

Optimum transplanting date maximizes the growth and yield of rice in Bangladesh

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ABSTRACT

Rice is the staple food crop and it grows in three seasons in Bangladesh. The optimum transplanting time can satisfy its appropriate temperatures and solar radiation for vigorous vegetative growth and maximum grain yield. Recently, climate change affected the transplanting date of crops which recalls us to determine optimum transplanting date of rice in Bangladesh. To optimize the transplanting date in transplanting Aman (T. Aman) season, field experiment was conducted to evaluate the effect of different transplanting dates on yield and yield components of rice. Four transplanting dates (20th July, 4th August, 19th August and 3rd September) of two rice varieties including BR11 and BRRI dhan39 were used to design the experiment. Results revealed that seedlings transplanted on 4th August led to maximum grain yield. Also, they produced maximum number of productive (panicle bearing) tillers, number of grains per panicle, and 1000-grain weight. From this study, it can be concluded that farmers should transplant rice on 4th August at T. Aman season in Bangladesh for getting maximum benefit from their unit area.

Keywords: Yield component, rice genotype, phenological stage, photoperiod, environmental condition, biological yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important and stable cereal crop on the global level, it is the main item of the diet of 3.5 billion people [1]. The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand [2]. Planting rice at the optimum time is critical to achieve high grain yield. However, optimum rice planting dates are regional and vary with location and genotypes [3]. Bruns and Abbas [4] reported that rice plants require a particular temperature for its phenological affair such as panicle initiation, flowering, panicle exertions from flag leaf sheath and maturity. Rice seeded before the window of optimum dates usually has slow germination and emergence, poor stand establishment, increased damages from soil borne, seedling diseases under cold conditions and seeds lose by birds or mice [5]. Planting rice after the optimum dates can result in low yield due to higher disease and insect incidence, tropical storm-related lodging and possible heat or cold damage during heading and the grain filling period [6]. The time of transplanting is also an important factor for uniform establishment of rice. The proper time of transplanting allows the crop to complete its life cycle timely and successfully under a specific agro-ecology [3]. Early date of transplanting is the appropriate time for gaining important properties such as the maximum tillers, number of tillers per m², plant height, 1000-grain weight and grain yield [7]. Bashir et al. [3] reported that a thousand-

grain weight decreased gradually with delay in planting time. The sowing time significantly influenced the grain yield [8].

Transplanted Aman (T. Aman) season is one of the most important rice growing period in Bangladesh which might suffer from high temperature at the different growth stages from germination to maturity [9]. The rice varieties grown in T. Aman season are mostly photoperiod sensitive. Their growth duration generally depends on the planting date due to their photoperiod sensitivity. Early planted photoperiod sensitive rice varieties pass a longer lag vegetative phase which increases tallness as well as biomass and are prone to lodging during grain filling stage. On the other hand, late transplanted plants get less time for vegetative growth and ultimately lower yields. Thus, by adjusting the transplanting time, the plants can take advantage of natural conditions favorable for growth and yield. Moreover, rice plants require a particular temperature for its phenological responses such as panicle initiation, flowering, panicle exertion from flag leaf sheath and maturity [10] and these are very much influenced by the planting dates during T. Aman season. Moreover, the genetic variability and the potentiality of the genotypes were expressed differently due to planting at different dates. Beside, the photoperiod sensitive varieties, photoperiod insensitive varieties are influenced during this season due to different environmental conditions such as temperature fluctuation, differences between day night temperature and duration of light.

Though the optimum planting time of T. Aman rice is in August [11], sometimes, transplanting is delayed due to various physical and socio-economic factors [12]. Late planting exposes the reproductive phase as well as phenological events of the crop to an unfavorable temperature regime, thereby causing high spikelet sterility and poor growth of the plants. However, optimum rice planting dates are regional and vary with location and genotypes [4]. Based on the above findings, the present study was undertaken to find out the optimum transplanting time of 2 selected high yielding inbred rice genotypes (one slightly photoperiod sensitive and one photoperiod insensitive) in T. Aman season. This study assumes that crop production can be optimized by identifying suitable transplanting date.

MATERIAL AND METHODS

Soil condition

The experiment was conducted at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experimental area was situated at 23° 77' N (latitude) and 90° 33' E (longitude) with an altitude of 8.6 m above the sea level. The soil texture was a clay loam, with soil pH ranging from 6.1 to 6.3 and an organic matter content of 1.29%.

Treatments

The experiment consisted of 2 inbred rice varieties (one slightly photosensitive i.e. BR11 and the other one photoperiod insensitive i.e. BRRI dhan39). Four transplanting dates were selected following the 20th July, 4th August, 19th August and 3rd September). The experiment was laid out in a randomized complete block design with three replications. Each experimental plot area was 12 m² (4.0 m x 3.0 m). The distances between plots and replications were 1.00 m and 1.05 m, respectively.

Seed collection and seedling nursery

Seeds of BR11 (Mukta) and BRRI dhan39 were obtained from Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. Viable seeds were selected by following the specific gravity method developed by XYZ (nnnn). The seedbed was prepared by puddling with repeated ploughing followed by laddering. The seeds were sown in a nursery seedbed for 30 days.

Land preparation and Fertilizer application

The experimental field was first ploughed by using a tractor drawn disc plough. The field was then irrigated and prepared by three successive ploughings and cross ploughings with a tractor drawn plough and subsequently leveled by laddering. The experimental area was fertilized with 120 kg of N, 80 kg of each of P₂O₅ and K₂O, 20 kg of S, and 5 kg of Zn per hectare in the form of urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate, respectively. The entire amount of TSP, MOP, gypsum and zinc sulphate was applied as a basal dose at final land preparation. Urea was top-dressed in three equal installments as recommended by the BRRI [9].

Transplanting and intercultural operations

Seeds of each cultivar were sown from June to July, 2010 in nursery beds and 30-35 day-old seedlings were uprooted carefully on the 20th July, 4th August, 19th August and 3rd September and transplanted into the experimental plots. The seedbeds were made wet by application of water one day prior to uprooting the seedlings to minimize mechanical injury of roots. Seedlings were transplanted as per BRRI recommendations. After transplanting the seedlings, gap filling and other inter-cultural operations were carried out when necessary. Other management practices were carried out following BRRI recommendations [9].

Data collection

The crop was considered mature and ready for harvest when 80-90% of the grains had become golden yellow in coloured. An area of 5 m² from the middle portion of each plot was separately harvested and bundled, properly tagged and brought to the threshing floor for recording grain and straw yield. Threshing was carried out using a pedal thresher. The grains were cleaned and sun dried and finally the yield was adjusted at 12% moisture content. The straw yield was determined on an oven dry basis. Plant height, number of tillers per hill, leaf area index, and plant biomass were recorded at 15 days interval after transplanting, and continued until harvesting. Days to flowering was recorded when 50% of the plants within a plot produced flowers. The necessary data on agronomic characters were based on ten selected hills from each plot in the field at 15-day intervals at harvest. The biological yield was calculated using the following formula:

$$\text{Biological yield} = \text{Grain yield} + \text{Straw yield}$$

Statistical analyses

One-way ANOVA was performed for plant height, number of tillers, leaf area index, dry weight of plants, days to flowering, panicle length, weight of 1000 grains, and grain yield. Treatment mean values were separated by Tukey Honesty Significant Test using SPSS software, version 16. Response variables were subjected to a logarithmic or arcsine transformation prior to analysis to stabilize the variance, and to verify that the back-transformed values were non-negative.

RESULTS AND DISCUSSION

Plant height

Plant height was significantly affected by the different transplanting dates and variety (Fig. S1, $p < 0.001$). The plant transplanted on 4th August produced the highest plant height but transplanted on the 3rd of September resulted shortest plant. Similar trend was found in both rice varieties. Before 4th August transplanted crop also showed lower plant height. This result indicates that the optimum planting time of T. Aman rice for better plant growth was 4th August. The reduction in plant height is attributed to the reason that late planting had shorter growing period due to photoperiodic response. Longer growing season of August planted crop produced taller plants and higher dry matter production as compared to the rest planting dates. Similar result was found in other studies [3, 8, 13]. They reported that plant height is significantly affected by sowing dates and early sowing dates of rice produce taller plants than delayed sowing dates. Plant height decreased significantly when sowing days were delayed from August to September. It may be happened due to another reason that the reduction in plant height regarding late sowing dates could be attributed to the effect of low temperature and low humidity in the dry season [14] since temperature in Bangladesh starts to decrease from September. Sowing date of crop significantly affected the plant height [8,15] and early sowing of rice produced taller plants than delayed sowing [16-17].

Tillering capacity

Number of tillers/m² was affected by various transplanting date (Fig. 1). The variation was also found in both rice varieties. They produced maximum number of total tillers hill⁻¹ when plant transplanted on 4th August while crop transplanted on 3rd September resulted minimum tillers/m² (Fig. 1). All the remaining treatments were also statistically different from each other in both varieties. Among yield components, productive tillers are very important because the final yield is mainly a function of the number of panicles bearing tillers (productive tillers) per unit area [3]. This increase of fertile tillers per m² at 4th August transplanting was attributed to favorable environmental conditions which enabled the plant to improve its growth and development as compared to other transplanting dates irrespective of variety. This increase in fertile tillers m⁻² in the 4th August transplanting is attributed to the favorable environmental conditions which improved plant growth and development as compared to other transplanting dates. Similar results are reported by Rakesh and Sharma [18] who found that delays in planting resulted in significant decrease in the number of productive tiller that ultimately affect rice yield. The number of fertile tillers per m² decrease with late transplanting dates [19-20]. Our result indicates that optimal transplanting date of rice variety produce maximum effective tillers/plant that is an important factor for getting higher rice yield per unit area.

Leaf area index (LAI)

Leaf area index (LAI) indicates photosynthetic effect and on the extent of photosynthetic area. Transplanting date influenced the LAI value irrespective of variety and effects were shown in Fig. 2. But significant different was not found in different transplanting date ($p > 0.05$). However, LAI depends on the processes of substrate allocation, leaf area development and senescence, and LAI regulate plant adaptation to environmental changes [21]. The maximum LAI was found in BR11 transplanted on 4th August. Before and after of this specific transplanting date, LAI value decreased in both tested varieties (Fig. 2). The higher LAI obtained on 4th August transplanted rice variety could be attributed to biological variability among the transplanting dates that resulted in a different leaf shape (length, width) and possibly number of leaves plant⁻¹. A positive correlation between LAI and NAR towards higher paddy yield at all phenological stages is found [22]. Transplanting date, spacing and number of seedlings hill⁻¹ have little effect on LAI [23]. These variations might be appeared due to change in environmental conditions and/or genetic make-up of the germplasm [24]. BR11 showed higher LAI value than BRRI dhan39 irrespective of transplanting date due to genetic effect.

Our result indicates that both too early and late transplanted plants reduced the LAI value and leaf area showed a better response with optimum transplanting date [25].

Dry weight of plants (g m^{-2})

Dry matter production was significantly influenced by variety as well as different days of transplanting ($p < 0.001$). Both varieties showed decreased dry matter with the delaying transplanting date and BR11 produced the highest dry weight at 4th August transplanting date (Fig. S2). The effect on plant dry matter production is the combine effect of other factors such as plant height, number of tillers produced, leaf area index and other biomass related factors that are also affected by different transplanting dates (described above).

Days to flowering and maturity

Different transplanting dates significantly influenced the days to flowering ($p < 0.05$). Among the transplanting dates, the 4th August transplanting required the shortest time for flowering and maturity, whereas the 3rd September planting needed a longer period for flowering and maturity (Fig. 3-4). Generally, it seems that early sowing dates induced early flowering days and maturity. On the other hand, late sowing dates produce late flowering and maturity. These results may be arose due to the effect of temperature from high to low on delaying flowering and maturity in rice [14] therefore this character can be considered as an indicator for the heat stress (effect) in rice flowering and maturity. Similar results were reported by Bashir et al. [3].

Panicle length (cm) and number of grains/panicle

The length of panicle was significantly affected by different sowing dates ($p < 0.001$). The plant transplanted on 4th August produced longer panicle than that of other transplanted dates irrespective of variety (Table S1). Panicle length decreased with increasing transplanting dates. The lowest Panicle length was observed for the sowing date 3rd September. The reduction in panicle length for late sowing dates could be attributed to the effect photoperiod and temperature according to the fact that rice is considered as a summer and short day crop [26-27]. Similar results were also reported by Osman et al. [14]. The total number of grains panicle⁻¹ was also significantly affected by the different transplanting dates and varieties ($p < 0.001$). The maximum number of total grains panicle⁻¹ was obtained from the 4th August transplanting, which was closely followed by the 20th July transplanting and the lowest number of grains panicle⁻¹ was recorded in the 3rd September transplanting (Table S1). These results are similar to that of Akram et al. [13] who reported that number of seeds per panicle was significantly affected as sowing date was delayed. There was a significant varietal effect on the number of grains produced per panicle. The maximum number of grains panicle⁻¹ was obtained from BR11. Total number of grains panicle⁻¹ forms the largest part of the yield characteristics which contributes towards the grain yield. Hence, the more grains panicle⁻¹ produced would result in more yield or production. Number of grains panicle⁻¹ varied due to varietal effect [28].

Weight of 1000 grains

Weight of 1000 grains was significantly influenced by the effect of transplanting date as well as variety ($p < 0.001$). The high yield of inbred variety BR11 produced the highest 1000-grain weight. A significant variation was found in 1000-grain weight both varieties at each transplanting date (Fig. S3). The 1000 grain weight of both variety decreased with delaying transplanted date of the tested season (Transplanted Aman) and they followed a linear trends ($R^2 = 0.722$ for BR11 and 0.728 for BRRI dhan39) (Fig. S3). Among the different transplanting dates in the T. Aman season, the 4th August transplanted plant including both varieties produced the highest 1000-grain weight, while the 3rd September transplanting

produced the lowest 1000-grain weight. These results suggest that the environmental conditions were most favorable for grain development during the 4th August transplanting as compared to other sowing dates. Filled grains/panicle and 1000 grain weight (g) are considered as the most important yield components in rice grain yield [26] and number of grains per panicle are significantly affected when the sowing date is delayed [13,29]. The number of filled grains per panicle was higher in the early seeding and declined gradually in the successive seeding dates [3,19]. However, these results are in contrary to that of Habibullah et al. [30], who reported that sowing date had no significant effect on a number of grains per panicle.

Grain yield

The grain yield of rice depends on several yield components such as number of grains per panicle, effective tillers and 1000 grains weight. Grain yield of each variety was significantly affected by different transplanting date ($p < 0.001$). The grain yield (t/ha) decreased when the sowing date delayed after 4th August of each variety (Fig. 5). The sowing date of 20th July also produced lower grain yield than 4th August. This result indicates that 4th August is the optimum transplanting date of rice irrespective of variety which might provide higher yield in Bangladesh. The higher yield in case of 4th August sowing date was attributed to increase the cumulative mean value of appropriate temperature and sunshine hours which resulted in more number of effective tillers/plant, more number of grains per panicle, higher 1000-grains weight and thus provided higher yield. Grain yield has a positive correlation with number of tillers/plant, number of panicles/m², number of filled grains/panicle, 1000 grain weight [14]. Highest yield in rice could be obtained when it is sown at an optimal sowing date [14,31]. The highest grain yield (6.30 t ha⁻¹) was found in BRRI released high yielding inbred variety BR11 at each transplanting date when compared to BRRI dhan39. This variation may be obtained due to genetic/varietal traits as BR11 is high yield compared to BRRI dhan39 [32].

Conclusion

The decreasing trend in the grain yield in delayed seeding might be associated with significantly lower number of productive tillers m⁻², less number of filled grains/panicle and low 1000-grain weight. Highest paddy yields were obtained in early sown rice variety whereas declining yields were produced as seeding date was delayed. Our study showed that the early transplanting dates resulted in increase of plant height, panicle length, number of panicles/m², number of tillers/plant⁻¹, number of filled grains/panicle, 1000 grains weight, and grain yield. Based on this study, it can be concluded that 4th August is the optimum transplanting date for getting maximum grain yield irrespective of variety.

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Figure legend

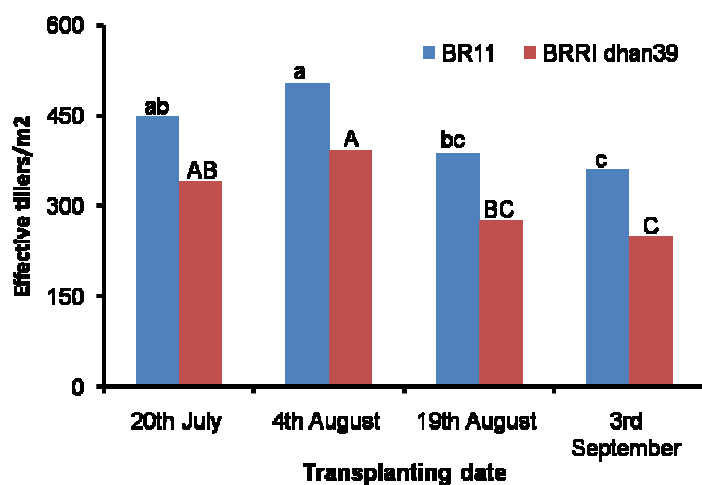


Fig. 1 Effect of transplanting date on the productive tillers of rice plant in different rice varieties. The mean bearing the different letters represent significant difference at 5% level.

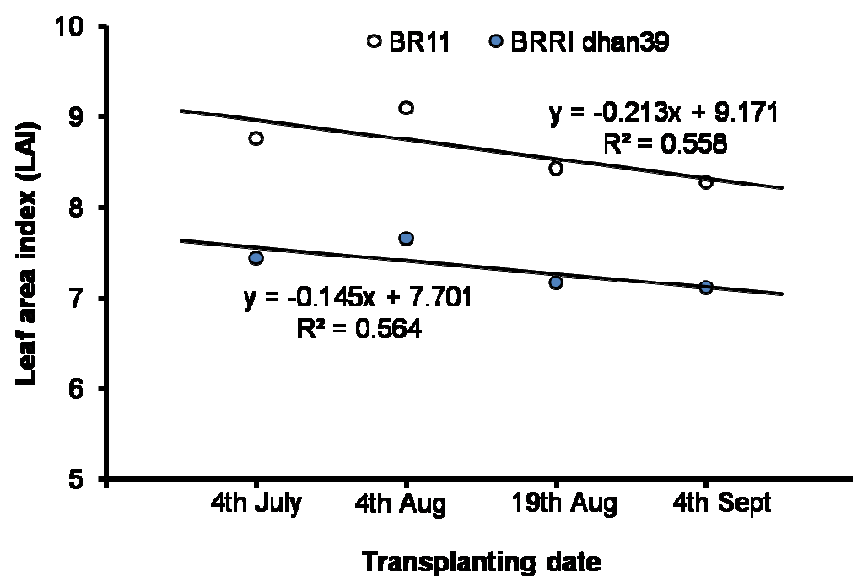
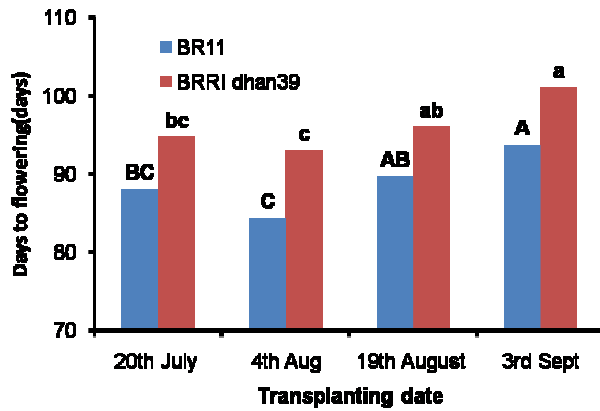
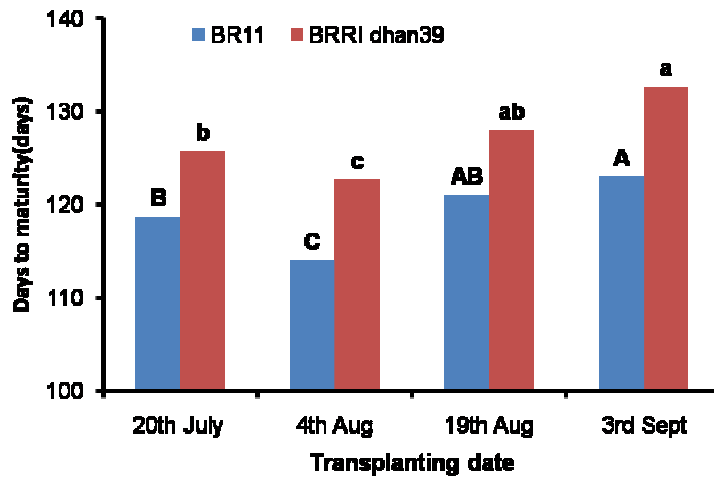


Fig. 2 Effect of transplanting date on leaf area index (LAI) in different rice varieties during T. Aman season.



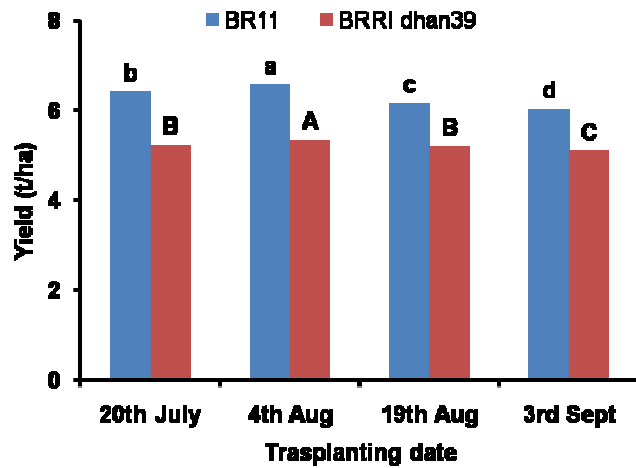
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360 Fig. 3 Effect of transplanting date on days to flowering in different rice varieties during T.
 361 Aman season. The mean bearing the different letters represent significant difference at 5%
 362 level.



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364 Fig. 4 Effect of transplanting date on days to maturity in different rice varieties during T.
 365 Aman season. The mean bearing the different letters represent significant difference at 5%
 366 level. Capital letters indicate the significant difference among the transplanting date on BR11
 367 and small letters indicate the significant difference among the transplanting date on BRR1
 368 dhan39.



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Fig. 5 Effect of transplanting date on grain yield in different rice varieties during T. Aman season. The mean bearing the different letters represent significant difference at 5% level.

Supplementary figure legend

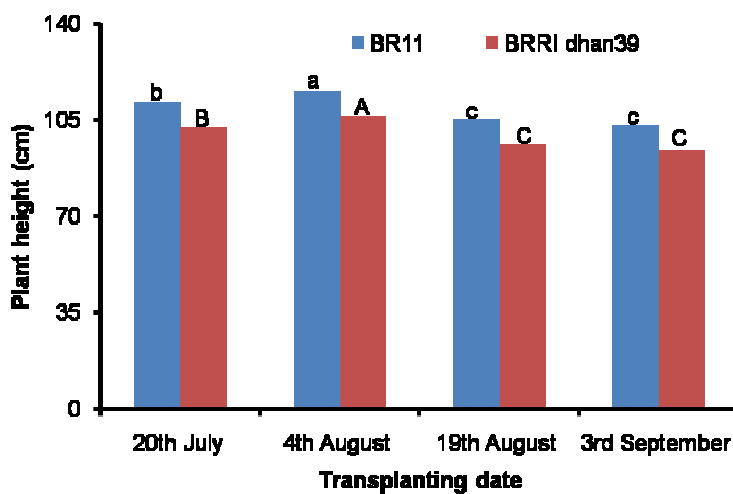
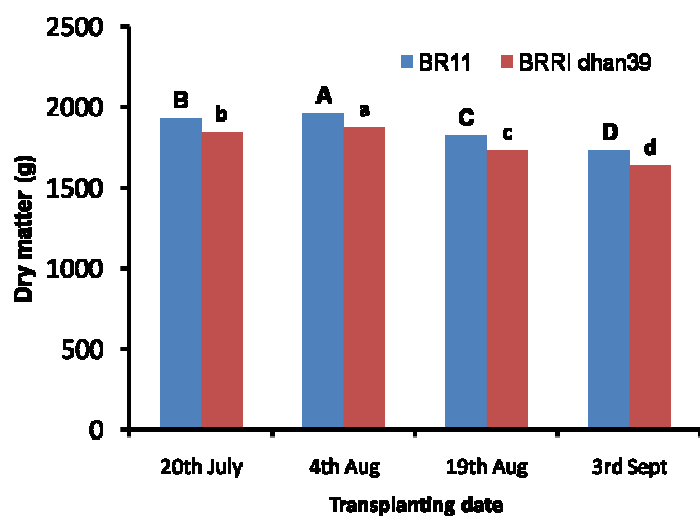


Fig. S1 Effect of transplanting date on plant height in different rice varieties during T. Aman season. The mean bearing the different letters represent significant difference at 5% level.

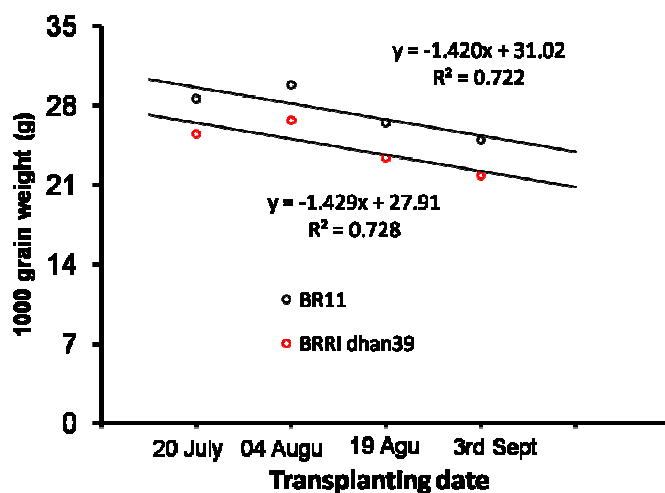
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385 Fig. S2 Effect of transplanting date on dry matter accumulation in different rice varieties
 386 during T. Aman season. The mean bearing the different letters represent significant difference
 387 at 5% level.

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390 Fig.S3 Effect of transplanting date on 1000 grains weight in two rice varieties during T.
 391 Aman season.

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Supplementary information Table

Table 1: Effect of transplanting dates and varieties on filled and unfilled grains panicle⁻¹

Transplanting date	Grains/panicle		Panicle length (cm)		Filled grain/panicle	
	BR11	BRR1 dhan39	BR11	BRR1 dhan39	BR11	BRR1 dhan3
20 th July	282b	250	28b	26	235b	212
4 th August	297a	263	28a	25	245a	220
19 th August	272bc	236	27c	26	230bc	205
3 rd September	261c	220	27d	26	227c	194
F value	603.43	48.88	28.21	NS	34.25	62.95
P value	<0.001	<0.001	<0.001		<0.001	<0.001

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