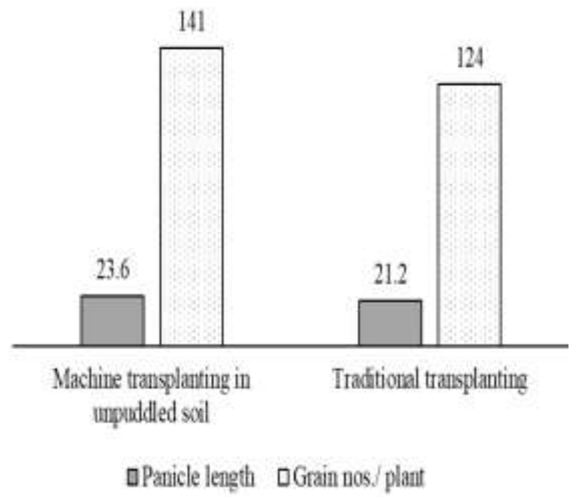

Figure 5. Comparative panicle length and no. of grain.

Financial Performance of the transplanter

***Cost items and operating cost of rice transplanter*:** The fixed cost of the transplanters is a function of purchase price. The purchase price was 4216.87 USD. Interest rate was considered as 10%. Variable cost is related to the use of transplanter and field capacity. The detail cost items are presented in Table 4.

Table 4. Cost items of rice transplanter.

Cost items		**values**
Fixed cost items	Depreciation, USD/yr.	632.53
	Investment on Interest (i=10%), USD/yr.	231.93
	Shelter, USD/yr.	105.42
	Total fixed cost, USD/yr.	969.88
	Total fixed cost, USD/ha	18.94
Variable cost items	Fuel, USD/h	0.80
	Lubricant, USD/h	0.12
	Repair and Maintenance cost, USD/h	1.48
	Cost of operator, USD/h	1.20
	Cost of labor, USD/h	1.81
	Total variable cost, USD/yr.	1730.20
	Total variable cost, USD/ha	33.79
Total operating cost, USD/ha		52.73

***** Field capacity = 0.16 ha/h, assuming days of transplanting per year = 40 and average working hour per day = 8 h

***Transplanter rent out charge*:** Transplanter rent out charge is the sum total of operating cost and profit. The rent-out charge for transplanter was estimated at 82.86 USD per ha based on entrepreneurs expected income.

***Financial analysis*:** The project appraisal method of financial analysis (Barnard and Nix, 1980) shows the acceptability of rice transplanter from the owners or service providers' point of view. From the analysis, at 10% discount factor, BCR of Daedong DP-480 transplanter was found 1.57. The BCR as higher than unity, the transplanter custom hire service was found to be profitable. The IRR value of the transplanter was 55%. The IRR values are also higher than the bank interest rate which is the indicator of profitability. The payback period was found 1.68 years. The payback period indicates that after this time period the owner can get back the payment for purchasing the machine. Considering these circumstances, the financial analysis substantiates the transplanter as highly profitable machine from the viewpoint of individual investors.

***Economic use of transplanter*:** A break-even analysis was conducted to determine the economic use of the transplanter in terms of operation area per year. Figure 6 illustrates the break-even analysis of Daedong DP-480 transplanter.

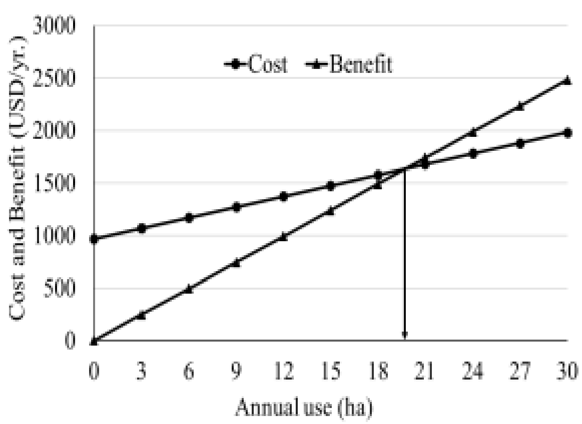

Figure 6. Economic use of transplanter.

The break-even analysis shows that if the transplanter is used to transplant more than 19.77 ha annually, it will bring profit.

Conclusions

As an important and labor-intensive activity, mechanization in rice transplanting is a demand of time. The rice transplanter saves labor, time of transplanting and also ensures scheduled cropping. So, mechanical transplanting is the ultimate solution of rice cultivation. The transplanter possesses a reliable result in unpuddled soil. The floating hill as a result of soil hardness and hole created by a penetration of human leg results high. But yield of crop is better than manually transplanted rice. All yield parameters show that the machine transplanting of hybrid rice in unpuddled soil performs better result than traditional transplanting methods. The financial analysis establishes the rice transplanter as a profitable machine for business for new entrepreneurs. It is estimated that a transplanter can be operated 40 days a year and can transplant around 51.2 ha per year. From the break-even analysis, the minimum operating area was found much lower than the estimated area. It's a fact that the *Aman* season is not so congenial for unpuddled soil as weed infestation is higher in *Aman* season than other two seasons and because of heavy rain, herbicide is not properly applicable. So, machine transplanting in unpuddled soil can be practices in *Boro* and *Aush* seasons. As the two seasons covers the two third of the transplanting time per year, So, it should be convenient to practice machine transplanting in unpuddled soil for custom hire business. From financial analysis it can be said that as the BCR is higher than unity and the IRR value is higher than bank interest rate, the transplanter was found as a profitable machine. Previous studies revealed that hybrid rice produces 20% more yield than inbred and local varieties. Based on the studies and findings, it can be said that, the use of rice transplanter to transplant in unpuddled soil can be a great opportunity of custom hire business as well as entrepreneurship development in marginal level with greater opportunity of yield using hybrid varieties.

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