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COMBINED EFFECT OF VARIETY AND PLANTING METHOD ON GROWTH AND YIELD PERFORMANCE OF *AUS* RICE (*ORYZA SATIVA* L.)

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ABSTRACT

A field experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, from April to August 2017 to evaluate the effect of variety and planting method on the growth and yield of aus rice (*Oryza sativa* L.). Four high-yielding varieties (BRRI dhan65, BRRI dhan55, BRRI dhan48 and BRRI dhan43) were established using three planting methods (broadcasting, dibbling and transplanting) in a randomized complete block design with three replications, giving twelve treatment combinations. Variety, planting method, and their interaction significantly ($p<0.05$) influenced plant height, root length, leaf number, dry matter accumulation, tiller production, panicle length, grain number, 1000-seed weight, and yield. BRRI dhan48 consistently outperformed the other varieties, while transplanting produced superior growth and yield compared with dibbling and broadcasting. The combination of BRRI dhan48 with transplanting (V_3M_3) recorded the highest effective tillers hill^{-1} (17.00), panicle length (22.42 cm), total grains panicle^{-1} (120.80), filled grains panicle^{-1} (110.10), 1000-seed weight (24.58 g), seed yield (4.63 t ha^{-1}), stover yield (6.30 t ha^{-1}), biological yield (10.90 t ha^{-1}) and harvest index (42.36%), whereas BRRI dhan43 under broadcasting (V_4M_1) gave the lowest values for nearly all traits. Pearson correlation analysis among the twelve treatment means revealed strong positive associations between yield-contributing traits (dry matter accumulation, tiller number, panicle length, grain number) and final seed yield ($r > 0.90$), underscoring the physiological basis of the variety × planting-method interaction. These findings indicate that adoption of BRRI dhan48 with the transplanting method can substantially improve aus rice productivity, while dibbling may serve as a comparatively water-economical alternative to transplanting in areas with limited irrigation.

1.0 INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population, and around 90% of the crop is produced and consumed in South and Southeast Asia, the most densely populated region on Earth (Nanda, 2002). Bangladesh is the fourth largest producer and consumer of rice in the world, with roughly 80% of its cropped area devoted to the crop and an annual production of 28.20 million tons from 11.04 million ha (IRRI, 2016). Despite this scale of production, the national average yield of 2.81 t ha^{-1} (BRRI, 2016) remains less than half the world average, indicating substantial scope for productivity gains through improved varieties and agronomic management (Anonymous, 2009; Bhuiyan et al., 2002). Rice in Bangladesh is cultivated across three distinct seasons - aus, aman, and boro under diverse hydrological regimes. *Aus* rice occupies only about 12.27% of the total rice area and records the lowest average yield among the three seasons (1.45 t ha^{-1}, compared with 1.97 and 3.17 t ha^{-1} for *aman* and *boro*, respectively) (BBS, 2016). Raising *aus* productivity is therefore essential for improving overall national rice output, and this requires a combination of high-yielding varieties and the best-suited planting method for the season. Crop establishment method is one of the most influential agronomic decisions in rice production. Direct seeding, comprising dry seeding, wet seeding and water seeding, has largely replaced transplanting in several Asian countries in recent decades, driven mainly by shrinking water resources and rising labor costs (Farooq et al., 2009; Farooq et al., 2011; Pandey and Velasco, 2002). However, direct-seeded systems face constraints such as weed infestation, uneven crop establishment, panicle sterility, and inconsistent nutrient availability, and several studies report lower yields under direct seeding relative to transplanting (Nakano and Morita, 2008; Nguyen and Ferrero, 2006). Since varietal response to establishment method is not uniform, the choice of planting method needs to be evaluated jointly with variety rather than in isolation. Given the comparatively low productivity of the aus season and the need to identify establishment methods that balance yield performance with resource efficiency, the present study was undertaken with the aus rice varieties BRRI dhan65, BRRI dhan55, BRRI dhan48 and BRRI dhan43 under broadcasting, dibbling and transplanting, with the specific objectives of (i) evaluating the varietal performance of aus rice, (ii) assessing the effect of planting method on crop growth and yield, and (iii) determining the combined (interaction) effect of variety and planting method on growth, yield-contributing characters and yield of *aus* rice.

2.0 MATERIALS AND METHODS

Experimental site, climate and soil: The experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh (23^{0}74′ N, 90^{0}35′ E; 8.2 m above sea level), from 5 April to 15 August 2017. The site experiences a sub-tropical climate with high temperatures, high humidity, and heavy rainfall during the kharif season (April-September). The soil belonged to the Tejgaon series under the Modhupur Tract (AEZ 28), classified as silty clay loam with pH 5.6 and 0.45% organic carbon.

Plant materials and treatments: Four high-yielding *Aus* rice varieties - BRRI dhan65 (V_1), BRRI dhan55 (V_2), BRRI dhan48 (V_3), and BRRI dhan43 (V_4) - obtained from the Bangladesh Rice Research Institute, Gazipur, were evaluated under three planting methods: broadcasting (M_1), dibbling (M_2), and transplanting (M_3). The 4 × 3 factorial combination produced 12 treatments, laid out in a randomized complete block design (RCBD) with three replications and 36 unit plots (2.5 × 2.5 m each).

Crop establishment and management: For the transplanting treatment, pre-germinated seeds were raised in a wet nursery bed and 25-day-old seedlings were transplanted at 20 × 20 cm spacing on 30 April 2017. For broadcasting and dibbling, dry seeds were sown directly into well-prepared dry soil, with thinning carried out 20 days after sowing. Recommended doses of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate (150, 120, 80, 70 and 10 kg ha^{-1}, respectively) were applied, with urea top-dressed in three equal splits at 15, 30 and 50 days after establishment. Standard intercultural operations - irrigation, weeding, gap-filling and plant protection against rice stem borer (Diazinon 10G @ 16.80 kg ha^{-1}) were performed uniformly across treatments.

Data recording: Five hills were randomly sampled from each plot at harvest for recording growth parameters (plant height, root length, number of leaves $hill^{-1}$, plant dry weight $hill^{-1}$, total and effective tillers $hill^{-1}$) and yield-contributing traits (panicle length, total and filled grains $panicle^{-1}$, 1000-seed weight, based on 10 randomly selected panicles per plot). Grain and straw yields were recorded from the whole plot after sun-drying to 12% moisture and converted to t ha^{-1}. Biological yield was calculated as the sum of grain and straw yield, and harvest index was expressed as the percentage ratio of grain yield to biological yield.

Statistical analysis: Data were subjected to analysis of variance (ANOVA) for a two-factor RCBD using the statistical package MSTAT-C. Mean separation among treatments was performed by Duncan's Multiple Range Test (DMRT) at the 5% level of significance (Gomez and Gomez, 1984). Pearson product-moment correlation coefficients were computed among the twelve treatment means of all growth and yield parameters using R (v4.3.3, R Core Team) with the ggplot2 and reshape2 packages, and visualized as a correlation heatmap.

3.0 RESULTS

Growth parameters: Plant height, root length, number of leaves $hill^{-1}$, plant dry weight $hill^{-1}$, and total and effective tiller number $hill^{-1}$ were all significantly affected by variety, planting method, and their interaction (Figures 1 and 2).

Among varieties, V_3 (BRRI dhan48) produced the tallest plants (103.50 cm), the longest roots (15.06 cm), the greatest number of leaves $hill^{-1}$ (96.02), the highest dry weight $hill^{-1}$ (42.88 g), and the greatest number of total (17.68) and effective (14.20) tillers $hill^{-1}$, while V_1 (BRRI dhan65) gave the shortest plants (92.49 cm) and shortest roots (11.10 cm), and V_4 (BRRI dhan43) gave the lowest values for leaf number (91.02), dry weight $hill^{-1}$ (38.05 g) and tiller number (14.18 total; 10.97 effective) (Fig. 1). Among planting methods, M_3 (transplanting) produced significantly taller plants (100.30 cm), longer roots (13.97 cm), more leaves $hill^{-1}$ (103.20), greater dry weight $hill^{-1}$ (43.83 g), and more total (18.37) and effective (15.02) tillers $hill^{-1}$ than M_2 (dibbling) or M_1 (broadcasting), which gave the lowest values for all growth traits (95.40 cm, 12.37 cm, 82.70, 35.67 g, 13.22 and 9.55, respectively) (Fig. 2). The variety × planting-method interaction was significant for every growth parameter (Fig. 3). The combination of BRRI dhan48 with transplanting (V_3M_3) consistently produced the tallest plants (106.1 cm), longest roots (15.67 cm), highest leaf number (105.8), greatest dry weight $hill^{-1}$ (46.75 g), and highest total (20.13) and effective (17.00) tiller number, whereas BRRI dhan65 under broadcasting (V_1M_1) gave the lowest values for plant height (89.14 cm), root length (10.22 cm) and leaf number (80.04), and BRRI dhan43 under broadcasting (V_4M_1) gave the lowest dry weight hill^{-1} (33.67 g) and tiller number (11.24 total; 8.84 effective).

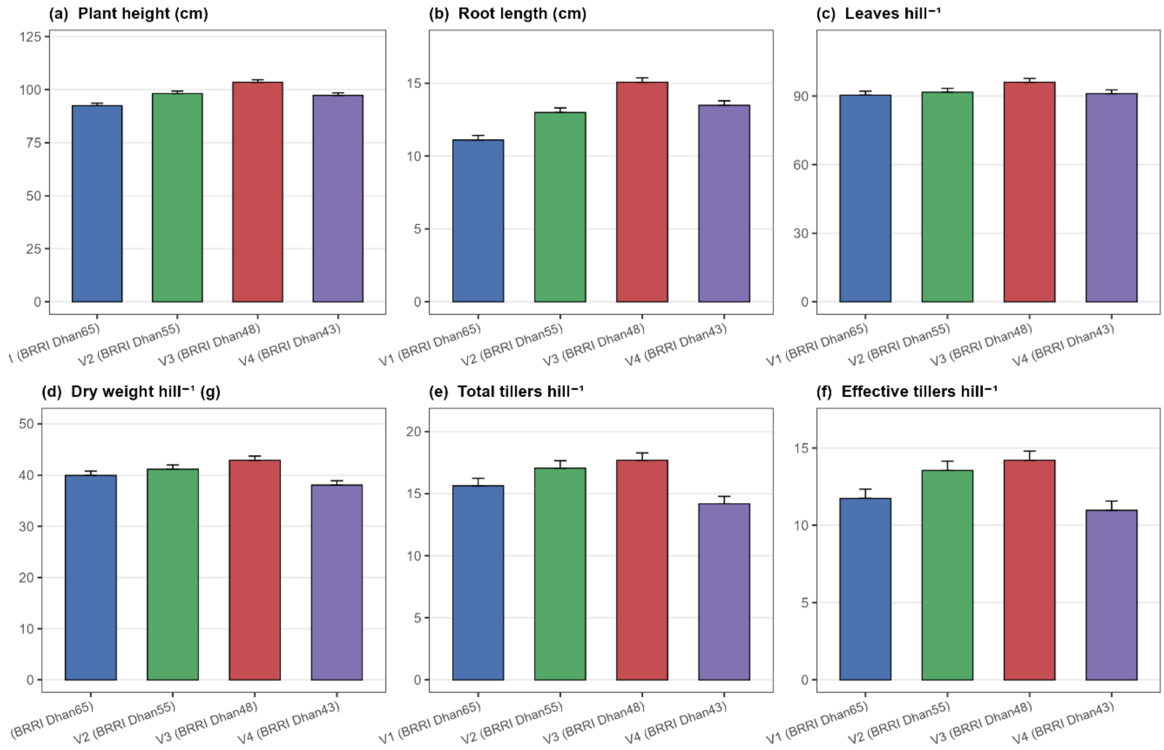

Figure 1. Effect of variety on growth parameters of *Aus* rice at harvest

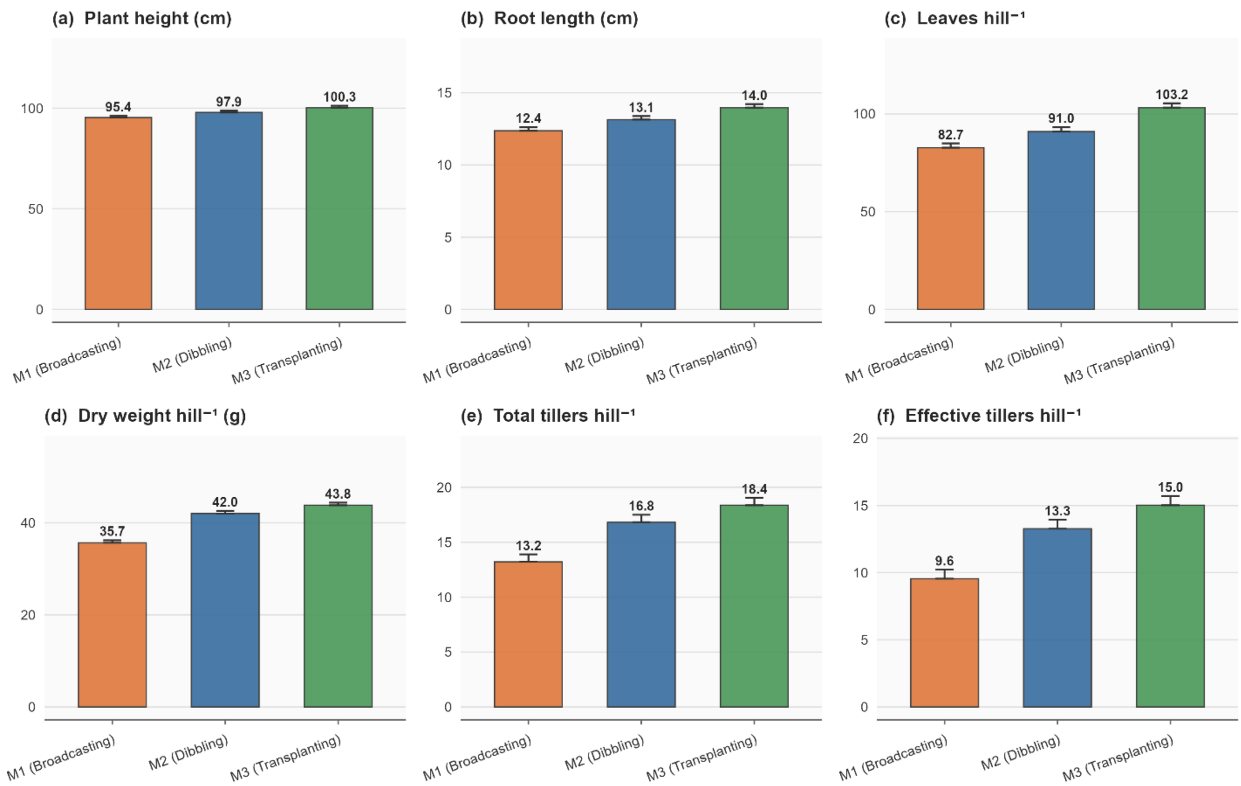

Figure 2. Effect of planting method on growth parameters of *Aus* rice at harvest

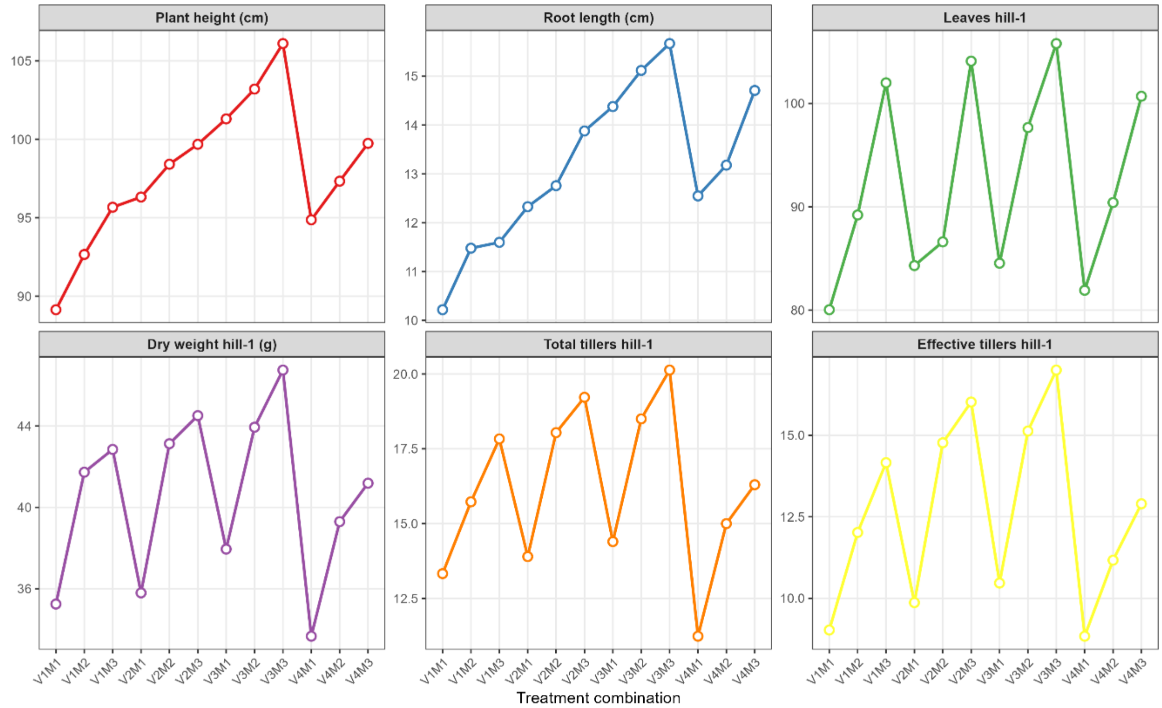

Figure 3: Combined effects of variety and planting methods on the growth of *Aus* rice

Yield-contributing parameters: Panicle length, total grains panicle^{-1}, filled grains panicle^{-1}, and 1000-seed weight were significantly influenced by variety, planting method, and their interaction (Table 1). V_3 (BRRI dhan48) produced the longest panicles (19.35 cm) and the highest grain number (109.40 total; 96.37 filled) and 1000-seed weight (22.42 g), while V_4 (BRRI dhan43) recorded the lowest values for all four traits (15.63 cm, 95.56, 79.20 and 20.10 g, respectively). Transplanting (M_3) outperformed dibbling (M_2) and broadcasting (M_1) for every yield-contributing trait, with broadcasting consistently giving the lowest values.

The interaction effect followed the same pattern observed for growth traits: V_3M_3 produced the longest panicles (22.42 cm) and the highest total grains panicle^{-1} (120.80), filled grains panicle^{-1} (110.10), and 1000-seed weight (24.58 g), values statistically at par with V_2M_3 for most traits. V_4M_1 recorded the lowest panicle length (14.15 cm), total grains panicle^{-1} (83.77), filled grains panicle^{-1} (65.29), and 1000-seed weight (18.43 g).

Table 1. Effect of variety and planting method on yield-contributing parameters of *Aus* rice.

Treatment	**Panicle length (cm)**	**Total grains panicle^{-1}**	**Filled grains panicle^{-1}**	**1000-seed weight (g)**
Effect of variety				
V_1	16.70 b	99.19 c	84.04 c	20.78 b
V_2	18.49 a	105.60 b	92.03 b	21.92 a
V_3	19.35 a	109.40 a	96.37 a	22.42 a
V_4	15.63 c	95.56 d	79.20 d	20.10 b
$LSD_{0.05}$	**1.024**	**3.098**	**3.149**	**0.9638**

Effect of planting method				
M_1	15.06 c	87.51 c	70.31 c	19.27 c
M_2	18.06 b	106.90 b	93.21 b	21.72 b
M_3	19.51 a	112.90 a	100.20 a	22.92 a
$LSD_{0.05}$	**1.049**	**4.366**	**4.742**	**0.8191**
Combined effect of variety × planting method				
V_1M_1	14.88 ef	84.68 gh	67.16 i	18.73 ef
V_1M_2	17.48 d	104.5 e	90.20 e	21.67 b
V_1M_3	17.73 d	108.4 de	94.77 d	21.94 b
V_2M_1	15.36 e	88.47 g	71.59 h	19.77 de
V_2M_2	19.32 c	111.4 cd	99.09 c	22.16 b
V_2M_3	20.78 b	116.9 ab	105.4 b	23.83 a
V_3M_1	15.84 e	93.10 f	77.18 g	20.13 d
V_3M_2	19.80 bc	114.5 bc	101.8 bc	22.55 b
V_3M_3	22.42 a	120.8 a	110.1 a	24.58 a
V_4M_1	14.15 f	83.77 h	65.29 i	18.43 f
V_4M_2	15.62 e	97.18 f	81.70 f	20.48 cd
V_4M_3	17.11 d	105.7 e	90.59 e	21.40 bc
$LSD_{0.05}$	**1.113**	**4.186**	**3.972**	**1.105**
CV (%)	**5.839**	**13.214**	**9.337**	**8.415**

In a column, means followed by common letter(s) do not differ significantly at P = 0.05 by DMRT.
V_1 = BRRI dhan65, V_2 = BRRI dhan55, V_3 = BRRI dhan48, V_4 = BRRI dhan43; M_1 = Broadcasting, M_2 = Dibbling, M_3 = Transplanting

Yield parameters: Seed yield, stover yield, biological yield, and harvest index were significantly affected by variety, planting method, and their interaction (Table 2). V_3 (BRRI dhan48) produced the highest seed yield (4.05 t ha^{-1}), stover yield (5.94 t ha^{-1}), biological yield (9.99 t ha^{-1}) and harvest index (40.33%), while V_4 (BRRI dhan43) gave the lowest values for all four traits (2.95 t ha^{-1}, 5.05 t ha^{-1}, 8.00 t ha^{-1} and 36.78%, respectively). Transplanting (M_3) produced significantly higher seed yield (4.06 t ha^{-1}), stover yield (5.95 t ha^{-1}), biological yield (10.00 t ha^{-1}) and harvest index (40.34%) than broadcasting (M_1), which gave the lowest values (2.79 t ha^{-1}, 4.77 t ha^{-1}, 7.56 t ha^{-1} and 36.86%, respectively); dibbling (M_2) was statistically at par with transplanting for biological yield and harvest index. The variety × planting-method interaction showed that V_3M_3 produced the highest seed yield (4.63 t ha^{-1}), stover yield (6.30 t ha^{-1}), biological yield (10.90 t ha^{-1}), and harvest index (42.36%), statistically similar to V_2M_3 for most traits and to V_3M_2 for seed and stover yield. The lowest values for all yield parameters were recorded from V_4M_1 (seed yield 2.36 t ha^{-1}, stover yield 4.36 t ha^{-1}, biological yield 6.72 t ha^{-1}, harvest index 35.12%).

Table 2. Effect of variety and planting method on yield parameters of *Aus* rice.

Treatment	Seed yield (t ha⁻¹)	Stover yield (t ha⁻¹)	Biological yield (t ha⁻¹)	Harvest index (%)
Effect of variety				
V_1	3.280 c	5.210 c	8.490 c	38.53 b
V_2	3.820 b	5.670 b	9.490 b	39.99 a
V_3	4.050 a	5.940 a	9.990 a	40.33 a
V_4	2.950 d	5.050 d	8.000 d	36.78 c
$LSD_{0.05}$	**0.171**	**0.184**	**0.3076**	**1.357**
Effect of planting method				
M_1	2.790 c	4.770 c	7.560 c	36.86 b
M_2	3.740 b	5.680 b	9.420 a	39.52 a
M_3	4.060 a	5.950 a	10.000 a	40.34 a
$LSD_{0.05}$	**0.1855**	**0.2454**	**0.647**	**1.585**
Combined effect of variety × planting method				
V_1M_1	2.640 fg	4.400 g	7.040 h	37.50 cd
V_1M_2	3.420 d	5.470 de	8.890 e	38.47 cd
V_1M_3	3.780 c	5.760 cd	9.540 d	39.62 bc
V_2M_1	2.930 ef	4.900 f	7.830 g	37.42 cd
V_2M_2	4.150 b	5.940 bc	10.10 c	41.13 ab
V_2M_3	4.370 ab	6.180 ab	10.60 ab	41.42 ab
V_3M_1	3.240 de	5.420 de	8.660 ef	37.41 cd
V_3M_2	4.280 ab	6.100 ab	10.40 bc	41.23 ab
V_3M_3	4.630 a	6.300 a	10.90 a	42.36 a
V_4M_1	2.360 g	4.360 g	6.720 h	35.12 e
V_4M_2	3.100 de	5.220 ef	8.320 f	37.26 d
V_4M_3	3.400 d	5.560 de	8.960 e	37.95 cd
$LSD_{0.05}$	**0.3592**	**0.3213**	**0.3935**	**2.004**
CV (%)	**4.729**	**6.314**	**5.221**	**8.544**

In a column, means followed by common letter(s) do not differ significantly at P = 0.05 by DMRT. V_1 = BRRI dhan65, V_2 = BRRI dhan55, V_3 = BRRI dhan48, V_4 = BRRI dhan43; M_1 = Broadcasting, M_2 = Dibbling, M_3 = Transplanting

Correlation among growth and yield parameters

Pearson correlation analysis performed on the twelve variety × planting-method treatment means (Fig. 4) revealed that seed yield was very strongly and positively correlated with stover yield (r = 0.99), biological yield (r = 0.97), harvest index (r = 0.97), 1000-seed weight (r = 0.97), filled grains panicle^{-1} (r = 0.97) and total grains panicle^{-1} (r = 0.97), and strongly correlated with effective tillers hill^{-1} (r = 0.98), total tillers hill^{-1} (r = 0.98) and dry weight hill^{-1} (r = 0.99). Plant height and root length, although significantly associated with the other traits, showed comparatively weaker correlations with final yield (r = 0.75 and r = 0.64 with seed yield, respectively) than the tillering and panicle-related traits, indicating that yield in *aus* rice under this experiment was driven more strongly by dry-matter partitioning, tillering capacity, and panicle-level grain-filling traits than by vegetative plant stature alone.

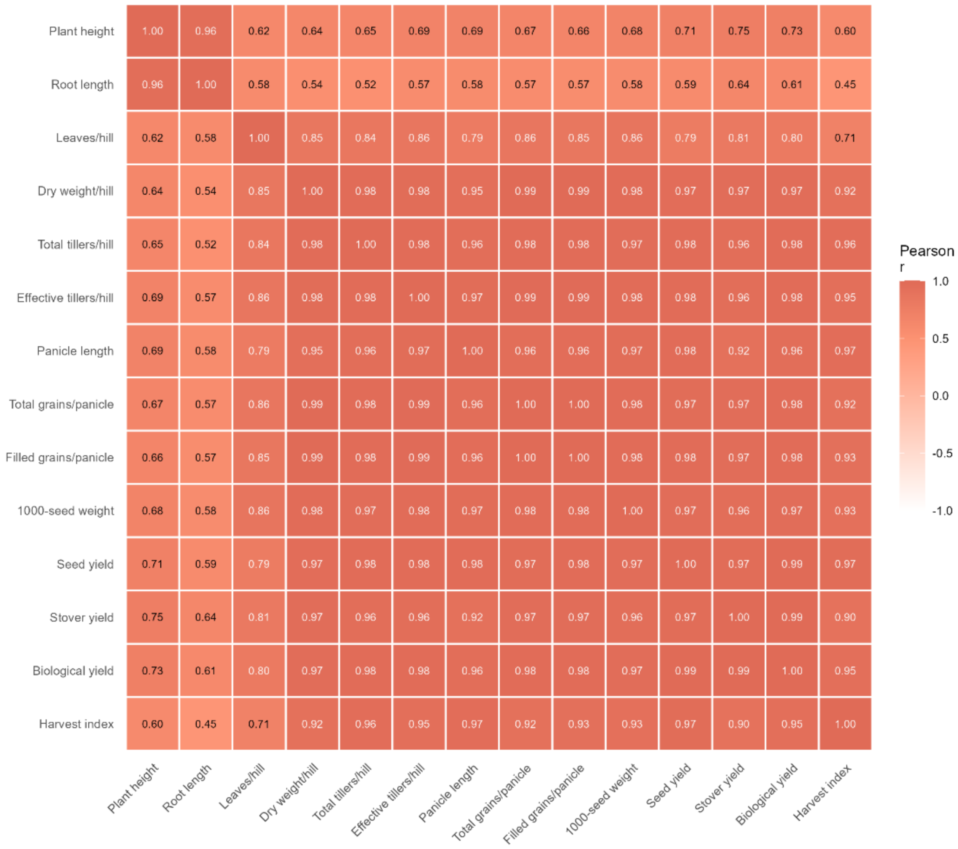

Figure 4. Pearson correlation heatmap among growth and yield parameters of *Aus* rice

4.0 DISCUSSION

The superior growth and yield performance of BRRI dhan48 over BRRI dhan65, BRRI dhan55 and BRRI dhan43 in the present study confirms that genotype exerts a strong and consistent influence on aus rice productivity, corroborating the findings of Hussain et al. (2014), who reported significant varietal differences in plant height, tillering, dry matter production and paddy yield among rice genotypes. The taller stature and greater root length of BRRI dhan48 relative to BRRI dhan65 are consistent with the varietal differences in plant height reported by Hussain et al. (2014), BINA (1993) and Hossain et al. (1991), and with the significant varietal effect on root length reported by Abou-Khalifa (2012). The higher leaf number, dry matter accumulation, and tillering capacity recorded in BRRI dhan48 agree with the observations of Hussain et al. (2014), Abou-Khalifa (2012), Akbar (2004), and WenXiong et al. (1996), who linked varietal differences in leaf area and tiller number to differences in light interception and photosynthetic capacity, ultimately reflected in dry matter accumulation. The superior panicle length, grain number and 1000-seed weight of BRRI dhan48 are similarly consistent with the varietal effects on yield-contributing traits reported by

Abou-Khalifa (2012), Obaidullah (2007), Ashrafuzzaman (2006) and Chowdhury et al. (2005), all of whom found that variety significantly altered panicle length, grain number panicle^{-1} and 1000-grain weight. Correspondingly, the highest seed yield, stover yield, biological yield, and harvest index obtained from BRRI dhan48 agree with the varietal yield advantages reported by Hussain et al. (2014), Abou-Khalifa (2012), and Ashrafuzzaman (2006). Since seed yield in the present study was very strongly correlated with dry weight hill^{-1}, tiller number, panicle length and grain number (Fig. 3), the yield superiority of BRRI dhan48 can be attributed to its greater capacity to produce and fill tillers and panicles, rather than to plant height alone - a pattern also emphasized by Obaidullah (2007), who reported that variety significantly influenced yield-contributing traits and grain yield but not effective tillers hill^{-1} or harvest index in a comparable set of genotypes. Transplanting consistently outperformed dibbling and broadcasting for every growth, yield-contributing and yield parameter measured, a result that is well supported in the direct-seeding literature. Abdul-Ganiyu et al. (2016) similarly reported that plant height, tiller count and leaf area index differed significantly among transplanting, drilling, dibbling and broadcasting under wet-season rice, while Ehsanullah et al. (2000) and Goel and Verma (2000) both found that transplanted rice out-yielded direct-seeded rice, attributing the advantage to more uniform crop establishment, reduced early-season competition, and a longer effective growth duration before the onset of reproductive development. The lower performance of broadcasting relative to transplanting in the present experiment is consistent with the yield reduction under direct seeding reported by Johnkutty et al. (2002), Maqsood et al. (1997) and Nakano and Morita (2008), and reflects the difficulties broadcast-sown crops face in establishing uniform stands, competing with weeds, and achieving efficient nutrient capture, as summarized by Nguyen and Ferrero (2006) and Farooq et al. (2011). The intermediate performance of dibbling, which was statistically at par with transplanting for several traits including biological yield and harvest index, agrees with Abdul-Ganiyu et al. (2016), who identified dibbling as a competitive alternative to transplanting under rainfed conditions, and suggests that dibbling can serve as a labor- and water-economical option where transplanting is not feasible. The significant interaction between variety and planting method for all measured traits indicates that varietal responses to establishment method were not uniform, and that the combination of BRRI dhan48 with transplanting (V_3M_3) captured the benefits of both factors simultaneously. This pattern parallels the findings of Vange et al. (2016), who reported that although direct-seeded rice was generally shorter and produced more tillers per stand, the longer growth duration afforded by transplanting allowed heavier panicles, more panicle branches, and better grain filling, ultimately producing higher grain yield in the transplanted crop. Similarly, Birhane (2013) found that grain yield differed significantly with planting method across six rice varieties, with the highest yield consistently associated with transplanting rather than direct sowing, particularly for varieties with a longer growth duration - a pattern also observed here, since BRRI dhan48 combined with transplanting allowed the crop to fully express its tillering and grain-filling potential. The strong positive correlations observed among dry weight hill^{-1}, tiller number, panicle length, grain number and final seed yield (Fig. 3) provide a physiological explanation for the interaction: the higher grain yield recorded under V_3M_3 can be attributed to a greater number of productive tillers, longer panicles and more filled grains per panicle, resulting from reduced inter-plant competition for growth resources under transplanting and a comparatively longer vegetative-to-reproductive transition period, as similarly proposed by Akhgari et al. (2013) and Naresh et al. (2013) to explain superior yield performance of transplanted rice relative to direct-seeded rice across different varieties.

5.0 CONCLUSION

Variety, planting method, and their interaction significantly influenced the growth, yield-contributing characters, and yield of *aus* rice. Among the four varieties evaluated, BRRI dhan48 showed the best overall performance, while transplanting was consistently superior to dibbling and broadcasting for crop establishment. The combination of BRRI dhan48 with transplanting (V_3M_3) produced the highest seed yield (4.63 t ha^{-1}) and was identified as the most productive treatment combination for aus rice cultivation under the agro-climatic conditions of the study area. Correlation analysis confirmed that yield gains were most closely tied to tillering capacity, dry matter accumulation, and panicle-level grain-filling traits rather than to plant height alone. Where transplanting is constrained by labor or water availability, dibbling may be considered a practical alternative, as it produced growth and yield performance statistically comparable to transplanting for several traits. Future multi-location and multi-season trials are recommended to confirm the stability of the BRRI dhan48 × transplanting combination across diverse aus-growing environments.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The datasets generated and analyzed during the current study, including the treatment-mean dataset used for correlation analysis, are available from the corresponding author upon reasonable request.

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