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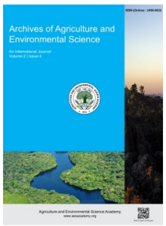

ORIGINAL RESEARCH ARTICLE

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Growth analysis of short duration transplanted *Aus* rice (cv. Parija) under three agronomic practices

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to investigate the growth of short duration transplanted *Aus* rice (cv. Parija) under three agronomic practices. The study comprised of two nursery seeding densities *viz.* 40 and 80 g seeds m^{-2}, three ages of seedlings viz. 20, 30 and 40-day old, and three levels of seedlings $hill^{-1}$ *viz.* 2, 4 and 6 seedlings $hill^{-1}$. The experiment was laid out in a Randomized Complete Block Design with three replications. For individual treatment effects, the highest plant height, number of tillers $hill^{-1}$, total dry matter, leaf area index and crop growth rate were found when seedlings were raised @ 40g seed m^{-2} and 30-day old seedlings were transplanted @4 seedlings $hill^{-1}$. In interaction, the highest number of tillers $hill^{-1}$ (13.00) and total dry matter (22.93 g) at 45 DAT, and crop growth rate (6.71 g m^{-2} day^{-1}) at 15-30 DAT were obtained from the interaction among 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings $hill^{-1}$. On the other hand, the tallest plant (73.27 cm) at 45 DAT was found from the interaction among 80 g seed m^{-2} × 30-day old seedlings × 4 seedlings $hill^{-1}$, while the highest leaf area index (2.87) was recorded from the interaction of 40 g seed m^{-2} × 30-day old seedlings × 2 seedlings $hill^{-1}$ at 50 DAT. Considering both the significant individual and interaction treatment effects on the growth parameters, the use of 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings $hill^{-1}$ could improve the growth performance of short duration transplanted *Aus* rice (cv. Parija). Therefore, a nursery seeding density of 40 g seed m^{-2} and 30-day old seedlings transplanting with 4 seedlings $hill^{-1}$ appears as the promising combination in respect of growth performance of short duration transplanted *Aus* rice (cv. Parija).

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INTRODUCTION

Bangladesh is an agrarian country, where rice (*Oryza sativa* L.) is consumed as the staple food and it constitutes a major part of human diet (Barua *et al*., 2014). Rice production in *Aus*, *Aman*, *Boro* seasons are 2.76, 14.20, and 19.65 million tons from 1.10, 5.56, and 4.76 million hectares of land in Bangladesh, respectively (BBS, 2020). Usually, the farmers of Bangladesh complete their *Boro* rice harvesting in April–May and start the cultivation of *Aman* rice on the same land at the end of July causing the land remain fallow and uncultivated for two months and a half in between *Boro* and *Aman* rice (Sarkar *et al*., 2021 and Paul *et al*., 2018). Parija, a short duration indigenous local *Aus* rice variety, cultivated as completely off-season in between late May and mid-August. If the farmers cultivate the Parija on their fallow land at minimum cost in between the *Boro* and *Aman* season, they could get additional rice and be benefited economically (Paul *et al*., 2018).

Growth performance and yield of rice plant depends on different agronomic practices. Among the different approaches of agronomic packages, the seeding densities, age of seedling and number of seedlings hill^{-1} are one of the most important factors which influence the growth, development and yield of rice plant. Growth, yield and yield contributing characters of rice plants are affected adversely at higher seed rate at the nursery bed, but the productivity increases when a lower seeding rate is used in the nursery bed (Singh *et al*., 1987). Age of seedling is an important aspect for uniform stand of rice population (Paddalia, 1980) as it has tremendous influence on plant height, tiller production, panicle length, grains per panicle and other yield contributing characters of some short-duration T. *Aus* rice varieties (BINA, 2007; BRRI, 2019). Due to prolonged stay of the rice seedlings at the nursery bed, primary tiller buds on the lower nodes of the main culm become degenerated resulting a fewer number of tiller hill^{-1} of rice plant (Mobasser *et al*., 2007). Again, early transplanting with younger seedlings facilitates better vegetative growth with low phyllochron interval, and this phyllochron allows a greater number of tillers production hill^{-1} of rice plant under favorable growing conditions (Singh *et al*., 2007). So, age of seedling plays an important role in tillering and growth when transplanted in time in terms of age but late transplanting leads to a fewer number of tillers hill^{-1} during plant growth (Mobasser *et al*., 2007).

Number of seedling hill^{-1} is another important factor which can play an important role in boosting growth of rice. It acts as a key factor for successful rice production as it influences the tiller number in the rice field (Bhowmik *et al*., 2012). Again, optimum number of seedling hill^{-1} influences the solar radiation interception, nutrient and water uptake, photosynthesis rate and other physiological processes which ultimately affect the growth and development of rice plant (Paudel *et al*., 2021 and Imran *et al*., 2015). Information regarding the growth analysis of local *Aus* rice in response to nursery bed seeding density, seedling age and number of seedling hill^{-1} are scare. Therefore, the present study was undertaken to find out the suitable nursery seeding density, age of seedling and number of seedling hill^{-1} for better growth analysis of short duration transplant *Aus* rice (cv. Parija).

MATERIALS AND METHODS

Experimental site and design

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the effect of nursery seeding density, age of seedlings and number of seedlings hill^{-1} on the growth of short duration transplanted *Aus* rice (cv. Parija). The experimental site is located at 24° 75' N latitude and 90° 50' E longitude having an altitude of 18m belonging to the Old Brahmaputra Floodplain Agroecological Zone (AEZ-9) having non-calcareous dark grey floodplain soils (UNDP and FAO, 1998). The land was medium high having sandy loam texture with low organic matter content (0.93%) and the pH 6.8, nitrogen, phosphorus (P_2O_5) and potassium of the soil ranged from 0.13%, 16.3 ppm and 0.28%, respectively (Chakraborty *et al*., 2020). The study consisted of two seeding densities viz. 40, 80 g m^{-2}, three ages of seedlings viz. 20, 30 and 40-day old and three levels of seedlings hill^{-1} viz. 2, 4 and 6 seedlings hill^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications and the size of each unit plot was 4.0 m × 2.5 m.

Crop husbandry

A local variety of *Aus* rice cv. Parija (short duration) was used as the test crop in the study. On 26 March, 5 April and 15 April, sprouted seeds were broadcasted uniformly in a well-prepared nursery bed. The experimental land was first opened with a tractor driven disc plough followed by repeated ploughing and cross ploughing with a country plough and then leveled using a ladder. Weeds and stubbles were removed from the field and plots were leveled properly. The experimental plots were laid out on 7 May and as per experimental specification. 20, 30 and 40-day old seedlings were transplanted on 8 May with 20 cm × 15 cm spacing using specified seedlings hill^{-1}. At the time of final land preparation, full dose of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at the rate of 90, 60, 38 and 8 kg ha^{-1}, respectively. Nitrogen fertilizer in the form of urea was applied in two equal splits at 10 and 30 days after transplanting (DAT). Irrigations and intercultural operations were done as and when necessary.

Data collection

To collect data on plant height and tiller number, five hills were marked by bamboo stick excluding boarder rows, and for leaf area index five hills were destructed every sampling dates. Data on crop growth parameters *viz*., plant height and number of tillers hill^{-1} were taken at 15, 30, 45 and 60 DAT, and data on leaf area index was taken at 20, 35, 50 and 65 DAT. An automatic leaf area meter (Type AAN-7, Hayashi Dam Ko Co., Japan) was used for measuring leaf area index. Leaf area index was calculated as the ratio of total surface area of leaves and its ground area as described by Hunt (1978).

$$LAI = LA/P$$

Where,

LAI = Leaf area index

LA = Total leaf area of the leaves of all the sampled plants (cm^2)

P = Area of the ground surface covered by the plant (cm^2)

To determine the total dry matter of plant, five hills were taken excluding boarder rows at 15, 30, 45 and 60 DAT. Then, the roots of each plant were removed and washed with tap water. The plant samples were then packed separately in labeled brown paper packets and placed in an electric oven at 85±5°C for 72 hours until constant weight was reached. Afterwards, the samples were weighed by using an electric balance after oven drying to have the total dry matter of plant.

Crop growth rate refers to the rate of plant's total dry matter production per unit of ground area per unit of time and it was calculated with the following formula as prescribed by Watson (1956):

$$CGR = \frac{1}{A} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2}\text{day}^{-1}$$

Where,

W_1 = dry matter production at T_1 time

W_2 = dry matter production at T_2 time

A= ground area (m^2)

Statistical analysis

Data on different parameters were statistically analyzed and tabulated in proper form using the "Analysis of Variance" technique with the help of computer package MSTAT and the mean differences among the treatments were adjudged with Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height

Plant height was significantly influenced by nursery seeding density, age of seedlings and number of seedlings hill^{-1} at different days after transplanting (Table 1). Results showed that low seeding density (40 g seed m^{-2}) produced the taller plants (36.64, 51.13 and 67.36 cm) at 15, 30 and 45 DAT, respectively than that of the higher seeding density (80 g seed m^{-2}). Higher seedling density with insufficient amount of fertilizer application in nursery bed significantly reduced the plant height of rice in a study by Sarwar *et al.* (2011). Low seedling age (20-day) produced the tallest plant (36.26 cm) at 15 DAT while moderate seedling age (30-day) produced the tallest plant (67.35 cm) at 45 DAT. Islam *et al.* (2021) documented that proper age of seedlings had helped rice plants to complete its vegetative phase in favorable climatic conditions resulting in tallest plant. Again, 4 seedlings hill^{-1} produced the tallest plant (36.58, 52.72, 69.81 and 74.49 cm, respectively) at 15, 30, 45 and 60 DAT, respectively. Transplanting with 4 seedlings hill^{-1} resulted in the vigorous stem elongation compared to that of other number of seedlings hill^{-1}. Such variations in plant height due to number of seedlings hill^{-1} was also reported by Khan *et al.* (2015).

Table 2 showed significant effect of interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} on plant height at 15 DAT and 45 DAT. At 15 DAT, the tallest plant (43.62 cm) was found in 40 g seed m^{-2} × 20-day old seedlings × 4 seedlings hill^{-1} which was at par with 40 g seed m^{-2} × 20-day old seedlings × 6 seedlings hill^{-1}, 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1} and 80 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1}, while the shortest plant (27.49 cm) was found in 80 g seed m^{-2} × 20-day old seedlings × 6 seedlings hill^{-1}. Again, at 45 DAT, the interaction 80 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1} produced the tallest plant (73.27 cm) which was statistically identical to 80 g seed m^{-2} × 20-day old seedlings × 4 seedlings hill^{-1}, 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1}, 40 g seed m^{-2} × 20-day old seedlings × 6 seedlings hill^{-1} and 40 g seed m^{-2} × 20-day old seedlings × 4 seedlings hill^{-1}, while the interaction 80 g seed m^{-2} × 40-day old seedlings × 2 seedlings hill^{-1} produced the shortest plant (55.11 cm). Plant growth characteristics *viz.* plant height usually depends on the utilization of the natural resources which was perhaps ensured by proper seedling age & density as well as seedlings number hill^{-1} in the study resulting in the improvement of plant stature. Sarkar *et al.* (2021) reported significant differences in plant height due to different plant densities of transplant *Aus* rice (cv. Parija). The variations in plant height of Parija rice due to various agronomic practice was also observed earlier by Roy *et al.* (2018).

Table 1. Effect of nursery seeding density, age of seedlings and number of seedlings hill^{-1} on plant height of short duration transplanted *Aus* rice (cv. Parija).

Treatments	Plant height (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
Seeding density				
D_1 (40 g m^{-2})	36.64a	51.13a	67.36a	72.62
D_2 (80 g m^{-2})	32.42b	48.98b	63.85b	71.73
CV(%)	5.44	5.72	3.12	3.63
Level of Significance	**	*	**	NS
Age of seedlings (days)				
A_1 (20)	36.26a	50.19	66.55ab	72.01b
A_2 (30)	35.23ab	51.24	67.35a	73.15a
A_3 (40)	32.10b	48.73	62.91b	71.38c
CV(%)	5.44	5.72	3.12	3.63
Level of Significance	**	NS	**	NS
Number of seedlings hill^{-1}				
H_1 (2)	33.86ab	48.57b	62.46c	70.89b
H_2 (4)	36.58a	52.72a	69.81a	74.49a
H_3 (6)	33.15b	48.86ab	64.54b	71.16b
CV(%)	5.44	5.72	3.12	3.63
Level of Significance	**	**	**	**

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

Table 2. Effect of interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} on plant height of short duration transplanted *Aus* rice (cv. Parija).

Interaction (Seeding density × age of seedling × number of seedlings hill^{-1})	Plant height (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
$D_1 \times A_1 \times H_1$	36.41b-f	51.27	66.49bc	72.18
$D_1 \times A_1 \times H_2$	43.62a	49.67	72.05a	74.08
$D_1 \times A_1 \times H_3$	40.77ab	55.00	68.88ab	70.77
$D_1 \times A_2 \times H_1$	38.22b-e	50.77	66.95bc	72.27
$D_1 \times A_2 \times H_2$	39.48abc	55.06	72.10a	79.86
$D_1 \times A_2 \times H_3$	35.31c-f	49.17	66.28bc	71.03
$D_1 \times A_3 \times H_1$	33.91def	51.73	63.00cd	69.80
$D_1 \times A_3 \times H_2$	31.15fg	48.67	65.50bc	71.67
$D_1 \times A_3 \times H_3$	30.93fg	48.80	65.00bcd	71.93
$D_2 \times A_1 \times H_1$	35.92b-f	47.27	62.93cd	73.00
$D_2 \times A_1 \times H_2$	33.34ef	52.87	72.33a	72.27
$D_2 \times A_1 \times H_3$	27.49g	45.07	56.60ef	69.73
$D_2 \times A_2 \times H_1$	27.71g	46.98	60.27de	71.97
$D_2 \times A_2 \times H_2$	39.01a-d	58.61	73.27a	74.84
$D_2 \times A_2 \times H_3$	31.66fg	46.87	65.27bcd	68.93
$D_2 \times A_3 \times H_1$	31.01fg	43.42	55.11f	66.11
$D_2 \times A_3 \times H_2$	32.89efg	51.47	63.60cd	74.21
$D_2 \times A_3 \times H_3$	32.71fg	48.27	65.23bcd	74.54
CV(%)	5.44	5.72	3.12	3.63
Level of Significance	**	NS	**	NS

In a column, values having the same letter or without letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

Table 3. Effect of nursery seeding density, age of seedlings and number of seedlings hill^{-1} on number of tillers hill^{-1} of short duration transplanted *Aus* rice (cv. Parija).

Treatments	Number of tillers hill^{-1}			
	15 DAT	30 DAT	45 DAT	60 DAT
Seeding density				
D_1 (40 g m^{-2})	7.41a	9.22a	10.89a	12.63a
D_2 (80 g m^{-2})	6.44b	8.37b	9.78b	11.52b
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	**	**	**	**
Age of seedlings (days)				
A_1 (20)	7.11a	8.94ab	10.61a	12.33a
A_2 (30)	7.17a	9.06a	10.56a	12.39a
A_3 (40)	6.50b	8.39b	9.83b	11.50b
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	*	*	*	**
Number of seedlings hill^{-1}				
H_1 (2)	6.83b	8.67	9.61c	10.94c
H_2 (4)	7.28a	9.11	11.11a	13.06a
H_3 (6)	6.67b	8.61	10.28b	12.22b
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	*	NS	**	**

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

Number of tillers hill^{-1}

Number of tillers hill^{-1} was significantly influenced by nursery seeding density, age of seedlings and number of seedlings hill^{-1} at different days after transplanting (Table 3). During the nursery management, low seeding density increased the number of total tiller hill^{-1} of Parija rice. Results showed that low seeding densities (40 g seed m^{-2}) produced the higher number of tillers hill^{-1} (7.41, 9.22, 10.89 and 12.63) at 15, 30, 45 and 60 DAT, respectively. Lower seeding density significantly favoured the number of effective tillers of rice plants as reported by Sarwar *et al.* (2011) and Thapa *et al.* (2019). Both the 20-day and 30-day old seedlings produced statistically highest number of tillers hill^{-1} at all the DATs. Older seedlings (40-day) had the poor tiller production behavior. Use of older age seedlings significantly affected the tillering pattern of the rice crop, and thus had the detrimental impacts on grain yield in a study by Liu *et al*., 2017. Again, 4 seedlings hill^{-1} produced the highest number of tillers hill^{-1} (7.28, 11.11 and 13.06) at 15, 45 and 60 DAT, respectively. Similar trends were observed by Baloch *et al*. (2006) who reported that the maximum tillers were noted with 4 seedlings hill^{-1} during both experimental years.

Interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} had statistically significant effect on number of tillers hill^{-1} at 15 DAT, 30 DAT and 45 DAT (Table 4). At 15 DAT, the maximum tillers hill^{-1} (9.33) was recorded in 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1} which was at par with 40 g seed m^{-2} × 20-day old seedlings × 2 seedlings hill^{-1} (8.33), while the minimum tillers hill^{-1} (5.00) was found in 80 g seed m^{-2} × 30-day old seedlings × 2 seedlings hill^{-1}. Again, at 30 DAT, the interaction 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1} produced the maximum number of tillers hill^{-1} (10.67) which was statistically identical to 40 g seed m^{-2} × 20-day old seedlings × 2 seedlings hill^{-1}, 40 g seed m^{-2} × 20-day old seedlings × 6 seedlings hill^{-1}, 40 g seed m^{-2} × 30-day old seedlings × 2 seedlings hill^{-1}, 40 g seed m^{-2} × 30-day old seedlings × 6 seedlings hill^{-1}, 80 g seed m^{-2} × 20-day old seedlings × 4 seedlings hill^{-1} and 80 g seed m^{-2} × 40-day old seedlings × 4 seedlings hill^{-1}, while the interaction 80 g seed m^{-2} × 30-day old seedlings × 2 seedlings hill^{-1} produced the lowest number of tillers hill^{-1} (7.00). At 45 DAT, the maximum tillers hill^{-1} (13.00) was recorded in 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1} followed by 40 g seed m^{-2} × 30-day old seedlings × 6 seedlings hill^{-1}, 40 g seed m^{-2} × 20-day old seedlings × 4 seedlings hill^{-1} and 80 g seed m^{-2} × 40-day old seedlings × 4 seedlings hill^{-1}, while the lowest number of tillers hill^{-1} (8.33) was found in 80 g seed m^{-2} × 30-day old seedlings × 2 seedlings hill^{-1} and 80 g seed m^{-2} × 40-day old seedlings × 2 seedlings hill^{-1}. The tiller production increased with the passage of time up to 60 DAT, however, the increasing trend was not statistically significant after 45 DAT. Singh *et al*. (2018) found the significant impact of seeding density on the growth performance of rice where Virk *et al*. (2020) reported that seedling age had influenced the growth pattern of rice plants greatly.

Total dry matter production

The total dry matter was significantly influenced by nursery seeding density, age of seedlings and number of seedlings hill^{-1} at different days after transplanting (Table 5). Results showed that low seeding density (40 g seed m^{-2}) produced the higher total dry matter (3.94, 10.04, 17.03 and 28.66 g) at 15, 30, 45 and 60 DAT, respectively. Seeding density governs canopy coverage, radiation interception and dry matter accumulation in a rice crop (Anwar *et al*., 2011). While moderate seedling age (30-day) produced the highest total dry matter (3.88, 10.38, 18.03 and 29.69 g) at 15, 30, 45 and 60 DAT, respectively. Delayed rice transplantation or older aged seedlings have been reported with short vegetative growth phase, and lower dry matter accumulation in rice plant (Liu *et al*., 2015). Transplanting with 4 seedlings hill^{-1} produced the highest total dry matter (4.38, 10.12, 17.29 and 28.47 g) at 15, 30, 45 and 60 DAT, respectively. Hasanuzzaman *et al*. (2009) observed significant differences in dry matter production in a rice cv. BRRI dhan46 due to variable number of seedlings hill^{-1} and reported that 4 seedlings hill^{-1} had produced the higher amount of dry matter. Use of excess seedling hill^{-1} resulted in intra plant competition among rice plants which ultimately decreased the total dry matter production.

Table 4. Effect of interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} on number of tillers hill^{-1} of short duration transplanted *Aus* rice (cv. Parija).

Interaction (Seeding density × age of seedling × number of seedlings hill^{-1})	Number of tillers hill^{-1}			
	15 DAT	30 DAT	45 DAT	60 DAT
$D_1 \times A_1 \times H_1$	8.33ab	9.67abc	10.67bcd	11.67
$D_1 \times A_1 \times H_2$	6.67c-f	8.67cde	11.33bc	13.33
$D_1 \times A_1 \times H_3$	7.33bcd	9.33abc	10.67bcd	12.67
$D_1 \times A_2 \times H_1$	8.00bc	10.33ab	11.00bc	12.00
$D_1 \times A_2 \times H_2$	9.33a	10.67a	13.00a	14.67
$D_1 \times A_2 \times H_3$	7.67bcd	9.33abc	11.67b	13.67
$D_1 \times A_3 \times H_1$	7.33bcd	9.00bcd	9.67d	11.67
$D_1 \times A_3 \times H_2$	5.67efg	7.67def	9.67d	11.67
$D_1 \times A_3 \times H_3$	6.33d-g	8.33c-f	10.33cd	12.33
$D_2 \times A_1 \times H_1$	7.00b-e	8.67cde	9.67d	11.00
$D_2 \times A_1 \times H_2$	7.67bcd	9.67abc	11.67b	13.67
$D_2 \times A_1 \times H_3$	5.67efg	7.67def	9.67d	11.67
$D_2 \times A_2 \times H_1$	5.00g	7.00f	8.33e	9.67
$D_2 \times A_2 \times H_2$	6.67c-f	8.67cde	9.67d	12.67
$D_2 \times A_2 \times H_3$	6.33d-g	8.33c-f	9.67d	11.67
$D_2 \times A_3 \times H_1$	5.33fg	7.33ef	8.33e	9.67
$D_2 \times A_3 \times H_2$	7.67bcd	9.33abc	11.33bc	12.33
$D_2 \times A_3 \times H_3$	6.67c-f	8.67cde	9.67d	11.33
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	**	*	*	NS

In a column, values having the same letter or without letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}

Table 5. Effect of nursery seeding density, age of seedlings and number of seedlings hill^{-1} on total dry matter (g hill^{-1}) of short duration transplanted *Aus* rice (cv. Parija).

Treatments	Total dry matter (g hill^{-1})			
	15 DAT	30 DAT	45 DAT	60 DAT
Seeding density				
D_1 (40 g m^{-2})	3.94a	10.04a	17.03a	28.66a
D_2 (80 g m^{-2})	2.36b	7.63b	14.73b	23.59b
CV(%)	9.69	16.96	11.72	9.7
Level of Significance	**	**	**	**
Age of seedlings (days)				
A_1 (20)	3.07ab	9.52b	16.83b	27.10b
A_2 (30)	3.88a	10.38a	18.03a	29.69a
A_3 (40)	2.50b	6.59c	12.78c	21.58c
CV(%)	9.69	16.96	11.72	9.7
Level of Significance	**	**	**	**
Number of seedlings hill^{-1}				
H_1 (2)	2.37b	8.02b	14.99c	23.79c
H_2 (4)	4.38a	10.12a	17.29a	28.47a
H_3 (6)	2.70ab	8.35ab	15.35b	26.11b
CV(%)	9.69	16.96	11.72	9.7
Level of Significance	**	**	**	**

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

Table 6. Effect of interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} on total dry matter (g hill^{-1}) of short duration transplanted *Aus* rice (cv. Parija).

Interaction (Seeding density × age of seedling × number of seedlings hill^{-1})	Total dry matter (g hill^{-1})			
	15 DAT	30 DAT	45 DAT	60 DAT
$D_1 \times A_1 \times H_1$	2.12def	7.85de	16.08b-f	28.60
$D_1 \times A_1 \times H_2$	6.71a	10.65bcd	17.02bcd	31.72
$D_1 \times A_1 \times H_3$	5.32ab	11.89b	19.42bc	29.28
$D_1 \times A_2 \times H_1$	4.61bc	11.34bc	19.08bc	32.52
$D_1 \times A_2 \times H_2$	6.48a	16.55a	22.93a	36.56
$D_1 \times A_2 \times H_3$	3.53cd	11.14bc	19.43bc	30.21
$D_1 \times A_3 \times H_1$	1.35f	7.13e	13.17efg	21.52
$D_1 \times A_3 \times H_2$	1.69ef	6.88e	13.42d-g	29.85
$D_1 \times A_3 \times H_3$	3.63cd	6.91e	12.72efg	17.67
$D_2 \times A_1 \times H_1$	1.50ef	7.39e	12.93efg	19.21
$D_2 \times A_1 \times H_2$	1.77ef	11.32bc	19.68b	23.22
$D_2 \times A_1 \times H_3$	1.00f	8.03de	15.82c-f	30.58
$D_2 \times A_2 \times H_1$	1.50ef	8.08de	16.18b-f	24.47
$D_2 \times A_2 \times H_2$	5.48ab	8.48cde	16.38b-e	25.87
$D_2 \times A_2 \times H_3$	1.70ef	6.70e	14.17d-g	28.53
$D_2 \times A_3 \times H_1$	3.14cde	6.34e	12.48fg	16.45
$D_2 \times A_3 \times H_2$	4.13bc	6.85e	14.32def	23.60
$D_2 \times A_3 \times H_3$	1.05f	5.43e	10.56g	20.41
CV(%)	9.69	16.96	11.72	9.7
Level of Significance	**	*	*	NS

In a column, values having the same letter or without letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

The total dry matter (g) of short duration transplanted *Aus* rice (cv. Parija) was significantly affected by interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} at all DATs except for 60 DAT (Table 6). The interaction of 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1} produced the highest total dry matter (16.55 g and 22.93 g) at 30 and 45 DAT, respectively, while the interaction of 80 g seed m^{-2} × 40-day old seedlings × 6 seedlings hill^{-1} produced the lowest total dry matter (5.43 g and 10.56 g) at 30 and 45 DAT, respectively. At 15 DAT, the lowest total dry matter (1.00 g) was found in 80 g seed m^{-2} × 20-day old seedlings × 6 seedlings hill^{-1}. Table 6 showed that the dry matter production increased exponentially over time upto 45 DAT at all the treatment combinations. After 45 DAT, there were an insignificant increase in dry matter production. This could be due to the termination of the vegetative phase and initiation of reproductive phase of the short duration transplanted *Aus* rice (cv. Parija) plants during this period. Sinha *et al.* (2018) reported significant variation of plant dry matter production of rice due to differences of seedling age.

Table 7. Effect of nursery seeding density, age of seedlings and number of seedlings hill^{-1} on leaf area index (LAI) of short duration transplanted *Aus* rice (cv. Parija).

Treatments	Leaf area index (LAI)			
	20 DAT	35 DAT	50 DAT	65 DAT
Seeding density				
D_1 (40 g m^{-2})	0.50a	1.74a	2.34a	1.23b
D_2 (80 g m^{-2})	0.42b	1.38b	2.23b	1.25a
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	**	**	**	**
Age of seedlings (days)				
A_1 (20)	0.52a	1.64a	2.42a	1.34a
A_2 (30)	0.46b	1.59b	2.32b	1.33a
A_3 (40)	0.39c	1.45c	2.11c	1.05b
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	**	**	**	**
Number of seedlings hill^{-1}				
H_1 (2)	0.44b	1.52c	2.65a	1.37a
H_2 (4)	0.43b	1.57b	2.09c	1.07c
H_3 (6)	0.49a	1.59a	2.11b	1.28b
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	**	**	**	**

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

Table 8. Effect of interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} on leaf area index (LAI) of short duration transplanted *Aus* rice (cv. Parija).

Interaction (Seeding density × age of seedling × number of seedlings hill^{-1})	Leaf area index (LAI)			
	20 DAT	35 DAT	50 DAT	65 DAT
$D_1 \times A_1 \times H_1$	0.51ab	1.90a	2.76a	1.88b
$D_1 \times A_1 \times H_2$	0.50ab	1.78ab	2.01d	0.69gh
$D_1 \times A_1 \times H_3$	0.50ab	1.91a	1.94de	0.59h
$D_1 \times A_2 \times H_1$	0.50ab	1.34bc	2.87a	1.18e
$D_1 \times A_2 \times H_2$	0.50ab	1.66ab	2.43bc	1.88b
$D_1 \times A_2 \times H_3$	0.50ab	1.72ab	2.76a	2.19a
$D_1 \times A_3 \times H_1$	0.50ab	1.88a	2.57b	1.31de
$D_1 \times A_3 \times H_2$	0.48ab	1.63ab	1.82e	0.74fgh
$D_1 \times A_3 \times H_3$	0.47ab	1.81ab	188de	0.59h
$D_2 \times A_1 \times H_1$	0.49ab	1.19c	2.84a	1.50c
$D_2 \times A_1 \times H_2$	0.48ab	1.59b	2.56b	1.59c
$D_2 \times A_1 \times H_3$	0.66 a	1.44bc	2.41bc	1.78b
$D_2 \times A_2 \times H_1$	0.46ab	1.78ab	2.56b	1.45cd
$D_2 \times A_2 \times H_2$	0.38bc	1.35bc	1.50f	0.69gh
$D_2 \times A_2 \times H_3$	0.41bc	1.71ab	1.80e	0.56h
$D_2 \times A_3 \times H_1$	0.20 d	1.01d	2.30c	0.91f
$D_2 \times A_3 \times H_2$	0.26cd	1.42bc	2.25c	0.82fg
$D_2 \times A_3 \times H_3$	0.42bc	0.95e	1.86de	1.96b
CV(%)	12.19	12.56	9.66	7.98
Level of Significance	**	**	**	**

In a column, values having the same letter or without letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

Leaf area index (LAI)

Leaf area index was significantly influenced by nursery seeding density, age of seedlings and number of seedlings hill^{-1} at different days after transplanting (Table 7). Low seeding density (40 g seed m^{-2}) produced the higher value of LAI (0.50, 1.74, and 2.34) at 20, 35 and 50 DAT, respectively but high seeding density (80 g seed m^{-2}) gave the higher value of LAI (1.25) at 65 DAT. LAI of rice plant varied significantly for various seeding densities as stated by Ameen *et al*., 2014. Sarwar *et al*. (2011) also reported that in case of nursery management, comparison of means showed maximum leaf area index of rice was recorded in low density with nitrogen application. Lowest seedling age (20-day) produced the highest value of leaf area index (0.52, 1.64, 2.42 and 1.34) at 20, 35, 50 and 65 DAT, respectively. Younger seedlings had produced the higher values of leaf area index compared to older aged seedlings of rice plant (Virk *et al*., 2020). Use of 6 seedlings hill^{-1} produced the highest value of LAI (0.49 and 1.59) at 20 and 35 DAT, respectively whereas 2 seedlings hill^{-1} produced the highest value LAI (2.65 and 1.37) at 50 and 65 DAT, respectively. These results corroborate the findings of Ali *et al*. (2017), who reported that LAI had increased with increase in plant density.

Table 9. Effect of nursery seeding density, age of seedlings and number of seedlings hill^{-1} on crop growth rate (CGR) of short duration transplanted *Aus* rice (cv. Parija).

Treatments	Crop growth rate (CGR) (g m^{-2} day^{-1})		
	15-30 DAT	30-45 DAT	45-60 DAT
Seeding density			
D_1 (40 g m^{-2})	4.07	4.66	7.75a
D_2 (80 g m^{-2})	3.51	4.73	5.91b
CV(%)	9.91	13.71	19.05
Level of Significance	NS	NS	**
Age of seedlings (days)			
A_1 (20)	4.30a	4.87b	6.85b
A_2 (30)	4.33a	5.10a	7.78a
A_3 (40)	2.73b	4.12c	5.87c
CV(%)	9.91	13.71	19.05
Level of Significance	**	**	*
Number of seedlings hill^{-1}			
H_1 (2)	3.77	4.64	5.87b
H_2 (4)	3.83	4.78	7.45a
H_3 (6)	3.77	4.67	7.18ab
CV(%)	9.91	13.71	19.05
Level of Significance	NS	NS	*

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1 = 40 g seeds m^{-2}, D_2 = 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

The interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} had significant effect on leaf area index of short duration transplanted *Aus* rice (cv. Parija) at all the DATs (Table 8). The LAI of all the treatments exerted an increasing trend from 20 DAT to 50 DAT. The highest LAI (2.87) at 50 DAT was recorded in 40 g seed m^{-2} × 30-day old seedlings × 2 seedlings hill^{-1} which was at par with 40 g seed m^{-2} × 20-day old seedlings × 2 seedlings hill^{-1}, 40 g seed m^{-2} × 30-day old seedlings × 6 seedlings hill^{-1} and 80 g seed m^{-2} × 20-day old seedlings × 2 seedlings hill^{-1}, while the lowest LAI (1.50) was found in 80 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1}. Meanwhile, at 65 DAT, the interaction 40 g seed m^{-2} × 30-day old seedlings × 6 seedlings hill^{-1} produced the highest LAI (2.19) while the interaction 80 g seed m^{-2} × 30-day old seedlings × 6 seedlings hill^{-1} produced the lowest LAI (0.56). The decreasing trend of LAI after 50 DAT could be due to beginning of leaf senescence as the growth duration of short duration transplanted *Aus* rice (cv. Parija) is comparatively shorter than the other season rice cultivars (Sarkar *et al*., 2021 and Paul *et al*., 2018 and Roy *et al*., 2018). Sarkar *et al*., 2016 and Roy *et al*., 2018 also observed the similar trend of leaf area index because of improved agronomic practices.

Crop growth rate (CGR)

Crop growth rate was significantly influenced by nursery seeding density, age of seedlings and number of seedlings hill^{-1} at 45-60 DAT (Table 9). Results showed that lower seeding density (40 g seed m^{-2}) gave the higher CGR (7.75 g m^{-2} day^{-1}) than that of 80 g indeterminate seed m^{-2} (5.91) at 45-60 DAT. Seeding densities exerted significant influence on crop growth rate among the rice plants as indicated elsewhere (Ameen *et al*., 2014). However, the age of seedlings had significant impact on CGR at all the sampling dates. Moderate seedling age (30-day) made the highest CGR (4.33, 5.10 and 7.78 g m^{-2} day^{-1}) at all DATs. Almost similar result was documented by Saha *et al.* (2017). The lowest CGR was recorded when 40-days-old seedlings were transplanted. Again, 4 seedlings hill^{-1} gave the highest CGR (7.45 g m^{-2} day^{-1}) at 45-60 DAT.

Crop growth rate was significantly influenced by the interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} only at 15-30 DAT (Table 10). Results revealed that the highest CGR (6.71 g m^{-2} day^{-1}) resulted from 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1} which was at par with 40 g seed m^{-2} × 30-day old seedlings × 6 seedlings hill^{-1}, 80 g seed m^{-2} × 20-day old seedlings × 4 seedlings hill^{-1} and 80 g seed m^{-2} × 20-day old seedlings × 6 seedlings hill^{-1}, while the lowest CGR (1.81 g m^{-2} day^{-1}) was found from 80 g seed m^{-2} × 40 -day old seedlings × 4 seedlings hill^{-1}. The growth study involving crop growth rate in rice by Sarkar *et al*., 2016 and Roy *et al*., 2018 also found significant differences over time. Crop growth rate is enhanced by better growth and photosynthetic activity of the plants which could be manipulated through ensuring less competition and better soil aeration involving the treatments *viz.* seeding density, number of seedlings hill^{-1} etc. (Sridevi and Chellamuthu, 2015).

Table 10. Effect of interaction among nursery seeding density, age of seedlings and number of seedlings hill^{-1} on crop growth rate (CGR) of short duration transplanted *Aus* rice (cv. Parija).

Interaction (Seeding density × age of seedling × number of seedlings hill^{-1})	Crop growth rate (CGR) (g m^{-2} day^{-1})		
	15-30 DAT	30-45 DAT	45-60 DAT
$D_1 \times A_1 \times H_1$	3.82c-f	8.34	5.49
$D_1 \times A_1 \times H_2$	2.63def	9.80	4.25
$D_1 \times A_1 \times H_3$	4.38b-e	6.58	5.02
$D_1 \times A_2 \times H_1$	4.49b-e	8.96	5.16
$D_1 \times A_2 \times H_2$	6.71a	9.09	4.25
$D_1 \times A_2 \times H_3$	5.08abc	7.18	5.53
$D_1 \times A_3 \times H_1$	3.86c-f	5.57	4.02
$D_1 \times A_3 \times H_2$	3.46c-f	10.96	4.36
$D_1 \times A_3 \times H_3$	2.19ef	3.30	3.87
$D_2 \times A_1 \times H_1$	3.93c-f	4.18	3.69
$D_2 \times A_1 \times H_2$	6.37ab	2.36	5.58
$D_2 \times A_1 \times H_3$	4.69a-d	9.84	5.19
$D_2 \times A_2 \times H_1$	4.39b-e	5.52	5.40
$D_2 \times A_2 \times H_2$	2.00f	6.32	5.27
$D_2 \times A_2 \times H_3$	3.33c-f	9.58	4.98
$D_2 \times A_3 \times H_1$	2.13ef	2.64	4.10
$D_2 \times A_3 \times H_2$	1.81f	6.19	4.98
$D_2 \times A_3 \times H_3$	2.92c-f	6.57	3.42
CV(%)	9.91	19.05	13.71
Level of Significance	**	NS	NS

In a column, values having the same letter or without letter do not differ significantly whereas values with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant. D_1= 40 g seeds m^{-2}, D_2= 80 g seeds m^{-2}; A_1= 20-days old, A_2= 30-days old, and A_3= 40-days old seedling; H_1= 2 seedlings hill^{-1}, H_2= 4 seedlings hill^{-1}, and H_3= 6 seedlings hill^{-1}.

Conclusion

Most of the growth descriptors *viz.* plant height, total tillers, LAI, TDM and CGR of Parija rice gave their highest values for the treatment of 40 g seed m^{-2} × 30-day old seedlings × 4 seedlings hill^{-1}. As the grain production of rice is dependent on the proper growth of the plant, 30-day old seedlings raised from nursery seeding density of 40 g seed m^{-2} could be transplanted with 4 seedlings hill^{-1} to obtain the maximum growth performance of short duration transplanted *Aus* rice (cv. Parija).

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