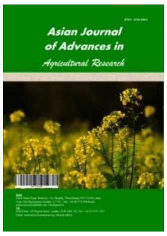

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Yield Response of Short Duration HYV Aman Rice to Transplanting Times in the Coastal Region of Southwestern Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Transplanted (T.) aman rice is the major crop in the southwestern coastal region of Bangladesh where most of the fields remain fallow the rest of the year due to the cultivation of late-maturing and long-duration aman rice varieties with low yield potential. Timely transplanting of short-duration HYV varieties increased grain yield and allowed the field to be cleared earlier for the next crop. The experiment was conducted in the experimental field of Agrotechnology Discipline, Khulna University, Khulna during the monsoon (June to December) for investigating the influence of transplanting dates on growth, yield attributes, and yield of Binadhan-7. The experiment was laid out in a randomized complete block design and replicated thrice. The experimental treatment comprised of ten transplanting dates (*viz.,*9 July, 16 July, 23 July, 30 July, 6 August, 13 August, 20 August, 27 August, 3 September, and 10 September) at 7 days intervals. Data recorded on different growth, yield, and yield contributing parameters were influenced substantially by the dates of transplanting. Results of this study showed that transplanting on 30 July produced the tallest plant (105.40 cm), highest tiller hill^{-1} (20.40), effective tillers hill^{-1} (17.30), panicle length (22.22 cm), number of grain panicle^{-1} (10.34), 1000 grain weight (22.83 g), grain yield (4.72 tha^{-1}), straw yield

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(5.15 tha^{-1}) and harvest index (47.85%) which were on parity with 6 August of transplanting. From the findings of this study, it can be concluded that from 30 July to 6 of August is optimum and recommended transplanting window for the short duration aman rice variety (Binadhan-7) in the coastal zone of southwestern Bangladesh. Furthermore, this transplanting window resulted in an early harvest and timely vacant the field for winter crop planting.

Keywords: Transplanting dates; Binadhan-7; short duration; yield and Southwestern coastal Bangladesh.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than three billion people, which is over half of the world's total population [1]. It is grown in more than a hundred countries across the world with an area and production of 160 million hectares and 700 million tons in a year, respectively [2]. In Bangladesh, about 80% of the total lands are used for rice cultivation. Rice is grown in three seasons (Aus, Aman, and Boro) in the country, however, the transplanted aman season (July to December) fully depends on rainfed conditions. In Bangladesh, among the rice-growing seasons, in the aman season rice suffers from high temperature from early growth stages to maturity. [3]. Aman rice occupies ~48.7% of total rice-growing areas of which modern varieties of T. aman cover ~81% of rice-growing area in the aman season [4]. The average productivity of rice in Bangladesh is 3.21 t ha^{-1}, where the average production of aman rice is 2.55 t ha^{-1}, which is much lower than other rice-growing countries [4]. The average production of local transplanted aman rice and high yielding varieties in 1.47 t ha^{-1} and 2.83 t ha^{-1}, respectively [4].

Among the agronomic practices, sowing time is very crucial and greatly influences the crop duration and yield. Transplanting rice at the optimum time is critical to achieving a high grain yield, while with the delay in transplanting accumulation and transportation of N, accumulation of dry matter declined due to the shorter growth period and finally reduced grain yield [5]. However, optimum rice transplanting dates are regional and vary with location, genotypes, and other factors [6]. Bruns and Abbas [7] reported that rice plants require a particular temperature for phenological events such as panicle initiation, flowering, and physiological maturity. The proper time of transplanting allows the crop to complete its life cycle timely and successfully under a specific agroecology [6]. Transplanting at an earlier date significantly influences important yield attributes such as the maximum number of tillers, number of tillers per m^2, plant height, 1000-grain weight, and grain yield [8]. Crop duration generally depends on dates of transplanting as rice varieties grown in the aman season are mostly photoperiod-sensitive and influenced by daily sunshine hours. Early transplanted rice varieties pass a longer lag vegetative phase which increases tallness as well as biomass and are prone to lodging during the grain filling stage. On the other hand, late transplanted plants get less time for vegetative and reproductive growth, mature earlier, and finally, have a lower yield. Thus, by adjusting the transplanting time, the plants can take advantage of natural conditions favorable for growth and yield. Though the optimum transplanting time of T. aman rice is in August, it is sometimes delayed due to various physical and socio-economic factors [9]. Late transplanting exposes the reproductive phase as well as phenological events of the crop to an unfavorable temperature, resulting poor growth, yield attributes, and yield.

In the southwestern region of Bangladesh, farmers mostly cultivate long-duration and late-maturing local aman rice varieties. In general, the transplanting time in this area is from mid-August to mid-September. Short-duration T. aman rice can also create an opportunity to facilitate winter crops cultivation at the right time, which can contribute significantly to achieving the twin objectives of increasing productivity and enhancing the cropping intensity in this region [10]. The yield potential of short-duration aman rice varieties was comparatively higher than the average yield of aman rice or existing local varieties. Thus, cultivation of short duration HYV improved productivity and additionally, vacant the land earlier thereby providing an opportunity to plant more crops in a year.

Different researchers conducted experiments using dates of transplanting to check the temperature regimes and rainfall frequency throughout the growth periods in T. aman season using different rice varieties [11]. They concluded from their findings that plants in the delayed transplanting coincided reproductive phase with temperature stress. Transplanting at an earlier date is always impractical due to the existing cropping system, weather conditions, and socioeconomic situations, whereas delayed transplanting reduces crop growth and yield due to the contrasting temperature and rainfall pattern during the growing season. Therefore, the field experiment was conducted to evaluate the time of transplanting on growth, phenology, yield attributes, and yield of short duration aman rice (Binadhan-7) in the coastal region of southwestern Bangladesh.

2. MATERIALS AND METHODS

2.1 Details of the Experimental Site

The experiment was conducted from June to November 2017 at the experimental field (22°48′07″ N and 89°31′59″ E) of Agrotechnology Discipline, Khulna University, Khulna. The soil texture was clay loam, with soil pH ranging from 6.5 to 7.0 and organic matter content of 1.73%. The experimental area was flat, had available irrigation and drainage systems, and was above flood level. The selected plot was medium-high land. The minimum and maximum temperature ranged from 16.1 to 26.9°C and 26.5 to 33.5°C, respectively. The total rainfall that occurred during the growth season (June-November) was 262 mm (Fig. 1).

2.2 Experimental Details and Crop Management

The experiment was laid out in a randomized complete block design and replicated thrice. The experiment consisted of ten transplanting dates (*viz,* 9 July, 16 July, 23 July, 30 July, 6 August, 13 August, 20 August, 27 August, 3 September, and 10 September) as treatment. The unit plot size was 12 m^2, maintaining a distance of 1.0 m and 0.75 m between block to block and plot to plot, respectively. Binadhan-7 high yielding rice variety was used as plant material in this research.

The seedbed was prepared with repeated plowing, cross plowing and laddering until a fine soft bed was attained for each sowing date. Sprouted seeds were sown manually on the seedbed as per the treatment. The main field was prepared by plowing, and cross plowing followed by laddering. The field was kept free from weeds and stubbles before transplanting. 21-days old seedlings were uprooted carefully

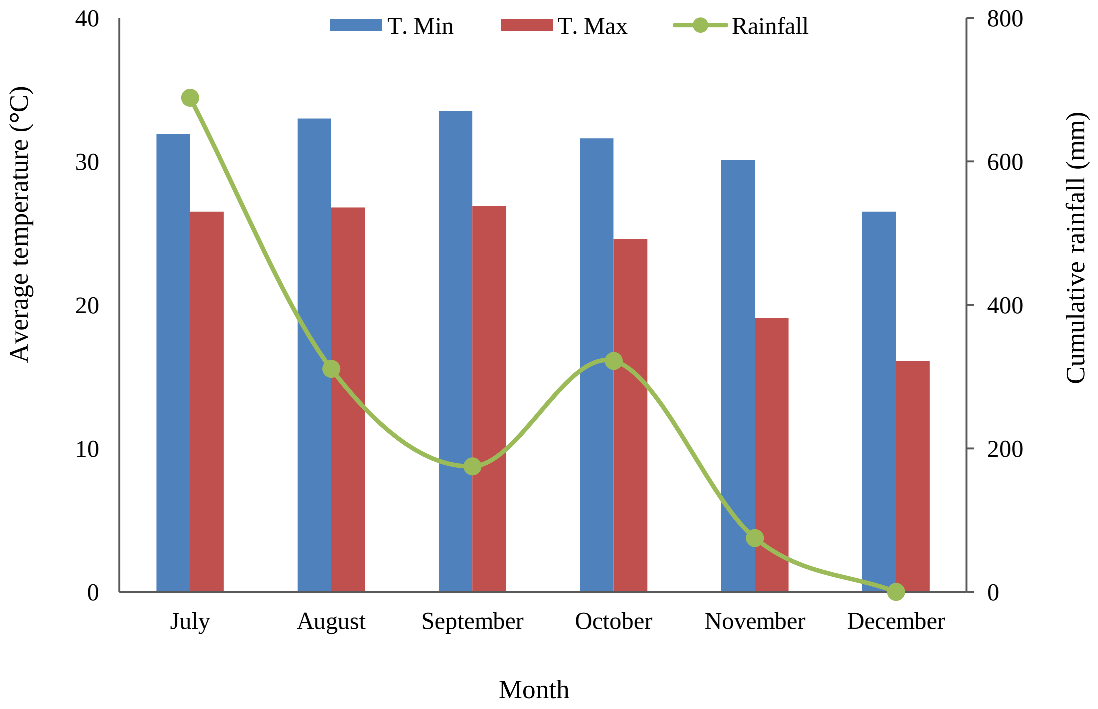

Fig. 1. Temperature and rainfall pattern during the growing season in the study area

and transplanted to the main field keeping 4 seedlings hill^{-1} at a spacing of 25 cm x 15 cm. Urea (170 kg ha^{-1}), TSP (100 kg ha^{-1}), MoP (100 kg ha^{-1}), Gypsum (60 kg ha^{-1}), and Zinc Sulphate (5 kg ha^{-1}) were used as the source of N, P, K, S, and Zn, respectively. All the fertilizers except urea were applied (the basal dose) 7 days before final land preparation. The urea was applied in three equal splits at 10 DAT, 30 DAT, and 45 DAT. Gap filling, weeding, and plant protection measures were taken as and when necessary and kept similar to all the plots. The crops were harvested at full maturity when 80-90% of the grains turned golden yellow in color.

2.3 Sampling and Data Collection

For the measurement of plant height, tiller number hill^{-1}, effective tiller hill^{-1}, panicle length, grain panicle^{-1}, 1000 grain weight, and harvest index, five hills were randomly selected from each plot, avoiding the borderline. Data on days to panicle initial, flowering, and physiological maturity was recorded. For the measurement of grain yield and straw yield, a 1 m^2 area was randomly selected from the center of the plot. The grain and straw from the selected area were sundried for 3-4 days to a constant moisture content (11-12%) and measured the weight afterward calculated the yield in t ha^{-1}. The harvest index was then calculated by the following equation:

$$\text{Harvest index (\%)} = \frac{Grain\ yield\ (kg/ha)}{Biological\ yield\ (kg/ha)} \times 100$$

2.4 Statistical Analysis

All the recorded data were compiled and statistically analyzed following the analysis of variance technique (One-way ANOVA) using the statistical package ‘Statistix-10’.The treatment means were separated using Duncan’s New Multiple Range Test (Gomez and Gomez, 1984) at a 95% confidence level.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Growth parameters were significantly affected by the time of transplanting (Table 01). The tallest plant (105.40 cm) and highest tiller hill^{-1} (20.80) were obtained from the 30 July transplanting, which was on parity with the transplanting on the 6 and 13 August, while the lowest plant height and tiller hill^{-1} were obtained from the 10 September transplanting. Both at earlier and delayed transplanting, plant growth and tillering capacity were relatively lower than 30 July to 6 August of transplanting but the reduction trend was more prominent in the delayed sowing. The results of this study are in agreement with the findings of Bashir et al. [6] and Kabir et al. [12], who noted that plant growth parameters were substantially varied with the dates of transplanting.

3.2 Phenological Parameters

Analysis of variance indicated that transplanting times had a significant influence on days to panicle initial and flowering (Fig. 2). Earlier transplanting (9 July) requires maximum time to panicle initiation (54 days) and flowering (71 days), while delayed transplanting (10 September) requires a minimum time (30 days and 46 days for panicle initiation and flowering, respectively). From the dates to transplanting, days to panicle initiation and flowering were steadily declined with the delayed of transplanting. Similarly, the physiological maturity duration of the crop was significantly decreased in the later transplant (Fig. 03). Crop physiological maturity duration was longer on 9 July transplanting (116 days), which was statistically comparable to 16 July transplanting, while 10 September transplanting had the shortest duration (80 days). Panicle initiation and flowering were late in the earlier sowing, while in the delayed sowing these were earlier. Dixit et al. [13] and Waniet al. [14] noted that panicle initiation, flowering, and crop maturity were significantly varied with the dates of transplanting. The crop matured later in the earlier transplanting due to the longer vegetative and reproductive growth but in the delayed of transplanting crop matured earlier due to the shorter growth phase. Similar findings are also reported by Biswas et al. [15] that crop maturity duration is steadily reduced with the delay of transplanting.

3.3 Yield Attributes

Analysis of variance indicated that 30 July transplanting produced a significantly higher number of effective tiller hill^{-1} (17.30), which was statistically identical to the transplanting dates of 6 August, 13 August and 23 July while the minimum (12.40) was recorded from 10 September transplanting (Table 01). With the delayed of transplanting effective tiller hill^{-1} was reduced. The results of this study are corroborated with the findings of Mahmud et al. [16] that effective tiller m^{-2} has steadily declined with later sowing.

Panicle length and the number of grain $panicle^{-1}$ differed significantly among the dates of transplanting (Table 01). The highest panicle length (22.22 cm) and grain $panicle^{-1}$ (106.34) were obtained from 30 July transplanting, which was in similarity with 23 July, 6 August and 13 August transplanting whereas the lowest was obtained from 10 September transplanting. The results are in accordance with the finding of Jalil et al. [17] that panicle length was comparatively shorter in the earlier transplanting and later sowing rather than 30 July transplanting.

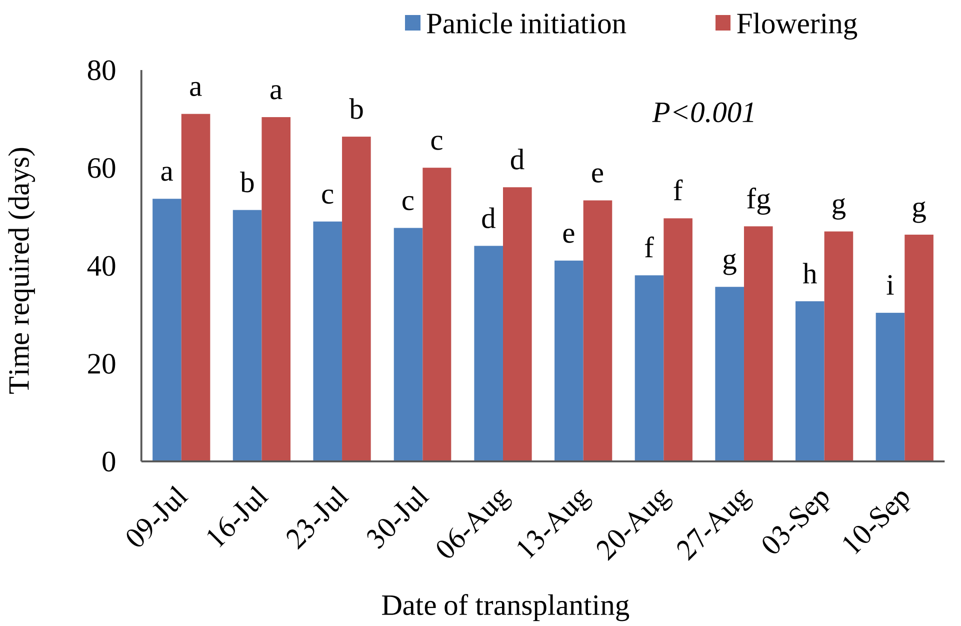

Fig. 2. Effect of transplanting dates on panicle initiation and flowering of aman rice (Binadhan-7) grown in the coastal region of southwestern Bangladesh

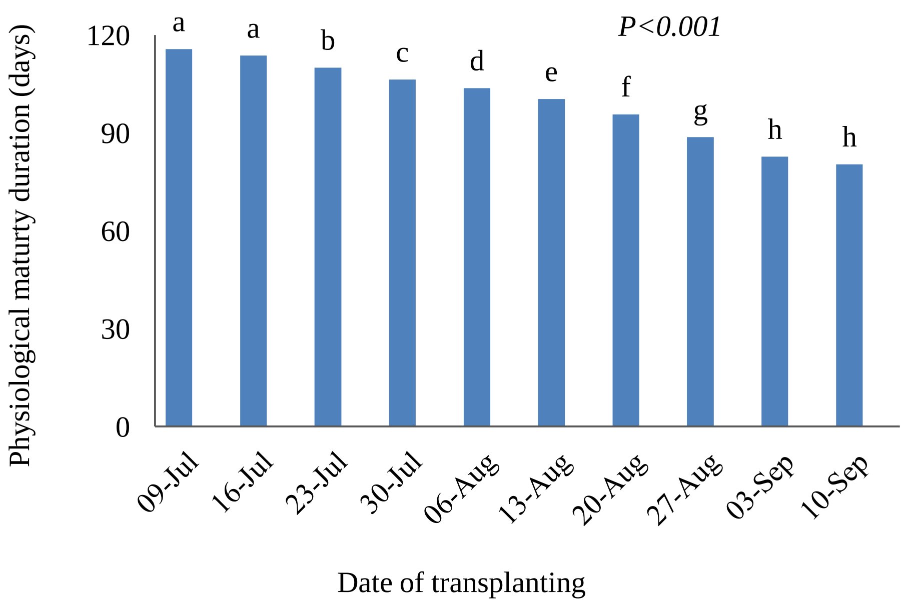

Fig. 3. Effect of transplanting dates on physiological maturity of aman rice (Binadhan-7) grown in the coastal region of southwestern Bangladesh

Transplanting dates had a significant effect on grain weight panicle^{-1} and thousand-grain weight (Table 01). 30 July transplanting resulted in the higher grain weight panicle^{-1} (1.80 g) and thousand-grain weight (22.83 g), which was on parity with the transplanting dates of 6 August, while the lower was measured from 10 September transplanting. Yield attributes were significantly reduced with the delay of sowing [18].

3.4 Yield

Data in Fig. 4 represented that grain yield of rice was significantly higher (4.72 t ha^{-1}) in 30 July transplanting, which was on an equality with 6 August of transplanting while the lower grain yield (3.22 t ha^{-1}) was obtained from the 10 September transplanting. Grain yield significantly decreased with the earlier and later transplanting but the rate of reduction was comparatively minimum (6-17%) in the earlier transplanting than later transplanting (8-31%), over 30 July to 6 August transplanting window. This might be was attributed due to the higher yield attributes such as panicle length, number of grain panicle^{-1}, grain weight panicle^{-1} and 1000 grain weight. The grain yield of rice is closely related to the number of grain panicle^{-1}, grain weight panicle$^{-1,}$ and thousand-grain weight. The grain yield in the later transplants steadily declined due to the shorter growth period due to the reduced number of grain panicle^{-1} and grain size [6] that might be the key responsible factors for reducing grain yield [19]. The results are in agreement with the findings of Al-Amim et al. [20], who reported that both at the earlier and delayed sowing grain yields were lower. The reduction in grain yield with the delayed sowing is noticed by Chandini et al. [21] and Satapathy et al. [22].

Similar to grain yield, straw yield significantly differed with the dates of transplanting (Fig. 4). The highest straw yield (5.15 t ha^{-1}) was found in 30 July transplanting which was statistically comparable to 6 August and 23 July transplanting, whereas the lowest (3.97 t ha^{-1}) was recorded from 10 September transplanting. The results of this study coincide with the findings of Salam et al. [23]. The vegetative growth period was longer in the early transplanted crop, leading to a higher accumulation of biomass, causing greater straw yield afterward reduced with the delay of transplanting time [24].

3.5 Harvest Index

The harvest index was significantly affected by the dates of transplanting (Table 1). 30 July transplanting resulted in the highest (47.85%) harvest index, which was in similarity with the earlier sowing from 9 July to 13 August, afterward decreased from 20 August and the lowest harvest index (44.75%) was obtained from 10 September transplanting. Shelley et al. [25] noted that the harvest index was significantly lower both in the very early and later transplanting than 30 July to 15August transplanting window.

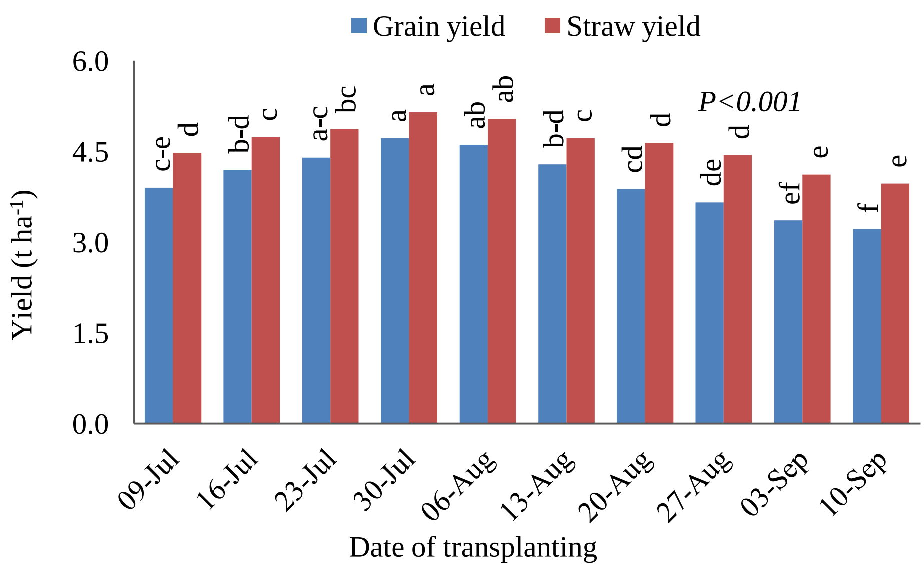

Fig. 4. Effect of transplanting dates on grain and straw yield of aman rice (Binadhan-7) grown in the coastal region of southwestern Bangladesh

Table 1. Effect of transplanting date on yield components of Binadhan-7 grown in the coastal soil of southwestern Bangladesh

Transplanting dates	Plant height (cm)	Tiller hill^{-1}	Effective tiller hill^{-1}	Panicle length (cm)	No. of grain panicle^{-1}	Grain weight panicle^{-1}	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
July 09	86.27cd	18.07cd	14.27de	20.38df	85.67bc	1.16c-f	20.50de	8.38ef	46.58a-d
July 16	88.13cd	18.80b-d	15.40b-e	20.81c-e	92.89ab	1.35b-d	20.95cd	8.94c-e	46.95a-d
July 23	93.40bc	19.67a-c	16.13a-c	21.25a-d	96.44ab	1.56ab	21.61bc	9.27bc	47.43a-c
July 30	105.40a	20.80a	17.30a	22.22a	106.34a	1.80a	22.83a	9.87a	47.85a
August 06	102.60ab	20.40b	17.13ab	21.93ab	102.11a	1.73a	22.45ab	9.65ab	47.79ab
August 13	95.20a-c	19.13a-c	15.60a-d	21.57a-c	93.00ab	1.41bc	21.47c	9.01cd	47.58a-c
August 20	86.77cd	18.73b-d	15.33c-e	20.91b-e	85.89bc	1.30b-e	20.99cd	8.52d-f	45.48b-d
August 27	82.03de	17.33d	14.40c-e	20.07e-g	78.00cd	1.10d-f	19.91e	8.10f	45.26cd
September 03	79de	15.27e	13.80ef	19.43fg	73.22cd	1.006ef	18.93f	7.48g	44.92d
September 10	74.98e	13.73e	12.40f	19.02g	69.11d	0.93f	18.36f	7.19g	44.75d
SE (±)	*5.12*	*0.81*	*0.85*	*0.51*	*6.88*	*0.13*	*0.43*	*0.28*	*1.11*
LS	**	**	**	**	**	**	**	**	**
CV (%)	*7.01*	*5.45*	*6.85*	*3.00*	*9.54*	*12.01*	*2.54*	*3.91*	*2.92*

In a column, same letter indicate statistically similar and different letter indicate statistically dissimilar results among the treatments
*** = Significant at 1% level of significance; LS = Level of significance; CV = Coefficient of variation*

3.6 Functional Relationship between Transplanting Dates and Grain Yield

Data in Fig. 5 has been shown a polynomial relationship between transplanting dates and grain yield. From the equation, it was clear that 88.7% of the variability of grain yield could be explained by the equation of $y = -0.0009x^2 + 79.782x - 2E+06$ with the advancement of transplanting time. Mannan et al. [24] explain and report a similar type of relationship in which grain yield was lower when transplanting was done earlier or later.

3.7 Functional Relationship between 1000 Grain Weight and Grain Yield

The functional linear relationship between 1000 grain weight and grain yield has been presented in Fig. 6 revealed that grain yield was significantly dependent on 1000 grain weight. The grain yield of rice increased from 3.22 to 4.72 t ha^{-1} with the increase of 1000 grain weight from 18.36 to 22.83 g. The effect of 1000 grain weight on grain yield could be explained at 96.7% with the equation of $y = 0.3504x - 3.2643$.

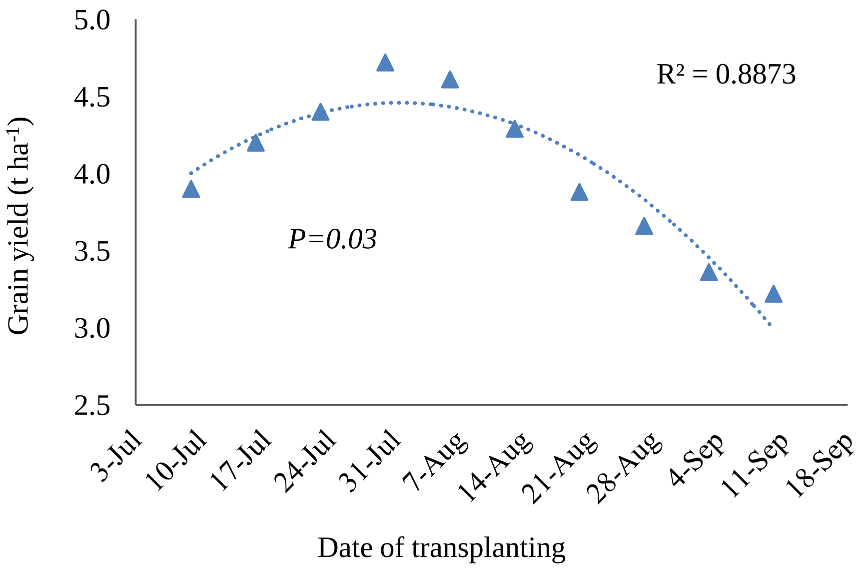

Fig. 5. Functional relationship between transplanting dates and grain yield of aman rice (Binadhan-7)

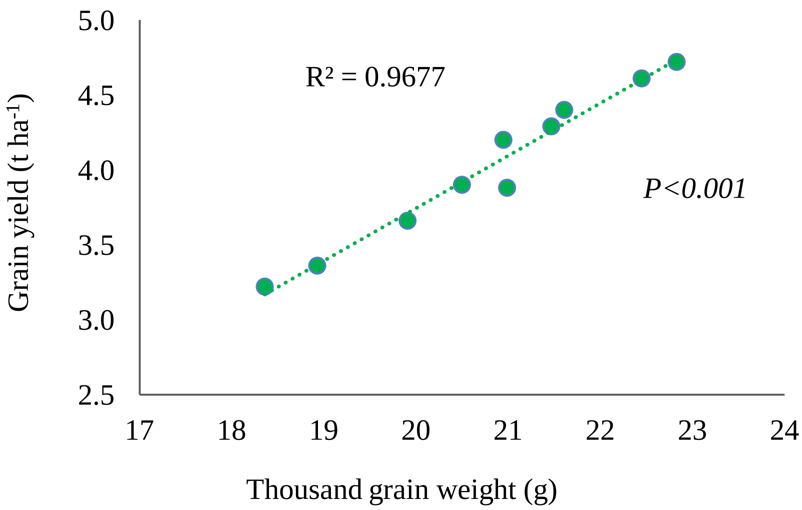

Fig. 6. Functional relationship between thousand-grain weight and grain yield of aman rice (Binadhan-7)

4. CONCLUSION

The growth, phenology, yield attributes, and yield of short duration aman rice variety (Binadhan-7) were substantially influenced by the dates of transplanting. Very early transplanting and late transplanting significantly reduced the seed yield. The transplanting window from 30 July to 6 August produced ~4-45% higher grain yield than other transplanting dates and also vacant the field in right time to use the land for the sowing of next winter crops. From the findings of this study, it could be suggested that from 30 July to 6 August is the suitable transplanting window for short duration HYV aman rice variety (Binadhan-7) in the coastal zone of southwestern Bangladesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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