**Original Research Article**

**Comparative Performance of Transplanted Aman Rice Varieties under Raised Bed and Conventional Cultivation Methods in Bangladesh**

**ABSTRACT**

Rice, a staple crop vital to nutrition and livelihoods of billions, must consistently achieve high yield to meet global food demands. The rice cultivation methods have a big impact on overall yield, productivity and water usage efficiency. This study compared the yield performance of four Transplanted Aman (T. Aman) rice varieties: BRRI dhan49, BRRI dhan52, BR11, and Binadhan-7, under raised bed and conventional method to determine the best genotype × planting method combinations for increased productivity. We conducted our study at Bangladesh Agricultural University using Randomized Complete Block Design (RCBD) with three replications. The result of the experiment figured out that, for T. Aman rice, varieties and planting methods interacted significantly. BRRI dhan49 consistently performed better than other varieties, especially when grown in raised beds. It had the best harvest index (45.94%), biological yield (11.79 t/ha), and grain yield (5.42 t/ha). In comparison to traditional planting, raised bed planting increased effective tiller number (+8.3%), panicle length (+4.8%), grains per panicle (+2.7%), and decreased sterile spikelets (−19%). Among the varieties, Binadhan-7 exhibited the weakest performance in conventional method. Features including effective tillers, grains per panicle, and 1000-grain weight were shown to have strong positive associations with grain yield, underscoring their significance as selection criteria. The findings of this study indicate that growing BRRI dhan49 using the raised bed method significantly increases the yield of T. Aman rice, suggesting that this technique may be a better agronomic approach than traditional techniques for raising rice production. For increasing food security and land productivity in rice-growing countries, these findings can help farmers, agricultural planners, and governments to adopt more effective production practices.

**KEYWORDS:** TransplantedAman rice, Raised Bed, Yield, BRRI dhan49

**INTRODUCTION**

More than half of the world's population depends on rice (*Oryza sativa* L.) as a staple food, making it the most widely cultivated cereal crop worldwide (Fiza et al., 2024; Chauhan and Johnson, 2011). Rice is the main food staple and accounts for around 80% of Bangladesh's total farmed area (Azad et al., 2022). Bangladesh produced around 27.85 million tons of rice from about 11.66 million hectares in the fiscal year 2023–2024, averaging about 4.72 t ha⁻¹ (BBS, 2024). With an annual per capita availability of roughly 213.5 kg of rice, Bangladesh ranks fourth among nations in the world in terms of rice consumption (FPMU Database, 2020). The production of rice provides a direct or indirect source of income for about 48% of rural laborers. Over 13 million farms, covering over 11.77 million hectares, grow rice during the winter (dry) and monsoon (wet) seasons (DAE, 2020). About 70% of the agriculture sub-sector's value comes from rice (Mottaleb & Mishra, 2016).

Despite its dominance, rice yield growth has stalled in recent decades. The main cause of this stalemate is the insufficient use of better agronomic techniques. Instead of combining high-yielding seed varieties with mechanized field preparation, precision planting, water-saving irrigation, and optimal nutrient timing, farmers continue to use traditional crops and management techniques (Foysal et al., 2023). Because of this, the average yield frequently stays well below the potential grain production levels that HYVs offer, resulting in a continuous yield gap (Quais & Khairul, 2015).

T. Aman rice (*Oryza sativa* L.), grown during the monsoon season (typically July–November) in Bangladesh, makes a substantial contribution to the country's rice supply (Rana et al., 2014). In 2023-24, Bangladesh produced 1001.6 thousand tons of T. aman rice on 585.4 thousand hectares of land (BBS, 2024). In Bangladesh and other agro-ecological zones, it is typically grown using two primary methods, with numerous variations. In traditional planting systems, the soil is puddled, seedlings are moved into flooded fields, and standing water is kept constant during crop growth. Although this technique makes it easier to control weeds and establish transplants, it tends to deteriorate soil structure, require a lot of work and irrigation, and eventually decrease resource efficiency (Sharma and Datta, 1986). Thus, T. Aman yields in conventional puddled flat systems are still below world standards, even though they account for more than one-third of Bangladesh's rice-growing land (Bhuyan et al., 2012).

In this scenario, scientists, researchers, and farmers have examined new technology or approaches to increase rice output. One promising strategy is raised bed planting that places rice seedlings on raised soil ridges (beds) with furrows in between. Furrows are used to supply water, which improves drainage, aeration, and flooding reduction. This strategy has drawn interest because it may increase grain output, control weeds, and improve the efficiency of fertilizer and water use (Singh et al., 2009; Das et al., 2021). Bhuyan et al., (2012) conducted a crucial field study at Rajshahi University that compared T. Aman rice (variety SORNO) under raised-bed planting versus conventional cultivation. The findings indicated that the raised-bed method significantly improved yield components, such as panicle density, grains per panicle, and 1000-grain weight, and increased grain yield by up to 16 percent, while lowering sterility and weed infestation. Additionally, labor time and irrigation water were reduced by approximately 42 percent, and water-use efficiency significantly increased (Bhuyan et al., 2012). These results have typically been supported by subsequent studies and regional experiments. Depending on site circumstances and management, raised-bed rice planting can produce improvements of 6–17% above traditional puddled transplanting in South Asian irrigated rice systems (Bhuyan et al., 2014). Dhillon et al., (2005) also showed that the highest number of effective tillers, ear length, number of grains, and test weight were recorded under bed planted wheat in comparison to traditional flatbed method of sowing.

The present study aimed to develop on this foundation by comparing the performance of T. Aman rice varieties under raised-bed vs traditional methods. We evaluated several genetically diverse rice varieties—BRRI dhan49, BRRI dhan52, BR11, and BINA dhan-7—under similar cultivation methods at Bangladesh Agricultural University, a separate agroecological zone with different soil and climatic characteristics. This multi-varietal approach offers a more thorough evaluation of how various rice genotypes react to raised bed vs conventional methods, providing a wider understanding of genotype × planting method (G × E) interactions. Furthermore, adding correlation analysis between important yield-contributing characteristics gives trait-based selection for breeding. Therefore, the current research is particularly helpful to recommend adaptive agronomic techniques as well as variety considering resource restrictions and climate change.

**MATERIALS AND METHODS**

The study was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from June to December 2024.

**Experimental Site and Soil**

The experimental location is 18 meters above mean sea level and is situated at 24o75' N latitude and 90o50' E longitude. The Sonatola Soil Series, which is part of the Old Brahmaputra Floodplain (Agro-Ecological Zone 9), contains non-calcareous dark grey floodplain soil, which is what defines the experimental area (UNDP and FAO, 1988). The experimental field's soil had a pH of 6.5, was neutral in reaction, and had little organic matter or fertility. The terrain was silty loam with modest elevation. Supplementary Table 1 presents the physical and chemical properties of the soil in the experimental field.

**Climate**

The tropical environment of the experimental site is characterized by high temperatures and excess amounts of rainfall during the *Kharif season* (April to September) and somewhat low temperatures and little rainfall during the *Rabi season* (October to March). The climatic pattern has been presented in Supplementary Table 2.

**Experimental Treatments and Design**

Varieties (Factor A) and Planting Methods (Factor B) were used as experimental treatments. Four T. Aman rice varieties i.e., BRRI dhan49, BRRI dhan49, BINA dhan7 and BR11 were used as varieties, and the raised bed and flatbed (conventional line planting) methods were used as planting methods. A randomized complete block design (RCBD) along with three replications were used to set up the experiment. Three blocks, each representing a replication, were separated from the experimental land. Once more, each block was separated into eight plots (four kinds × two planting methods). Thus, there were 24-unit plots in all, with each plot measuring 4.0 m by 2.5 m. The unit plots were kept 0.5 meters apart, while the replications were kept 1.0 meters apart.

**Seed bed Preparation to Transplanting**

To raise seedlings, a plot of land was chosen. A country plow was used to puddle the soil thoroughly, and then a ladder was used to level it. On June 30, 2024, the sprouting seeds were planted in the nursery bed. The nursery bed's healthy seedlings were raised with the right attention. A power tiller was used to open the experimental field, and then a country plough was used four times before laddering was done. Following the latter stages of site preparation, the field's layout was created. Each plot was cleaned and weeded of stubble and weeds. The day before the plants were uprooted, water was applied to the nursery bed to make it moist. On July 29, 2024, the seedlings were detached without significant mechanical damage to their roots, and they were moved right away to the main field. After uprooting the seedlings were graded. For transplantation, seedlings that were healthy and comparable in size were chosen. On July 30, 2024, seedlings were moved into the main field in accordance with experimental treatments, with a spacing of 25 cm by 15 cm and a pace of three seedlings per hill.

**Fertilizer application and Intercultural Operations**

Urea, triple superphosphate, muriate of potash, gypsum, and zinc sulphate at the rate of 200-100-125-60-10 kg ha-1 respectively were used to fertilize the experimental area. At the time of final land preparation, the full amounts of zinc sulphate, gypsum, muriate of potash, and triple superphosphate were spread out and mixed with the soil. Three doses of nitrogen in the form of urea were administered at 15, 30, and 45 days following transplantation (DAT). On the designated plots, weeding was carried out at 15 and 30 DAT. When necessary, additional operations were carried out.

**Sampling, Harvesting and Processing**

When the crops reached full maturity, they were harvested. The crops were considered mature when 90% of the grains turned a golden yellow. We harvested crops in December 2024. Following the threshing of the tagged crops, plot-by-plot fresh weights of grain and straw were noted. After cleaning the grains, the weight was ultimately adjusted to achieve a 14% moisture content. The yields of grain and straw plot-1 were measured and converted to t ha-1 after the straw was sun-dried.

**Data Collection**

Five hills were randomly chosen from each unit plot, thoroughly uprooted, and labeled prior to harvesting to capture data. Data was collected on plant height, number of total tillers hill-1,number of effective tillers hill-1,number of non-effective tillers hill-1, panicle length, number of grains panicle-1, number of sterile spikelets panicle-1,1000-grain weight, grain yield and straw yield. Biological yield and harvest index were calculated using the following formulas respectively.

Biological yield = Grain yield + Straw yield



Harvest index (%) =

**Statistical Analysis**

For statistical analysis, the collected data was compiled and tabulated. R-Studio is a statistical software used to examine data. We used Duncan's Multiple Range Test to compare means (Gomez and Gomez, 1984).

**RESULTS**

**Effect of variety on different yield parameters**

The study revealed significant varietal differences for all ten measured traits of T. Aman rice (Table 1). The tallest plants were observed in BRRI dhan52 (112.02 cm), whereas the shortest plants were recorded in Binadhan-7 (91.48 cm). The highest No. of total tillers hill-1 was found in BRRI dhan49 (14.43), while the lowest was observed in Binadhan-7 (11.48). Similarly, BRRI dhan49 had the maximum number of effective tillers hill-1 (13.05), and the lowest was in Binadhan-7 (10.03), which was statistically similar to BRRI dhan52 (10.07). The number of non-effective tillers hill-1 was highest in BR11 (1.48) and lowest in BRRI dhan49 (1.38). For panicle length, the longest was produced by BRRI dhan49 (23.00 cm), which were statistically similar to BR11 (22.70 cm) and the shortest was by BRRI dhan52 (21.82 cm). The number of grains panicle-1 was highest in BRRI dhan49 (141.33) and lowest in Binadhan-7 (123.53). The maximum number of sterile spikelets panicle-1 was observed in BR11 (13.05), while the minimum was in BRRI dhan49 (12.65). In terms of yield components, BRRI dhan49 recorded the highest 1000-grain weight (21.43 g), grain yield (5.19 t/ha), biological yield (11.29 t/ha), and harvest index (45.94%). In contrast, the lowest 1000-grain weight (19.47 g), grain yield (4.49 t/ha), and biological yield (9.88 t/ha) were observed in Binadhan-7 (Figure 1, Table 1).

**Table 1. Effect of variety on yield attributes and yield of T. Aman** **rice**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variety | Plant height (cm) | No. of total tillershill-1 | No. of effective tillershill-1 | No. of non-effective tillershill-1 | Panicle length (cm) | No. of grains panicle-1 | No. of sterile spikelets panicle-1 | 1000-grain weight (g) | Biological yield(t ha-1) | Harvest index (%) |
| V1 | 102.63c | 14.43a | 13.05a | 1.38b | 23.00a | 141.33a | 12.65b | 21.43a | 11.29a | 45.94a |
| V2 | 112.02a | 11.50c | 10.07c | 1.43ab | 21.82c | 123.67c | 12.88ab | 19.76b | 10.13c | 44.77c |
| V3 | 91.48d | 11.48c | 10.03c | 1.45ab | 22.45b | 123.53c | 12.88ab | 19.47c | 9.88d | 45.32b |
| V4 | 110.92b | 13.33b | 11.83b | 1.48a | 22.70ab | 140.12b | 13.05a | 20.47b | 10.93b | 45.47b |
| Sx̄ | 4.75 | 0.73 | 0.73 | 0.02 | 0.25 | 4.95 | 0.08 | 0.44 | 0.33 | 0.24 |
| Level of significance | \*\* | \*\* | \*\* | \* | \*\* | \*\* | \* | \*\* | \*\* | \*\* |
| CV (%) | 0.18 | 1.61 | 1.70 | 4.89 | 1.92 | 0.63 | 2.04 | 1.28 | 1.64 | 0.74 |
| Here, means with the same letters within the same column do not differ significantly; \*\* = Significant at 1% level of probability, \* = Significant at 5% level of probability; V1 = BRRI dhan49; V2 = BRRI dhan52; V3 = Binadhan-7; V4 = BR11 |

**Figure 1. Effect of variety on yield of T. Aman** **rice (Vertical bar represents the Least Significant Difference (LSD) value at 1%)**

Here, V1 = BRRI dhan49; V2 = BRRI dhan52; V3 = Binadhan-7; V4 = BR11

**Effect of planting methods on different yield parameters**

The raised bed planting method (P1) consistently outperformed the conventional line transplanting method (P2) for most growth, yield, and yield-contributing traits of T. Aman rice (Table 2). Plant height was slightly higher in the raised bed method (104.52 cm) than in the conventional method (104.01 cm) (Table 2). No. of total tillers hill-1 increased from 12.36 to 13.01, and No. of effective tillers hill-1 from 10.79 to 11.69. The number of non-effective tillers was lower in raised beds (1.32) compared to the conventional system (1.56). Panicle length was higher in the raised bed system (23.02 cm) than in conventional planting (21.97 cm). Consequently, No. of grains panicle-1 also increased from 130.39 to 133.93 while No. of sterile spikelets panicle-1 were reduced in raised beds (11.52) compared to the conventional method (14.22). The 1000-grain weight was slightly higher in raised beds (20.44 g) than in conventional planting (20.12 g). Grain yield increased significantly from 4.58 to 5.01 t/ha under the raised bed method. Straw yield rose from 5.57 to 5.95 t/ha, and biological yield from 10.15 to 10.96 t/ha. The harvest index also improved slightly, from 45.10% in conventional method to 45.64% in raised beds (Figure 2; Table 2).

**Table 2. Effect of cultivation methods on yield attributes and yield of T. Aman** **rice**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cultivation methods | Plant height (cm) | No. of total tillershill-1 | No. of effective tillershill-1 | No. of non-effective tillershill-1 | Panicle length (cm) | No. of grains panicle-1 | No. of sterile spikelets panicl-1 | 1000-grain weight (g) | Biological yield(t ha-1) | Harvest index (%) |
| P1 | 104.01b | 13.01a | 11.69a | 1.32b | 23.02a | 133.93a | 11.52b | 20.44a | 10.96a | 45.64a |
| P2 | 104.52a | 12.36b | 10.79b | 1.56a | 21.97b | 130.39b | 14.22a | 20.12b | 10.15b | 45.10b |
| Sx̄ | 0.25 | 0.32 | 0.45 | 0.12 | 0.53 | 1.77 | 1.35 | 0.16 | 0.41 | 0.27 |
| Level of significance | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* | \*\* |
| CV (%) | 0.18 | 1.61 | 1.70 | 4.89 | 1.92 | 0.63 | 2.04 | 1.28 | 1.64 | 0.74 |
| Here, means with the same letters within the same column do not differ significantly; \*\* = Significant at 1% level of probability, \* = Significant at 5% level of probability; P1 = Raised bed; P2 = Conventional line transplanting |

**Figure 2. Effect of variety on yield of T. Aman** **rice (Vertical bar represents the LSD value at 1%)**

Here, P1 = Raised bed; P2 = Conventional line transplanting

**Interaction between variety and planting methods**

The interaction between variety and planting methods significantly influenced agronomic and yield traits of T. Aman rice (Table 3). The tallest plants were recorded in BRRI dhan52 under raised beds (112.17 cm, V2P1), which was statistically similar to its conventional counterpart (V2P2), while Binadhan-7 with raised beds exhibited the shortest plant stature (90.93 cm, V3P1) (Table 3). BRRI dhan49 under raised beds (V1P1) produced the highest No. of total tillers hill-1 (14.90) and effective tillers hill-1 (13.67); conversely, Binadhan-7 under conventional planting (V3P2) recorded the lowest values (11.22 and 9.65). For No. of non-effective tillers hill-1, the values were reduced in BRRI dhan49 on raised beds (1.23) and increased in BR11 on conventional plots (1.60).

Panicle length was longest in BRRI dhan49 on raised beds (23.17 cm, V1P1), followed by BR11 on raised beds (V4P1), and shortest in BRRI dhan52 on conventional plots (21.30 cm). No. of grains panicle-1 peaked at 143.57 in BRRI dhan49 raised beds and was statistically similar to BR11 raised beds (142.17), while BRRI dhan52 conventional planting (V2P2) produced the fewest grains (122.07). No. of sterile spikelets panicle-1 were lowest in BRRI dhan49 raised beds (10.93) and highest in BR11 conventional plots (14.63). The highest 1000-grain weight was recorded in BRRI dhan49 raised beds (21.77 g), and the lowest in Binadhan-7 conventional plots (19.43 g).

Yield-related traits were markedly influenced by the interaction of variety and planting methods. The highest grain yield (5.42 t/ha), straw yield (6.20 t/ha), and biological yield (11.71 t/ha) were achieved by BRRI dhan49 under raised bed planting (V1P1), while the lowest grain (4.25 t/ha), straw (5.17 t/ha), and biological yields (9.42 t/ha) were recorded in Binadhan-7 under conventional line planting (V3P2). A similar trend was observed for harvest index, reflecting the superior resource-use efficiency of BRRI dhan49 in the raised bed system (Table 3).

**Table 3. Interaction effect of variety and cultivation methods on yield attributes and yield of T. Aman** **rice**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variety | Plant height (cm) | No. of total tillershill-1 | No. of effective tillershill-1 | No. of non-effective tillershill-1 | Panicle length (cm) | No. of grains panicle-1 | No. of sterile spikelets panicl-1 | 1000-grain weight (g) | Grain yield(t ha-1) | Straw yield(t ha-1) | Biological yield(t ha-1) | Harvest index (%) |
| V1:P1 | 102.27e | 14.90a | 13.67a | 1.23c | 23.77a | 143.57a | 10.93e | 21.77a | 5.42a | 6.29a | 11.71a | 46.28a |
| V1:P2 | 103.00d | 13.97b | 12.43b | 1.53a | 22.23c | 139.10b | 14.37a | 21.09b | 4.96c | 5.91b | 10.87b | 45.60b |
| V2:P1 | 112.17a | 11.78d | 10.45d | 1.33bc | 22.33c | 125.27c | 11.33de | 19.85de | 4.69d | 5.70c | 10.39c | 45.14b |
| V2:P2 | 111.87a | 11.22e | 9.68e | 1.53a | 21.30d | 122.07d | 14.43a | 19.67e | 4.38e | 5.48d | 9.86d | 44.40c |
| V3:P1 | 90.93g | 11.73d | 10.40d | 1.33bc | 22.80bc | 124.73c | 12.33c | 19.51e | 4.72d | 5.62cd | 10.34c | 45.50b |
| V3:P2 | 92.03f | 11.22e | 9.65e | 1.57a | 22.10c | 122.33d | 13.43b | 19.43e | 4.25e | 5.17e | 9.42e | 45.13b |
| V4:P1 | 110.67c | 13.62b | 12.25b | 1.37b | 23.17ab | 142.17a | 11.47d | 20.65bc | 5.21b | 6.20a | 11.41a | 45.66b |
| V4:P2 | 111.17b | 13.03c | 11.40c | 1.60a | 22.23c | 138.07b | 14.63a | 20.29cd | 4.73d | 5.72c | 10.45c | 45.28b |
| Sx̄ | 3.11 | 0.49 | 0.51 | 0.05 | 0.26 | 3.31 | 0.54 | 0.3 | 0.14 | 0.13 | 0.27 | 0.19 |
| Level of significance | \*\* | \* | \* | \* | \* | \* | \*\* | \* | \* | \* | \* | \* |
| CV (%) | 0.18 | 1.61 | 1.70 | 4.89 | 1.92 | 0.63 | 2.04 | 1.28 | 1.55 | 1.92 | 1.64 | 0.74 |
| Here, means with the same letters within the same column do not differ significantly; \*\* = Significant at 1% level of probability, \* = Significant at 5% level of probability; V1 = BRRI dhan49; V2 = BRRI dhan52; V3 = Binadhan-7; V4 = BR11; P1 = Raised bed; P2 = Conventional line planting |

**Figure 3. Interaction effect of variety and cultivation methods on yield of T. Aman rice (Vertical bar represents the LSD value at 1% level)**

Yield (t ha -1)

Here, V1 = BRRI dhan49; V2 = BRRI dhan52; V3 = Binadhan-7; V4 = BR11 P1 = Raised bed; P2 = Conventional line transplanting

**Correlation between Grain Yield and Yield-Contributing Traits**

The correlation matrix (Figure 4) illustrates the relationships among grain yield and its yield-contributing traits, highlighting significant positive associations among key parameters.

Grain yield showed highly significant positive correlations with the number of tillers per hill, effective tillers per hill, and number of grains per panicle (*p < 0.01*). It also exhibited a significant positive correlation with 1000-grain weight (*p < 0.05*).

The number of tillers per hill was strongly and positively correlated with effective tillers per hill and number of grains per panicle (*p < 0.001*) and showed a significant positive correlation with 1000-grain weight (*p < 0.05*). Effective tillers per hill demonstrated significant positive associations with both number of grains per panicle (p < 0.001) and 1000-grain weight (p < 0.05). In addition, number of grains per panicle showed a significant positive correlation with 1000-grain weight (*p < 0.05*).

**Figure 4.** **Correlation matrix of Grain Yield and Yield-Contributing Traits of T. Aman rice.**

**DISCUSSION**

Traditional line transplanting remains the most common rice planting method in Bangladesh, yet it presents several limitations, including poor water-use efficiency, increased weed infestation, restricted aeration, and high labor requirements (Bhuyan et al., 2012). Raised bed planting has emerged as a viable alternative due to its capacity to improve drainage, root aeration, and resource-use efficiency while supporting mechanized operations (Bhuyan et al., 2012; Borrell et al., 1998; Singh et al., 2009). The present study demonstrated significant effects of variety, planting methods, and their interaction on the growth and yield traits of T. Aman rice under both systems.

**Effect of variety on different yield parameters**

Significant genotypic differences across all measured traits revealed substantial inherent genetic variability among the tested rice varieties (Table 1). This diversity provides breeders with the opportunity to select and combine favorable traits through targeted breeding and hybridization (Alam et al., 2025; Chowdhury et al., 2023). In this study, BRRI dhan49 consistently outperformed other varieties in key growth and yield traits including, total and effective tillers hill⁻¹, panicle length, grain number panicle⁻¹, and 1000-grain weight, resulting in the highest grain yield (5.19 t/ha), biological yield (11.29 t/ha), and harvest index (45.94%). These findings align with previous reports confirming its high yield potential and adaptability (Islam et al., 2014; Tahsin et al., 2017). In contrast, Binadhan-7 showed the lowest performance across most traits, including shorter plant stature, fewer grains panicle⁻¹, and reduced harvest index, reflecting inefficient biomass partitioning. BR11 and BRRI dhan52 exhibited intermediate performance; however, BR11’s higher number of non-effective tillers and sterile spikelets panicle⁻¹ likely constrained its sink capacity despite having longer panicles.

**Effect of Planting Methods on Yield Parameters**

The planting method significantly influenced growth and yield-related traits of T. Aman rice. Overall, the raised bed system (P1) outperformed conventional line transplanting (P2) across most parameters (Table 2), aligning with earlier findings on the physiological and structural benefits of bed planting (Bhuyan et al., 2012; Borrell et al., 1998).

Notably, the number of total tillers and effective tillers hill-1 increased by approximately 5.3% and 8.3%, respectively, under raised beds suggesting improved conditions for productive tillering due to enhanced soil structure and root activity (Bhuyan et al., 2012). Similarly, Singh et al., (2009) observed nearly double the tiller number in bed planting, attributing it to rapid drying, greater surface area, and superior root spread. Reproductive traits also benefited: panicle length increased by 4.8%, and grains panicle⁻¹ by 2.7%, consistent with Bhuyan et al., (2012) and Borrell et al., (1998), who observed higher panicle density and grain numbers in bed-planted rice due to better resource acquisition and utilization. Sterile spikelets panicle⁻¹ declined by 19%, indicating improved fertility and grain filling under raised beds. Although the 1000-grain weight rose modestly (1.6%), it still contributed to yield gains. Grain yield increased by 9.4% under raised beds, consistent with Tang et al. (2008), who reported a 6.7% rise. Straw and biological yields also increased by 6.8% and 8.0%, respectively, and the harvest index improved by 1.2%, reflecting more efficient biomass allocation to grain. These findings are supported by Hobbs and Gupta, (2003), Vethaiya et al., (2007), Meisner et al., (2005), and Jat and Sharma, (2006), who all documented yield benefits from raised bed planting.

**Interaction between variety and planting methods**

The significant interaction between rice variety and planting method highlights the importance of aligning genotype-specific agronomic practices to optimize yield potential. Among the variety–method combinations, BRRI dhan49 under raised bed planting (V1P1) consistently outperformed all others in terms of tiller production, reproductive development, and final yield, indicating a strong genotype × environment (G×E) interaction (Table 3). While BRRI dhan52 exhibited the tallest plants (V2P1), it did not outperform BRRI dhan49 in other yield-contributing traits, confirming that plant height alone is not a reliable predictor of grain yield, in agreement with earlier findings (Peng et al., 2008). Raised beds improved total and effective tillers hill⁻¹ in BRRI dhan49, likely due to better root aeration, moisture regulation, and nutrient availability (Timsina et al., 2010). Fewer non-effective tillers in this combination also indicate better assimilate partitioning and sink strength (Lafitte et al., 2004). Reproductive traits: panicle length, grains panicle⁻¹, and 1000-grain weight, were also enhanced under raised beds, particularly in BRRI dhan49, likely due to improved source–sink dynamics and root zone conditions (Yuan et al., 2024).

Grain yield peaked in BRRI dhan49 under raised beds (5.42 t/ha), with corresponding increases in straw yield, biological yield, and harvest index. These results align with previous studies reporting improved drainage, root growth, and nutrient uptake under raised bed systems (Bhuyan et al., 2012; Borrell et al., 1998). In contrast, Binadhan-7 under conventional planting yielded the lowest (4.25 t/ha), confirming its limited suitability for such conditions. Overall, the interaction effects reveal that BRRI dhan49 is the most suitable genotype for raised bed planting (V1P1), combining higher tiller productivity, panicle fertility, and grain filling efficiency.

**Correlation between Grain Yield and Yield-Contributing Traits**

Since yield is a complex trait governed by multiple genetic factors, direct selection based solely on yield is often inefficient. Correlation analysis, therefore, serves as a valuable tool to uncover genetic associations among agronomic traits, aiding in the identification of secondary traits that indirectly contribute to yield improvement (Jayasudha and Sharma, 2010; Ratna et al., 2015). In the present study, grain yield exhibited highly significant positive correlations with the number of tillers hill-1, effective tillers hill-1, number of grains panicle-1, and 1000-grain weight. These associations suggest that genotypes with more productive tillers, higher grain numbers, and heavier seeds tend to produce higher yields. Similar trends have been reported by Alam et al., (2025), Chowdhury et al., (2023), and Hannan et al., (2020). The strong association between total and effective tillers confirms the importance of productive tillering in enhancing yield. Additionally, effective tillers showed significant correlations with both grain number and grain weight, reflecting their role in determining sink strength and grain filling efficiency. These findings align with previous reports emphasizing the contribution of tillering capacity, panicle fertility, and grain weight to yield potential in rice (Alam et al., 2025; Chowdhury et al., 2023; Hannan et al., 2020). Collectively, the findings confirm that traits such as effective tillers, grains per panicle, and 1000-seed weight are valuable selection indices in rice improvement programs.

**CONCLUSION**

The present study clearly demonstrates that compared to traditional line transplanting, raised bed planting was shown to be a more resource-efficient and yield-enhancing farming technique. The method proved its potential for sustainable rice production by enhancing biomass partitioning, decreasing sterile spikelets, and improving soil aeration. Out of the genotypes that were evaluated, BRRI dhan49 in raised beds consistently demonstrated superior agronomic performance. We also noticed strong genotype × planting method interaction which strengthens the need of combining varietal selection with suitable agronomic methods to maximize performance under field conditions. Thus, we conclude that the most promising combination for increasing T. Aman rice yield in Bangladesh is BRRI dhan49 grown in raised beds. In rice-based cropping systems, we recommend the use of genotype-specific planting techniques and a multi-trait selection strategy to optimize yield potential and resource use efficiency.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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**Supplementary Table 1: Morphological, physical and chemical properties of the experimental land**

**1A. Morphological characteristics of the experimental site**

|  |
| --- |
| **Morphological characteristics of the experimental site** |
| **Parameters** |  | **Characteristics** |
| LocationLand typeGeneral soil typeSoil seriesParent materialsAEZFlood levelTopographySoil colorCropping pattern |  | Agronomy Field Laboratory, BAU, Mymensingh high landMedium high landNon-calcareous Dark grey Floodplain SoilsSonatolaOld Brahmaputra river borne depositsOld Brahmaputra Floodplain (AEZ 9)Above flood levelFairly leveledDark greyRice crop grown year round (rice-rice) |

**1B. Physical characteristics of the soil (Particle size distribution)**

|  |  |  |
| --- | --- | --- |
| Parameters |  | Value |
| Sand (%) (0.2-0.02 min)Silt (%) (0.02-0.002 min)Sand (%) (0.2-0.02 min)Soil textural classParticle density (g/cc)Bulk density (g/cc)Porosity (%) |  | 5.5370.9123.56Silt loam2.601.3546.67 |

**1C. Chemical characteristics of the soil**

|  |  |
| --- | --- |
| Parameters | Value |
| Soil pHOrganic matter (%)Total nitrogen (%)Available phosphorus (ppm)Exchangeable potassium (me/100g soil) | 6.52.020.1173.190.092 |

**Source:** Humboldt Soil Testing Laboratory, Department of soil science, Bangladesh Agricultural University, Mymensingh.

**Supplementary Table 2: Distribution of monthly average air temperature relative humidity, rainfall and sunshine hours of the experiment site during the period from June to December 2019**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Month | \*\*Air temperature  (0C) |  \*\* Relative  humidity (%) |  \*Rainfall (cm) |  \*\*Sunshine (hrs) |
| June | 29.2 | 84.4 | 421.3 | 3.7 |
| July | 29.6 | 84.5 | 582.9 | 3.9 |
| August | 30.2 | 81.6 | 316.5 | 4.4 |
| September | 29.3 | 84.6 | 203.0 | 4.9 |
| October |  27.95 |  82.90 |  82.9 |  6.76 |
| November |  23.85 |  82.20 | 25.45 |  7.00 |
| December |  19.00 |  83.40 | 20.45 |  4.50 |

\* Monthly total

\*\* Monthly average

**Source:** Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh.