Agricultural Sciences, 2025, 16(11), 1227-1242
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Performance Assessment of BRRI and Imported Self-Propelled Rice Transplanters in Bangladesh during Aman Season

Arafat Ullah Khan[1], AKM Saiful Islam[1], Fariha Akhter[2], Md. Rizwanur Rahman[3], Md. Kamruzzaman[1*]

[1]Farm Machinery and Post Harvest Technology Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh
[2]SFMRA Project, Farm Machinery and Post Harvest Technology Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh
[3]Department of Agro Machinery Production and Assembly, Banglamark Limited, Chittagong, Bangladesh
Email: *pintubrri21@gmail.com

How to cite this paper: Khan, A.U., Islam, A.S., Akhter, F., Rahman, M.R. and Kamruzzaman, M. (2025) Performance Assessment of BRRI and Imported Self-Propelled Rice Transplanters in Bangladesh during Aman Season. *Agricultural Sciences*, **16**, 1227-1242.
https://doi.org/10.4236/as.2025.1611071

Received: September 29, 2025
Accepted: November 23, 2025
Published: November 26, 2025

Abstract

Mechanical rice transplanting has been emerged as an alternative of traditional rice transplanting in Bangladesh. This study aimed to compare the performance of the BRRI-developed and imported self-propelled 4-row walking-type rice transplanters to identify which model is more efficient, cost-effective, and suitable for local field conditions to support sustainable rice cultivation. Field trials were executed in a mechanized village and on a farmer's field in Jashore during the Aman season of 2023 to minimize the expenses associated with the operations of rice transplanting. The performance of the BRRI-developed 4-row self-propelled rice transplanter was shown to be significantly superior to that of imported rice transplanters and manual transplanting methods. The field capacity, field efficiency, and fuel consumption of the 4-row self-propelled rice transplanter that was BRRI developed and imported were as follows: 40.12 decimal/hr, 79.50%, 1.52 lit/hr, and 35.73 decimal/hr, 78.03%, and 1.32 lit/hr, respectively. The cost of BRRI- developed and imported 4-row self-propelled rice transplanter was determined to be BDT 1200-1500 per decimal, in contrast to BDT 3500 per decimal for the traditional manual transplanting method employed by farmers in the Jashore region. The machine was determined to be more practical and user-friendly for farmers when compared to manual rice transplanting in terms of time, money and labour requirements.

Keywords

Efficiency, Crop Production, Fuel Consumption, Technology Assessment, Transplanting

1. Introduction

Rice is a crucial crop and staple meal for millions, cultivated in numerous countries worldwide. These days, rice cultivation has become one of the most essential means of livelihood for people around the world. Rice is the main food for more than half of the world's people, meeting about 80% of their daily diet and acting as a vital staple for nearly half of humanity [1]. According to the Food and Agriculture Organization (FAO, 2001), global rice production, which was 586 million metric tons in 2001, needs to increase to about 756 million metric tons by 2030 to meet the expected demand.

Transplanting plays a key role in rice farming. It starts with raising seedlings in a nursery for about 15 to 40 days, after which they are carefully uprooted and moved to larger fields, either by hand or with the help of machines [2].

Manual hand transplantation necessitates no expensive machinery and is ideally suited for regions with excess labor and small rice paddies. Manual transplantation occurs in areas characterized by suboptimal levelling and fluctuating water levels. Most paddy is still grown using manual transplanting, which is labor-intensive, tiring, and costly. Manual transplanting requires approximately 250 - 300 man-hours per hectare, accounting for roughly 25 percent of the overall labor demand for the crop.

The procedure for mechanical rice transplanting involves the use of specialized equipment, such as a rice transplanter, to transplant young rice seedlings. A standard rice transplanter is made up of parts like mechanical linkages for planting seedlings, a tray to hold them, a frame, a fork, a handle, and a ground wheel. It is capable of planting two, three, or up to six rows of seedlings simultaneously at a uniform distance.

The manual transplanting takes about 123 to 150 man-hours per hectare, whereas mechanical transplanting reduces the need to just 9 to 10.5 man-hours per hectare [3]. This means manual transplanting uses around 19% - 22% of the total labor in rice production, while mechanical transplanting requires only about 1.65% - 2% [4]. Manual transplanting is a very tiring process that demands a lot of time, effort, and energy.

The two main methods of mechanized rice planting are mechanical direct seeding (MDS) and mechanical transplantation of rice (MTR). Mechanical transplantation of rice (MTR) is a more cost-effective way to establish rice fields than the commonly used manual transplanting method. The key reasons for adopting machine transplanting are growing labor shortages and the high costs associated with manual transplanting. Mechanical transplanting, in comparison to hand transplanting, can reduce transplant and labour costs by upto 45% and 60%, respectively [2]. Additionally, mechanical transplanting ensures a healthier crop stand and higher yields compared to manual hand transplanting [5].

The first hand-push rice transplanter was developed in Japan, with around

50,000 units introduced between 1960 and 1965 [2]. This single-row machine, weighing 25 - 28 kg, featured a seedling platform, handles, a ground drive wheel, and a float, and worked with seedlings 12 - 15 cm tall. Under ideal conditions, one person could operate the transplanter to cover about 0.05 hectares per hour, completing a 1-hectare field in 25 - 30 hours.

The shortage of labour is a significant issue in certain paddy cultivation regions of the country. Significant efforts have been undertaken to attain elevated rice yields via comprehensive process mechanisation, hence facilitating labour savings and enhancing production efficiency. Transplanting equipment that is effective in countries like Japan, China, India, and Korea is prohibitively expensive and unsuitable for the agricultural practices of smallholder farmers in Bangladesh, exceeding the needs of medium-scale farmers. An agricultural initiative is crucial in our country, focusing on bringing together the private and public sectors to improve land cultivation practices and promote sustainable and holistic agricultural development [6]. The future of mechanized transplanting lies in developing efficient, accurate, and reliable automatic systems that integrate intelligent and information technologies for improved seedling picking and planting in both paddy and dry fields [7]. Engine-driven mechanical planters offer higher planting efficiency than manual methods, while automated transplanters achieve over 90% planting accuracy using advanced technology [8].

The researchers designed a 4-row self-propelled rice transplanter and compared its performance with both imported transplanters and traditional hand transplanting. The developed 4-row walking-type rice transplanter is anticipated to enhance the efficiency and effectiveness of our country's farmers by alleviating their manual workload in paddy transplantation. This equipment will enhance the efficiency and speed of rice production compared to the previous manual method.

However, there is limited scientific evidence comparing field performance, operational efficiency, fuel consumption, transplanting quality, and overall cost-effectiveness of BRRI developed and imported transplanter under real Bangladeshi conditions. This study is conducted to see how both types perform under real farming conditions; so, farmers, policymakers, and researchers can make informed choices that support food security and promote sustainable mechanization.

2. Materials and Method

2.1. Study Location and Season

The study was carried out directly in farmers' fields during the Aman season in the year of 2023. The research took place in Churamonkati, a village of Jashore district (**Figure 1**). The soil at the experimental site was sandy loam in texture.

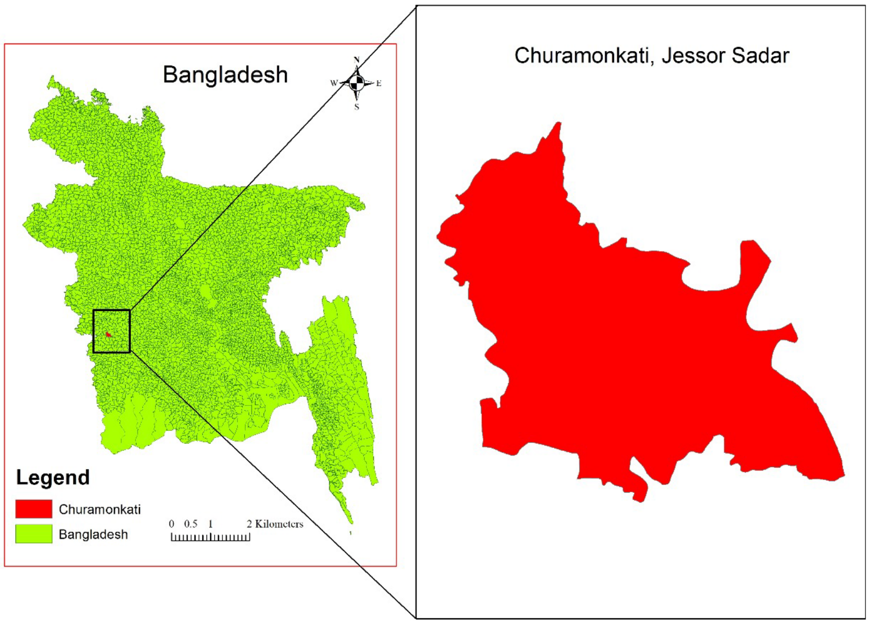

Figure 1. Study area at Churamonkathi, Jashore.

2.2. Description of Machines

The study was conducted for both BRRI developed 4-row rice transplanter (Model: BRRI PRT 2023); as shown in Figure 2 and imported rice transplanter (Model: JANATA 2ZS-4C) and both transplanters are 4-row walking type having ten seedling density control setting, six depth control setting and six seeding intervals setting (Table 1).

Table 1. Specifications of the BRRI developed 4-row self-propelled rice transplanter and imported rice transplanter.

Particulars	Specifications	Specifications
Model	BRRI PRT 2022	JANATA 2ZS-4C
Drive method	2 Wheel 3-float type steering clutch	2 Wheel 3-float type steering clutch
Overall dimensions (L × W × H), mm	2140 × 1530 × 910	2140 × 1580 × 890
Weight, kg	172	165
Engine	Air-Cooled 4-stroke Petrol Engine	Air-Cooled 4-stroke Petrol Engine
Engine rated power, kW/hp	3.4	2.6
Fuel	Gasoline	Gasoline
Fuel tank capacity, l	4	4
Fuel consumption (l/hr)	1.5	1.4
No. of rows	4 nos.	4 nos.
Adaptable seedlings	Mat type	Mat type

Continued

Transplanting space row to row, cm	30	30
Planting speed, m/s	0.44 and 0.54	0.6 and 0.7
Distance between hills, mm	130 (5 steps)	150 (5 steps)
Planting depth, mm	0 - 30	0 - 35
Travel steering	Hydraulic power steering mode	Hydraulic power steering mode
Wheel type	Rubber lug wheel	Rubber lug wheel
Gearshift	Forward: 2 levels, Reverse: 1 level	Forward: 2 levels, Reverse: 1 level
Transplanting mechanism	Mechanical/Rotary	Mechanical/Rotary
Transplanting distance, cm (plant to plant)	12, 14, 16	12, 14, 16
Seedling/hills control	Adjustable (7 options)	Adjustable (5 options)
Transplanting speed, m/sec	0.6 to 1.0	0.3 to 0.7

Figure 2. BRRI developed 4-row rice transplanter.

2.3. Experimental Design

The experiment was arranged as a Randomized Complete Block Design (RCBD) with three treatments and four replications (blocks) to account for field heterogeneity. Treatments were:

T1—BRRI developed transplanter operation;

T2—Imported transplanter operation;

T3—Control manual transplanting operation.

Each treatment plot consisted of four rows, 20 m long (row spacing 0.25 m), giving a gross plot area of 20 m^2. A buffer of 1 - 2 m was maintained between plots and 2 - 3 m between blocks. To avoid edge effects, data were collected from the central 2 rows and the inner 18 m of each plot (net plot). A total of 12 plots (3 treatments × 4 replications) were used. Data were analyzed by ANOVA for RCBD.

Under these three treatments as showed in Figure 3, there are four rows in each treatment stated below:

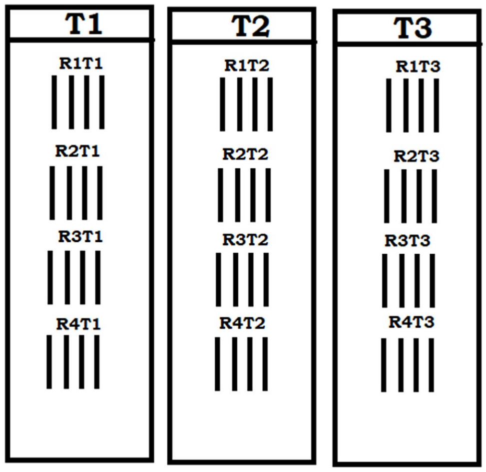

Figure 3. Experimental design.

2.4. Field Preparation

Three plots with clay soil were chosen to test the transplanter. The fields were initially prepared using a motorized tiller and irrigated before the first puddling, with water levels maintained at 5 - 10 cm. After the initial puddling, the fields were left for 3 - 4 days to allow the decomposition of leftover straw and stubble from the previous crop. Final puddling was then carried out using the same tiller, followed by a one-day rest period to consolidate the soil and restore its strength, creating optimal conditions for the transplanter's performance.

2.5. Performance Indicators

The performance of the 4-row self-propelled rice transplanter was evaluated based on the following parameters.

2.6. Transplanting Depth

The transplanting depth was measured by uprooting seedlings right after transplanting. The seedlings were carefully lifted from the surface of the puddled soil, and the distance from the soil surface to the root tip was measured with a scale. Ten random samples were taken to record the transplanting depth [9].

2.7. Number of Seedlings Per Hill

The number of seedlings per hill was determined by counting the seedlings placed in each hill by the planting fingers after transplanting. The average of these counts was then calculated to represent the typical number of seedlings per hill, and ten observations were randomly selected [10].

2.8. Hill Spacing

Hill-to-hill spacing was measured after transplanting using a metric scale. Ten random measurements were taken, and the average was calculated to represent the typical spacing between hills [10].

2.9. Missing Hills

The quantity of missing hills was determined with the overall number of hills in square meters. Five observations were randomly collected, and the mean was represented as a percentage of missing hills. The percentage of missing hills was determined using the subsequent equation [11].

$$\text{Missing hills, \%} = \frac{\text{Number of missing hills per m}^2}{\text{Total number of hills per m}^2} \times 100 \quad (1)$$

2.10. Floating Hills

Floating hills are characterized by seedlings that are either buoyant on the surface or simply positioned atop the muck. The area of floating hills was measured in square meters following transplantation. Five measurements were taken, and the average was calculated to determine the percentage of floating hills, using the following formula [10].

$$\text{Floating hills, \%} = \frac{\text{Number of floating hills per m}^2}{\text{Total number of hills per m}^2} \times 100 \quad (2)$$

2.11. Buried Hills

Hills completely covered with soil after transplanting are called buried hills. These were counted within a one-square-meter area, with five observations recorded. The average was expressed as a percentage of buried hills, calculated using the following formula [11].

$$\text{Burried hills, \%} = \frac{\text{Number of burried hills per m}^2}{\text{Total number of hills per m}^2} \times 100 \quad (3)$$

2.12. Damaged Hills

Seedling damage can be classified into two types: cutting or bending of seedlings, and internal damage to the growing point caused by crushing from the planting fork. Damaged hills were counted within a one-square-meter area after transplanting. Five observations were recorded, and the average was expressed as a percentage of damaged hills, calculated using the following formula [11].

$$\text{Damaged hills, \%} = \frac{\text{Number of damaged hills per m}^2}{\text{Total number of hills per m}^2} \times 100 \quad (4)$$

2.13. Theoretical Field Capacity

The theoretical field capacity of a machine refers to the area it could cover if it operated at full efficiency; moving at its rated speed and consistently covering its entire working width [12].

$$\text{TFC} = \frac{\text{W} \times \text{S}}{\text{C}} \quad (5)$$

where,

TFC = Theoretical field capacity, ha/hr;
W = Operating width of the machine, m;
S = Speed of travel, in km/h;
C = Constant, 10.

2.14. Actual Field Capacity

The actual field capacity was determined the function of transplanted area (A) and operation time (T) by using the formula [12].

$$AFC = \frac{A}{T} \tag{6}$$

where,
AFC = Actual field capacity, ha/hr;
A = Total area transplanted, ha;
T = Total operating time required for transplanting, hr.

2.15. Field Efficiency

The field efficiency is ratio of actual field capacity and theoretical field capacity is express as percentages and calculated by following formula [13].

$$Ef = \frac{AFC}{TFC} \times 100 \tag{7}$$

where,
Ef = Field efficiency, %.

2.16. Fuel Consumption

At starting of transplanting operation fuel tank of transplanter was filled with fuel and required fuel was measured at end of transplanting. Fuel consumption was calculated as the function of required fuel volume and transplanting time [12].

$$F_{cu} = \frac{V}{T} \tag{8}$$

where,
F_{cu} = Fuel consumption rate, L/hr;
V = Fuel used during operation, L;
T = Time needed for operation, hrs.

2.17. Seedling and Tray Preparation

Standard sized plastic seedling trays having dimension 58 × 28 × 3 cm were used for preparing seedling at farmer's field. For this experiment BRRI dhan 87 variety paddy seeds were selected and sown at specified seed rate in trays before 17 days of transplanting. **Table 2** presents the field and nursery conditions observed during the transplanting process. Data collection from experiment field is shown in **Figure 4** (**Table 2**).

Table 2. Field and nursery condition.

Particulars	Specifications
Date of nursery sowing	28 days
Type of nursery	Mat Type
Variety of rice	BRRI dhan87
Seed rate, gm/tray	140 - 160
Age of seedlings, days	17
Plant density, no/cm^2	10
Height of seedling, mm	1010
Leaf stage	3
Root length, mm	120
Standing water level, mm	15 - 20

Figure 4. Data collection from experiment field.

3. Result and Discussion

3.1. Transplanting Depth

The transplanting depth across the three treatments showed noticeable variation as shown in Figure 5. The BRRI developed rice transplanter (T1) achieved an average transplanting depth of 3.10 cm, while the imported RT model (T2) showed a slightly lower depth of 3.05 cm. In contrast, manual hand transplanting (T3) exhibited a higher average transplanting depth of 3.36 cm. This indicates that hand transplanting ensures deeper placement of seedlings compared to both mechanical options. Both mechanical transplanting models displayed relatively uniform but shallower transplanting depths, which may affect initial plant anchorage and establishment in certain soil conditions. The slight variance between the BRRI-developed and imported models suggests minimal mechanical advantage or disadvantage in depth control precision between local and imported units.

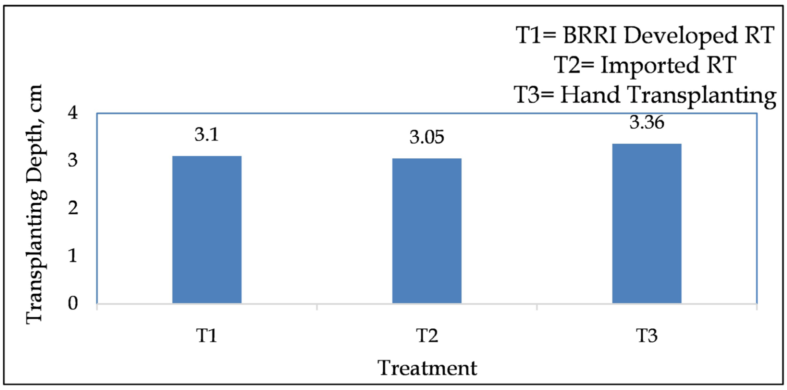

Figure 5. Transplanting depth at different treatment of depth controller.

3.2. Seedling Per Hill at off Field Condition

During off-field tests on a concrete surface, the imported rice transplanter consistently planted more seedlings per hill than the BRRI-developed model at all planting positions as shown in Figure 6. At the high position, the imported RT delivered an average of 13 seedlings per hill, while the BRRI model delivered 11, reflecting a 25% increase. In the medium setting, the imported model achieved 7 seedlings per hill versus 6 in the BRRI model, marking a 14.28% rise. At the low position, the imported RT planted 4 seedlings per hill, compared to 3 from the BRRI-developed model, a 15.38% increase. This pattern suggests that the planting fingers or pickup mechanism in the imported model grips and releases more seedlings per operation. While this could enhance plant population density, especially in low-tillering or hybrid varieties, it may also risk overcrowding if not adjusted properly for spacing and variety type. The results indicate a need for calibration or design adjustment based on planting objectives and crop management strategies.

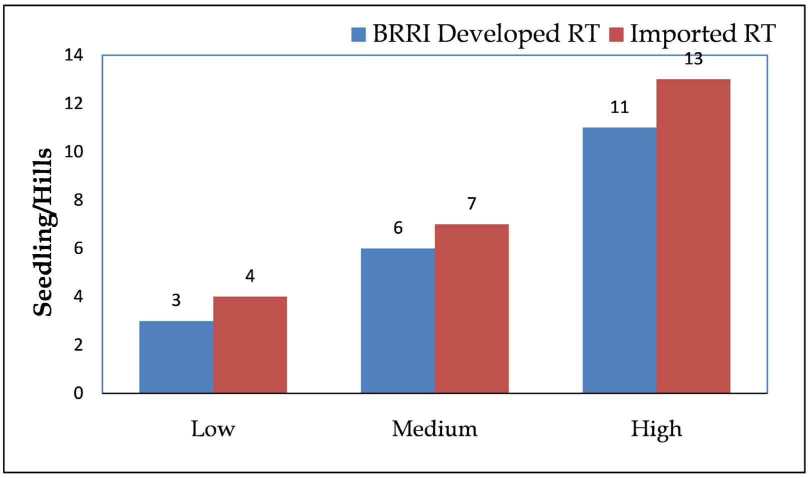

Figure 6. Number of seedlings per hill at different positions under off-field conditions.

3.3. Seedling Per Hill at in Field Condition

During field testing, the number of seedlings per hill showed slight variation between the BRRI-developed and imported rice transplanters, depending on tray position as shown in Figure 7. At the high tray position, the imported RT placed 11 seedlings per hill, while the BRRI model placed 10, indicating a 9.09% increase. For the medium position, both models delivered an equal number of seedlings 6 per hill, showing no difference. However, at the low tray position, the imported RT again outperformed the BRRI model by planting 4 seedlings per hill compared to 3, a 25% increase. These results suggest that while performance between the two models was mostly comparable at medium depth, the imported RT tends to deliver more seedlings at both low and high positions. This implies a potentially more sensitive or responsive seedling pickup mechanism in the imported unit under field conditions. Such variations, although minor, can influence plant population density and may require machine calibration depending on the crop variety and field requirements.

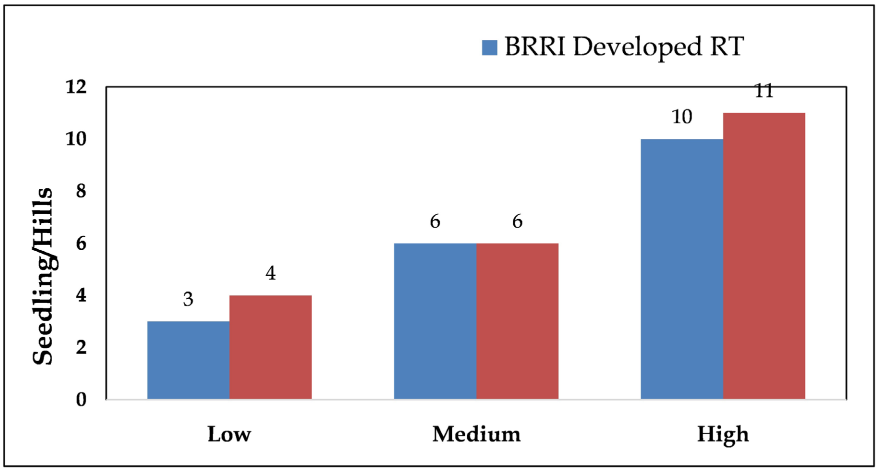

Figure 7. Seedling per hill at different position for in field condition.

3.4. Number of Seedlings

The seedling count was monitored from day 0 to 60 after transplanting to evaluate early establishment and survival. During the initial stages (0 to 30 days), the BRRI-developed rice transplanter (T1) consistently showed a higher number of seedlings per hill compared to the imported RT (T2) and hand transplanting (T3) as shown in Figure 8. Specifically, T1 maintained a lead at day 0, 15, and 30, indicating better early seedling placement and establishment. However, by day 45 and 60, the seedling counts for both T1 and T2 became nearly identical, suggesting that the initial advantage of the BRRI-developed RT equalized over time due to plant mortality or thinning. Hand transplanting (T3) consistently showed a slightly lower seedling count throughout, possibly due to non-uniform planting and manual error. These results highlight the BRRI-developed RT's strength in early establishment, which may be beneficial in ensuring crop uniformity and vigor during the early growth stages.

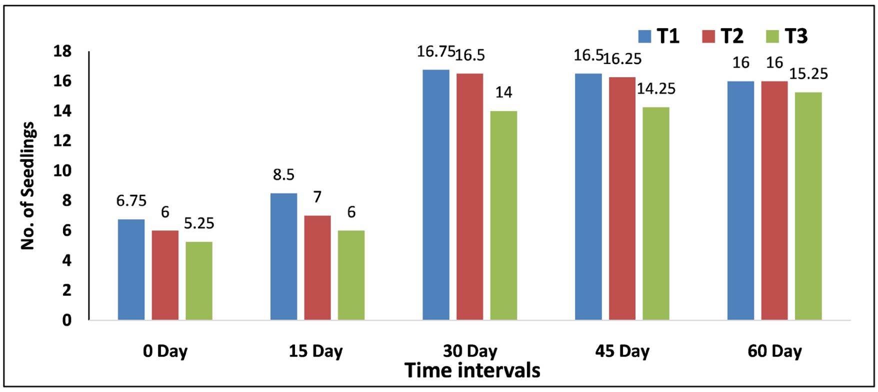

Figure 8. No. of seedling count at different interval of time in field condition.

3.5. Number of Panicles

As shown in Figure 9, after transplanting, the number of panicles observed was highest in the BRRI-developed rice transplanter (T1), with an average count of 151.75, compared to 146.75 in the imported RT (T2) and 149 in hand transplanting (T3). This corresponds to a 3.29% increase over T2 and a 1.81% increase over T3, suggesting that the BRRI model may offer slightly better conditions for tillering and panicle development. The higher panicle count reflects improved seedling establishment and possibly better spacing or root anchoring, especially in the early growth phase. Although the difference is modest, it indicates a performance edge of the BRRI-developed RT in supporting productive tillers, which could translate into marginally higher yield potential under similar agronomic conditions.

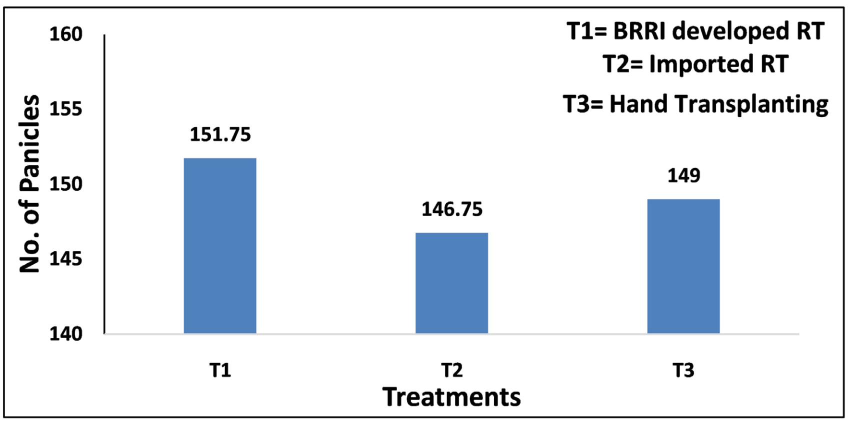

Figure 9. No. of panicles count at different interval of time in field condition.

3.6. Percentage of Missing Hill

The percentage of missing hills; comprising floating, buried, and damaged hills was highest in the imported RT model (T2), recording 5%, followed by the BRRI-developed RT (T1) at 3.5%, and the lowest in hand transplanting (T3) at 2.75% as shown in Figure 10. This result suggests that the imported RT may have relatively less control or stability during seedling placement, leading to a higher rate of planting errors. The BRRI-developed RT performed better in minimizing planting gaps, though it still lagged behind manual transplanting, which naturally benefits from human judgment and placement accuracy. These findings highlight the need for further optimization in mechanical transplanters to reduce missed planting spots, particularly in imported models where floating or improper placement may be more frequent.

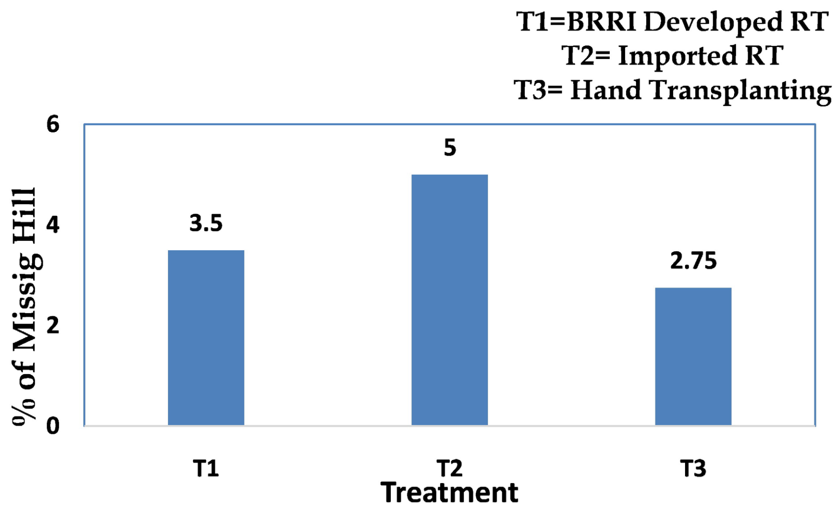

Figure 10. Percent of missing hill during field operation.

3.7. Actual Field Capacity

The actual field capacity was evaluated based on the total time taken to transplant a fixed area of 10.84 decimal (a local unit of land area commonly used in Bangladesh, where 1 decimal = 40.47 square meters). The BRRI-developed PRT2022 model completed the operation in 16.21 minutes, achieving a field capacity of 40.12 decimal/hr, while the imported RT took 18.20 minutes for the same area, resulting in a lower field capacity of 35.73 decimal/hr. This indicates that the BRRI model performed 10.94% more efficiently in terms of area coverage per hour. The improved performance of the BRRI PRT2022 may be attributed to better maneuverability, faster transplanting speed, or reduced non-productive time. The findings suggest that the BRRI-developed transplanter offers a time-saving advantage in field operations, making it a more efficient option under similar conditions (Table 3).

Table 3. Comparison of field operation time and actual field capacity between BRRI PRT2022 and imported RT model.

Model name	Starting time	End time	Total operation (min)	Area covered (Decimal)	Field capacity (decimal/hr)
BRRI PRT2022	9:41:23	9:57:45	16.21	10.84	40.12
Imported RT	10:05:32	10:23:53	18.20	10.84	35.73

3.8. Fuel Consumption

The fuel consumption rate was found to be slightly higher in the BRRI-developed PRT2023 model, which recorded a usage of 1.52 liters per hour, compared to 1.32 liters per hour in the imported RT. Despite this difference, the fuel consumption between the two models can be considered nearly similar, especially when factoring in the faster operation time and higher field capacity of the BRRI model. Specifically, the BRRI PRT2023 completed the operation in 16.21 minutes, while the imported RT took 18.20 minutes for the same area. This indicates that the BRRI model consumes slightly more fuel per hour, but this is offset by its higher efficiency and faster performance. In practical terms, the marginal increase in fuel use is justifiable given the time savings and improved field output (**Table 4**).

Table 4. Comparison of fuel consumption between BRRI PRT2023 and imported RT models during field operation.

Model name	Starting time	End time	Total operation (min)	Area covered (Decimal)	Total fuel consumption (ml)	Fuel consumption (l/hr)
BRRI PRT2023	9:41:23	9:57:45	16.21	10.84	420	1.52
Imported RT	10:05:32	10:23:53	18.20	10.84	400	1.32

3.9. Field Efficiency

The field efficiency of the two rice transplanter models revealed that the BRRI-developed RT (T1) achieved a field efficiency of 79.50%, slightly higher than the 78.03% recorded for the imported RT (T2) as shown in **Figure 11**. This represents a 1.84% improvement in efficiency for the BRRI model. The higher efficiency indicates that the BRRI transplanter utilized productive time more effectively, likely due to reduced turning time, quicker adjustment mechanisms, or better maneuverability. Although the margin is modest, it reinforces the advantage of the BRRI-developed RT in real-world field conditions where efficiency directly influences operational cost, fuel use, and overall timeliness of transplanting.

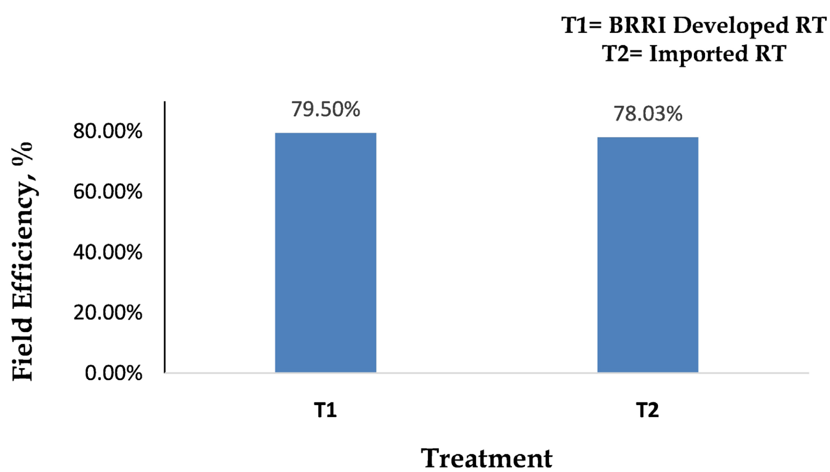

Figure 11. Field efficiency of BRRI developed RT and Imported RT.

4. Conclusion

The field performance of both the rice transplanter and manual transplanting was found to be satisfactory, with no breakdowns occurring during operation. The planting fingers and fork worked efficiently without clogging. The BRRI-developed PRT model featured a more convenient depth control mechanism compared to the imported transplanter. It also demonstrated higher field capacity, and its field efficiency was 79.5%, which is 1.84% higher than the imported model. Working time included both productive time (actual transplanting) and non-productive time (time lost due to turning, supplying seedlings, cleaning, and adjustments). Proper transplanting depth and speed can help reduce missing, floating, damaged, and buried hills. Overall, based on these observations and experiments, the BRRI-developed rice transplanter proved to be more efficient and suitable than the imported model.

Acknowledgements

This study was conducted under the project "Strengthening Farm Machinery Research Activity for Mechanized Rice Cultivation (SFMRA)", Bangladesh Rice Research Institute, Gazipur.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Saka, J.O. and Lawal, B.O. (2009) Determinants of Adoption and Productivity of Improved Rice Varieties in Southwestern Nigeria. *African Journal of Biotechnology*, **8**, 4923-4932.

[2] Hossen, M.A., Shahriyar, M.M., Islam, S., Paul, H. and Rahman, M.M. (2022) Rice Transplanting Mechanization in Bangladesh: Way to Make It Sustainable. *Agricultural Sciences*, **13**, 130-149. https://doi.org/10.4236/as.2022.132011

[3] Islam, A., Rahman, M., Rahman, A., Islam, M. and Rahman, M. (2016) Techno-Economic Performance of 4-Row Self-Propelled Mechanical Rice Transplanter at Farmers Field in Bangladesh. *Progressive Agriculture*, **27**, 369-382. https://doi.org/10.3329/pa.v27i3.30834

[4] Kavin, P., Sivakumar, A., Gaudam, A.L., Kamalakannan, V.M. and Moulidharan, M. (2017) Optimization and Analysis of Manual Paddy Transplanter. *Advances in Natural and Applied Sciences*, **11**, 184-192.

[5] Shi, M., Paudel, K.P. and Chen, F. (2021) Mechanization and Efficiency in Rice Production in China. *Journal of Integrative Agriculture*, **20**, 1996-2008. https://doi.org/10.1016/s2095-3119(20)63439-6

[6] Reganold, J.P., Jackson-Smith, D., Batie, S.S., Harwood, R.R., Kornegay, J.L., Bucks, D., *et al.* (2011) Transforming U.S. Agriculture. *Science*, **332**, 670-671. https://doi.org/10.1126/science.1202462

[7] Yu, G.H., Wang, L., Sun, L., *et al.* (2022) Advancement of Mechanized Transplanting Technology and Equipments for Field Crops. *Transactions of the Chinese Society of Agricultural Machinery*, **53**, 1-20.

[8] Rajendran, M. and Ranganathan, T. (2025) Advancements in Paddy Transplanter Mechanization Implications for Sustainable Agriculture. *Sustainable Futures*, **10**, Article 101235. https://doi.org/10.1016/j.sftr.2025.101235

[9] Deres, A. and Katahira, M. (2024) Performance Evaluation of Self-Propelled Rice Transplanter for Impact Study on Rice Cultivation. *SAARC Journal of Agriculture*, **22**, 153-167. https://doi.org/10.3329/sja.v22i1.73728

[10] Manikyam, N., Guru, P.K., Naik, R.K. and Diwan, P. (2020) Performance Evaluation of Self-Propelled Rice Transplanter. *Journal of Pharmacognosy and Phytochemistry*, **9**, 980-983.

[11] Islam, A.K.M.S. and Rahman, M.A. (2014) BRRI-Syngenta Tegra Transplants under Public Private Partnership Approach. Syngenta Bangladesh Limited.

[12] Mehta, M.L., Verma, S.R., Mishra, S.R. and Sharma, V.K. (2005) Testing and Evaluation of Agricultural Machinery. Daya Publishing House.

[13] Hunt, D.R. (1979) Farm Power and Machinery Management. 4th Edition, The Iowa State University Press.