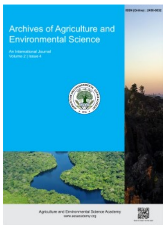
Archives of Agriculture and Environmental Science 5(2): 137-143 (2020)
https://doi.org/10.26832/24566632.2020.050208

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE

Growth and yield of *boro* rice (*Oryza sativa* L.) in response to crop establishment methods and varieties

Afrina Rahman[*] , **Md. Abdus Salam, Md. Abdul Kader, Md. Shafiqul Islam and Suriaya Perveen**

Department of Agronomy, Bangladesh Agricultural University, Mymensingh - 2202, BANGLADESH
[*]Corresponding author's E-mail: trishaagron@bau.edu.bd

ARTICLE HISTORY

Received: 18 May 2020
Revised received: 05 June 2020
Accepted: 19 June 2020

Keywords

Boro rice
Crop establishment methods
Growth
Variety
Yield

ABSTRACT

Physiological attributes and yield performance of high yielding varieties (HYV) of rice cultivars need to be assessed by crop establishment methods before promoting a suitable crop establishment method in Bangladesh. We, therefore, conducted an experiment to study the effects of crop establishment methods on the growth and yield of *boro* rice. The experiment comprised of two factors; factor A: methods of crop establishment *viz*., dry direct seeding, unpuddle transplanting, alternate wetting and drying (AWD) and puddle transplanting; factor B: rice cultivars *viz*., BRRI dhan28, BRRI dhan58, BRRI dhan74 and BRRI hybrid dhan3. The experiment was laid out in a split-plot design with three replications where method of crop establishment was assigned to the main plot and rice cultivar was assigned to the sub plots. Data were collected at different growth stages and at harvest. From the results, it was found that growth, yield and yield contributing characters were significantly influenced by crop establishment methods. The highest leaf area index (LAI), total dry matter and grain yield were found in puddle transplanting method. The highest grain yield was obtained in puddle transplanting method due to accumulation of maximum dry matter and production of highest number of effective tillers hill^{-1} and grains panicle^{-1}. Among the varieties the highest grain yield was obtain in BRRI hybrid dhan3 due to highest number of grains panicle^{-1} and 1000-grain weight. The highest grain yield (6.21 t ha^{-1}) was found in puddle transplanting with BRRI dhan28, while the lowest grain yield (2.80 t ha^{-1}) was produced in dry direct seeding with BRRI dhan28. Therefore, puddle transplanting with BRRI dhan28 might be recommended due to best physiological performance and obtaining highest grain yield of *boro* rice.

Citation of this article: Rahman, A., Salam, M.A., Kader, M.A., Islam, M.S. and Perveen, S. (2020). Growth and yield of *boro* rice (*Oryza sativa* L.) in response to crop establishment methods and varieties. *Archives of Agriculture and Environmental Science*, 5(2): 137-143, https://dx.doi.org/10.26832/24566632.2020.050208

INTRODUCTION

Rice (*Oryza sativa* L.) is considered as a staple food in Bangladeshi diet as it is consumed by 164 million people of the country. It is grown on large scale by the farmers of the country to meet the expected demand of consumption as well as exportation. Approximately 77% of the cropped area is devoted to rice production, with some 60-70% of the agricultural labour employed in rice production, marketing and distribution (Julfiquar, 2009). Production of rice contributes one half of the agricultural GDP and one sixth of the national income in Bangladesh (BBS, 2018). According to the provisional data by the Bangladesh Bureau of Statistics in FY 2016-17, the production of milled rice reached around 33.803 million tons (BBS, 2017) in Bangladesh. Among the total rice production, *boro* rice occupies 18.01 million tons in 2016-2017 and yield was 4.03 tha^{-1}(BBS, 2017). Though Bangladesh has excellent sub-tropical climate for boro rice cultivation but its productivity is low compared with other Asian countries like Indonesia, Malaysia etc. Rice requires an improvement of 50% by the year 2025 (Khush, 2001) because of the increasing rate of population, decreasing rate of agricultural land and no horizontal expansion of rice area. Therefore, to overcome this situation, increase in rice growth and production per unit area is the only alternative to bring self sufficiency in food production.

Production potential of rice cultivars yet to be achieved due to various reasons-rice establishment method is one of them (Kour *et al*., 2018). Rice is mainly grown as transplanted crop in puddled soil in Bangladesh which requires a large quantity of water starting from land preparation to grain filling (Pathak *et al*., 2011). But recent estimates indicate that there would be acute water shortage in the coming decades (PRIO, 2013). So, to fulfill the recent necessity "more rice with less water" researchers have evolved different water saving technologies such as system of rice intensification (SRI), alternate wetting and drying (AWD) and dry direct-seeded rice (DSR) (McDonald *et al*., 2019 and Devkota *et al*., 2020). There is evidence that SRI, AWD, DSR methods need (40-46%, 16-36% and 35-57%, respectively) less water than continuous flooding (Belder *et al*., 2004; Singh *et al*., 2003; Bouman *et al*., 2007) and have different physiological aspect on plant. Plants respond to different crop establishment methods at the molecular, cellular and physiological levels which vary among species and genotype, crop age and stage of development, organ and cell type and sub-cellular compartment (Yamakawa *et al*., 2007; Jana *et al*., 2017). Furthermore, physiological basis of yield gap among high yielding rice cultivars assessed by crop establishment methods has not been studied extensively. Such information is vital for identifying the physiological and morphological traits to support the selection and breeding of high yielding rice cultivars and sustainable crop establishment method. Efforts are few to address the growth, physiological responses and yield of rice to crop establishment methods under tropical environment (Zain *et al*., 2014). Therefore, keeping these points in view, the present investigation was undertaken to evaluate the comparative effects of different rice establishment methods on growth and yield of boro rice cultivars during the subsequent growth period of crop ontogeny.

MATERIALS AND METHODS

Study area

The research work was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh. The experimental field belongs to the non-calcareous dark grey floodplain soil under the Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9) (FAO and UNDP, 1988) located at 24.75° N latitude and 90.50°E longitude at an elevation of 18 m above the sea level. The field was a medium high land with flat and well drained condition with the pH value of the soil ranged from 5.9-6.5.

Experimentation

The experiment consists of two factors; factor A: methods of crop establishment *viz*., dry direct seeding, unpuddle transplanting, AWD (alternate wetting and drying) and puddle transplanting; factor B: rice cultivars *viz*., BRRI dhan28, BRRI dhan58, BRRI dhan74 and BRRI hybrid dhan3. The experiment was laid out in a split-plot design with three replications where method of crop establishment was assigned to the main plot and rice cultivar was assigned to the sub plots. Thus total number of plot was 48. Each plot size was 4 m × 2.5 m. The distance between block to block was 1.0 m, the distance between replication to replication was 1.5 m and that of plot to plot distance was 0.75 m.

Preparation of nursery bed and main field

A piece of land was selected at Agronomy Field Laboratory, BAU, Mymensingh to raise seedlings. The sprouted seeds were sown in the nursery bed on 22 November 2017 for puddle transplanting, unpuddle transplanting and AWD methods. The main field was prepared by power tiller with three to four times ploughing and cross ploughing followed by laddering. After laying out the land was fertilized with urea, Muriate of Potash (MoP), triple super phosphate, gypsum and zinc sulphate @ 300-100-120-60-10 kg ha^{-1}, respectively (FRG, 2012). The entire amounts of TSP, MoP, gypsum and zinc sulphate were applied at the time of final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after transplanting.

Transplantation and cultivation practices

The seedlings were uprooted and immediately transferred to the main field for puddle transplanting, unpuddle transplanting and AWD methods and for dry direct seeding method sprouted seeds were sown in the main field manually on 30 December 2017. Seedlings were transplanted at the rate of two seedlings $hill^{-1}$, maintaining a spacing of 25 cm × 15 cm. Weed was removed when necessary. Irrigations were given in the plots as per treatment specification e.g. dry direct seeding, alternate wetting drying, unpuddle transplanting as well as puddle transplanting required only 7, 10, 15 and 15 irrigations, respectively. When 80-90% of the panicles turned into golden yellow color, the crop was assessed to attain maturity. The crops of puddle transplanting, unpuddle transplanting and AWD plots were harvested on 1 May 2018 at 160 DAS and dry direct seeding plots on 30 May 2018 at 151 DAS.

Observation and collection of data

Five hills (excluding border hills) were selected randomly from each unit plot for recording data. Data were collected on different growth dynamics, such as leaf area index (LAI), total dry matter (TDM) production (g), absolute growth rate (AGR), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) at different growth stages. The data were recorded for each pot through destructive sampling. For each destructive sample, a hill was uprooted and washed with water. The leaf blades were alienated from the leaf sheath and leaf area was measured by a leaf area meter (LI 3100, Licor, Inc., Lincoln NE, USA). Leaf area index was accordingly calculated from leaf area data. After measurement of leaf area, the plant samples were dried in an electric oven for 72 hour until they reached at constant weight, and their dry weights were recorded. LAI, AGR, CGR, RGR, and NAR were calculated following the standard formulae (Radford, 1967; Hunt, 1978). Five hills (excluding border hills) were selected randomly from each unit plot for recording data. An area of central 1m × 1m was selected from each plot to record the yield of grain. The harvested crop of each unit area was separately bundled, properly tagged and then brought to the threshing floor of the Agronomy Field Laboratory. Grains were separated from the plants by thresher. Grains were then sun dried at 14% moisture level and cleaned. Finally, the yields of grain plot^{-1} were recorded and converted to t ha^{-1}.

Statistical analysis

The collected data were compiled and tabulated in proper from and subjected to statistical analysis. Data were analyzed using the analysis of variance technique with the help of computer package program MSTAT-C and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of crop establishment method on growth parameters

Crop establishment method exerted significant effect on LAI and TDM at 30, 45, 60 and 75 DAS (Table 1). The highest LAI at 30, 45, 60 and 75 DAS (1.10, 3.39, 14.11 and 20.47, respectively) was obtained in puddle transplanting method and the shortest leaf area index (0.40, 0.65, 2.81 and 5.43, respectively) was obtained in dry direct seeding method of crop establishment at 30, 45, 60 and 75 DAS. Singh *et al.* (2009) stated that the crop establishment method which produces highest LAI might have had the capacity to higher photosynthesis rate resulting higher biological and economical yield. Considering growth stage, LAI increased sharply and reached at peak with maturity and LAI differed due to treatment difference. The highest TDM (3.45g, 12.18g, 72.99g and 103.4g, respectively) was observed in puddle transplanting method at 30, 45, 60 and 75 DAS but statistically similar result was found in alternate wetting and drying at 45 and 75 DAS. The lowest TDM (1.77g, 4.20g, 11.66g and 23.16g, respectively) was obtained in dry direct seeded method at 30, 45, 60 and 75 DAS. Fageria and Baligar (2011) also reported that TDM production increased with the advancement of plant age up to flowering. In addition, it has been reported that in puddle transplanting rice plant received an ideal rhizosphere environment which may provide higher nutrient uptake which resulting in the greater source accumulation and efficient translocation of photosynthates into the sink (Bhardwaj *et al.*, 2018).

At 60 DAS, the highest AGR (4.05) was found in puddle transplanting and at 75 DAS, the highest AGR (3.19) was found in alternate wetting and drying treatment but in both 60 and 75 DAS, the lowest AGR was found in dry direct seeding treatment (Figure 1). CGR, RGR and NAR were not significantly influenced due to crop establishment method at different growth stages (Table 4). Higher AGR and CGR were observed in puddle transplanting method at 60 DAS because of the higher accumulation of photosynthesis. Irrespective of treatments, RGR was more at early phase and showed a diminishing trend with the progress of plant age (Ghasal *et al.*, 2014). The decline in RGR was possibly due to the raise of metabolically active tissue, which contributed less to the plant growth. The trend of NAR for different crop establishment methods were relatively equal but the higher NAR was observed in 60 DAS after that it reduced in all the treatments. It can be due to decrease in photosynthetic efficiency (Watson, 1958; Ghasal *et al.*, 2014).

Table 1. Effect of crop establishment method on LAI and total dry matter.

Methods of crop establishment	LAI				Total dry matter (g)			
	30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Dry direct seeded	0.40c	0.65d	2.81d	5.43d	1.77c	4.20b	11.66d	23.16c
Unpuddle transplanting	0.57b	1.51c	4.84c	10.81c	2.33bc	6.41b	34.05c	75.40b
AWD	1.08a	2.42b	9.93b	15.35b	3.30ab	11.52a	48.57b	96.43a
Puddle transplanting	1.10a	3.39a	14.11a	20.47a	3.45a	12.18a	72.99a	103.4a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	14.40	15.27	10.30	9.51	36.41	49.07	9.77	9.59

In a column figures having common letter(s) do not differ significantly as per DMRT.

Table 2. Effect of variety on LAI and total dry matter.

Variety	LAI				Total dry matter (g)			
	30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT
BRRI dhan28	0.83ab	2.23a	8.86a	16.91a	3.01a	10.07a	53.30a	92.91a
BRRI dhan58	0.67c	1.63b	6.78b	9.34d	2.02b	6.57b	31.07d	57.98d
BRRI dhan74	0.87a	2.11a	8.80a	12.26c	2.96a	9.25a	45.99b	81.59b
BRRI Hybrid dhan-3	0.79b	2.00a	7.25b	13.56b	2.91a	8.44ab	36.90c	65.90c
Level of significance	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01
CV (%)	9.67	14.08	8.16	10.64	16.71	33.15	10.05	11.61

In a column figures having common letter(s) do not differ significantly as per DMRT.

Table 3. Effect of interaction between crop establishment and variety on LAI, total dry matter and absolute growth rate (AGR).

Interaction (crop establishment method× Variety)	LAI				Total dry matter (g)				AGR (g day^{-1})		
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
M_1V_1	0.28h	0.79gh	2.11k	6.02gh	1.36f	4.987	7.75h	29.50f	0.24	0.18j	1.45e
M_1V_2	0.41gh	0.47h	2.67jk	4.29hi	2.31de	3.44	13.43h	16.34f	0.07	0.67ij	0.19h
M_1V_3	0.39gh	0.57h	3.16ijk	3.36i	1.69def	4.780	11.39h	20.61f	0.21	0.44j	0.61gh
M_1V_4	0.52g	0.77gh	3.31ij	8.05fg	1.76def	3.630	14.08h	26.19f	0.13	0.67ij	0.80fg
M_2V_1	0.89ef	1.67ef	3.9hi	17.59cd	3.25bc	8.140	51.33e	85.83cd	0.33	2.88cd	2.30d
M_2V_2	0.53g	1.21fg	5.32fg	7.45fg	1.58ef	5.387	12.83h	80.68cd	0.26	0.49j	4.52a
M_2V_3	0.36h	1.71ef	4.46gh	9.27f	2.07def	6.270	48.31e	87.78cd	0.28	2.8de	2.63cd
M_2V_4	0.54g	1.46f	5.70f	8.92f	2.46cd	5.843	23.72g	47.33e	0.22	1.19hi	1.57e
M_3V_1	0.99de	2.61bc	11.85d	14.37e	3.21bc	13.06	73.41c	124.6a	0.66	4.02b	3.42b
M_3V_2	0.91ef	2.27cd	6.81e	9.19f	1.81def	9.627	39.12f	56.73e	0.52	1.97fg	1.17efg
M_3V_3	1.11cd	2.05de	13.33bc	16.71de	4.36a	10.93	35.08f	109.9b	0.44	1.61gh	4.98a
M_3V_4	1.34b	2.767bc	7.75e	21.13b	3.83ab	12.47	46.65e	94.48bc	0.57	2.28ef	3.19bc
M_4V_1	1.17c	3.87a	17.62a	29.64a	4.01ab	14.09	80.69b	131.7a	0.67	4.44ab	3.4b
M_4V_2	0.83f	2.58bc	12.33cd	16.45de	2.41de	7.823	58.91d	78.15d	0.36	3.40c	1.28ef
M_4V_3	1.62a	4.11a	14.27b	19.68bc	3.76ab	15.00	89.19a	108.1b	0.75	4.94a	1.26ef
M_4V_4	0.78f	3.03b	12.24cd	16.12de	3.64ab	11.82	63.15d	95.60bc	0.55	3.42c	2.16d
Level of significance	0.01	0.01	0.01	0.01	0.01	NS	0.01	0.01	NS	0.01	0.01
CV (%)	9.67	14.08	8.16	10.64	16.71	33.15	10.05	11.61	50.35	14.35	15.46

*In a column figures having common letter(s) do not differ significantly as per DMRT; NS= Not significant, M_1= Dry direct seeding, M_2= Unpuddle transplanting, M_3=AWD (Alternate wetting and drying), and M_4= Puddle transplanting, V_1= BRRI dhan28, V_2= BRRI dhan58, V_3=BRRI dhan74, V_4= BRRI Hybrid dhan3.

Table 4. Effect of crop establishment method on crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR).

Methods of crop establishment	CGR (g cm^{-2} day^{-1})			RGR (g g^{-1}day^{-1})			NAR (g cm^{-2} day^{-1})		
	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
Dry direct seeded	0.0004	0.001	0.002	0.032	0.042	0.021	0.0004	0.0004	0.0002
Unpuddle transplanting	0.0007	0.005	0.007	0.031	0.047	0.026	0.0003	0.0007	0.0005
AWD	0.001	0.007	0.008	0.036	0.043	0.018	0.0004	0.0005	0.0003
Puddle transplanting	0.001	0.01	0.005	0.035	0.053	0.009	0.0003	0.0006	0.0002
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	31.62	5.27	5.27	30.30	21.74	17.56	31.62	31.62	31.62

*In a column figures having common letter(s) do not differ significantly as per DMRT; NS= Not significant.

Effect of variety on growth parameters

LAI and total dry matter of different rice cultivars showed substantial differences throughout the growth stages (Table 2). At 30 DAS, the highest LAI (0.87) was obtained in BRRI dhan74, at 45 DAS, the highest LAI (2.23) was obtained in BRRI dhan28 which was statistically identical to BRRI Hybrid dhan3 as well as BRRI dhan74, after that at 60 DAS, the highest LAI (8.86) was obtained in BRRI dhan28 which was statistically identical to BRRI dhan74 and lastly at 75 DAS, the highest LAI (16.91) was obtained in BRRI dhan28. At 30, 45, 60 and 75 DAS, the lowest LAI (0.67, 1.63, 6.78 and 9.34, respectively) was recorded in BRRI dhan58. Cultivar having more LAI has the possibility to absorb more solar radiation and more photosynthetic capacity which ultimately leads to higher yield. Similar results have also been reported by Yadav *et al.* (2009).

At 30 DAT, the highest total dry matter (3.01 g) was obtained in BRRI dhan28 which was statistically identical to BRRI Hybrid dhan3 as well as BRRI dhan74 and the lowest total dry matter (2.02g) was recorded in BRRI dhan58. At 45 DAS, the highest total dry matter (10.07g) was obtained in BRRI dhan28 which was statistically identical to BRRI dhan74 and the lowest total dry matter (6.57g) was recorded in BRRI dhan58. At 60 and 75 DAS, the highest total dry matter (53.30g and 92.91g, respectively) was obtained in BRRI dhan28 and the lowest total dry matter (31.07g and 57.98g, respectively) was recorded in BRRI dhan58. BRRI dhan28 cultivar might have potentiality to produce more photosynthates than other variety which helped in producing highest dry matter in this variety. A wide variability in photosynthetic rates exists in rice cultivars (Sharma and Singh, 1994) which may cause difference in dry matter accumulation. Alam *et al.* (2009) found difference in total dry matter accumulation indifferent genotypes. At 60 and 75 DAS significantly the highest AGR (2.88 and 2.64, respectively) was obtained in BRRI dhan28 than other varieties (Figure 2). In case of other parameters such as CGR, RGR and NAR variety have shown insignificant effect.

Table 5. Effect of methods of crop establishment on yield and yield components of *boro* rice.

Treatments	Effective tillers hill^{-1} (no.)	Grains panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})
Dry direct seeded	7.98b	86.68b	24.04	3.13c
Unpuddle transplanting	9.44a	91.40b	23.74	4.39b
AWD	9.75a	92.85b	23.24	4.84ab
Puddle transplanting	10.62a	99.95a	24.45	5.54a
Level of significance	0.05	0.05	NS	0.01
CV (%)	14.20	7.22	7.02	18.69
BRRI dhan28	11.00a	86.58b	21.43b	4.61
BRRI dhan58	7.92b	92.96b	21.71b	4.15
BRRI dhan74	10.55a	88.21b	25.69a	4.36
BRRI Hybrid dhan-3	8.30b	103.1a	26.65a	4.80
Level of significance	0.01	0.01	0.01	NS
CV (%)	14.28	9.64	6.56	19.65
Interactions				
M_1V_1	8.60cde	85.72bc	21.27	2.80
M_1V_2	6.67e	89.07bc	21.20	3.50
M_1V_3	7.93cde	86.16bc	26.80	3.28
M_1V_4	8.67cde	85.77bc	26.89	2.97
M_2V_1	10.14bcd	84.93c	21.33	4.17
M_2V_2	7.73de	92.29bc	21.77	3.98
M_2V_3	11.73ab	85.53bc	26.20	4.77
M_2V_4	8.13cde	102.9b	25.67	4.65
M_3V_1	12.00ab	87.99bc	20.67	5.27
M_3V_2	8.53cde	95.27bc	21.87	4.29
M_3V_3	10.40bc	90.39bc	23.40	4.10
M_3V_4	8.07cde	97.76bc	27.01	5.74
M_4V_1	13.27a	87.69bc	22.45	6.21
M_4V_2	8.73cde	90.76bc	22.00	4.84
M_4V_3	12.13ab	95.20bc	26.35	5.30
M_4V_4	8.33cde	126.2a	27.01	5.83
Level of significance	0.05	0.05	NS	NS
CV (%)	14.28	9.64	6.56	19.65

In a column figures having common letter(s) do not differ significantly as per DMRT; NS= Non significant; M_1= Dry direct seeding, M_2= Unpuddle transplanting, M_3=AWD (Alternate wetting and drying), and M_4= Puddle transplanting, V_1= BRRI dhan28, V_2= BRRI dhan58, V_3=BRRI dhan74, V_4= BRRI hybrid dhan3.

Effect of crop establishment method and variety on growth parameters

Leaf area index was significantly affected by the interaction of crop establishment method and variety at 30, 45, 60 and 75 days after sowing (DAS) (Table 3). At 30 DAS, the highest LAI (1.623) was recorded in puddle transplanting × BRRI dhan74 and the lowest LAI (0.28) was recorded in dry direct seeding × BRRI dhan28 which was statistically identical to unpuddle transplanting × BRRI dhan74 treatment. At 45 DAS, the highest LAI (4.11) was found in the treatment combination Puddle transplanting × BRRI dhan74 and the lowest LAI was observed (0.47) in dry direct seeding × BRRI dhan58 treatment which was statistically identical to dry direct seeding × BRRI dhan74 treatment. At 60 and 75 DAS, the highest LAI (17.62, 29.64) was found in the treatment puddle transplanting × BRRI dhan28. But at 60 and 75 DAS, the lowest LAI was observed (2.11 and 3.36, respectively) in dry direct seeding × BRRI dhan28 treatment and dry direct seeding × BRRI dhan74 treatment, respectively.

Total dry matter was significantly influenced by the interaction of crop establishment method and variety at 30, 60 and 75 days after sowing (DAS) except 45 DAS (Table 3). At 30 DAS, the highest total dry matter (4.36g) was found in alternate wetting and drying × BRRI dhan74 and the lowest total dry matter (1.36g) was found in dry direct seeding × BRRI dhan28. At 60 DAS, the highest TDM (89.19g) was found in puddle transplanting × BRRI dhan74 and the lowest TDM was observed (7.75g) in dry direct seeding × BRRI dhan28 At 75 DAS, the highest TDM (131.7 g) was found in puddle transplanting × BRRI dhan28 which is statistically identical to alternate wetting and drying × BRRI dhan28 and the lowest TDM was observed (16.34g) in dry direct seeding × BRRI dhan58 treatment which was statistically similar with dry direct seeding × BRRI dhan28, dry direct seeding × BRRI dhan74, and dry direct seeding× BRRI hybrid dhan3.

AGR was significantly influenced by the interaction of crop establishment method and variety at different DAS except 45 DAS (Table 3). At 60 DAS, the highest and lowest AGR was observed in puddle transplanting × BRRI dhan74 and dry direct seeding × BRRI dhan28 treatment. At 75 DAS, the highest AGR was observed in alternate wetting and drying × BRRI dhan74 treatment and the lowest AGR was recorded in dry direct seeding × BRRI dhan58. Other parameters such as CGR, RGR and NAR were not significantly influenced by the interaction of crop establishment method and variety.

Yield and yield contributing attributes

At harvest, different crop establishment methods had significant effect on yield and yield contributing characters. The highest grain yield (5.54 t ha^{-1}) was obtained in puddle transplanting method (Table 5). The increased yield in puddle transplanting method might be due to higher LAI, dry matter accumulation, effective tiller $hill^{-1}$ and grains $panicle^{-1}$ production. Singh *et al.* (2009) stated that highest LAI might have had the capacity to higher photosynthesis which is connected to higher yield. The lowest grain yield (3.13 t ha^{-1}) was obtained in dry direct seeding method which might be due to direct seeded rice suffered from inadequate moister during growth period. Grain yield was not significantly influenced by different varieties (Table 5). However, numerically the highest grain yield (4.80 t ha^{-1}) was produced by BRRI Hybrid dhan3, while the lowest grain yield (4.15 t ha^{-1}) was found in BRRI dhan58. This might be due to the fact that BRRI Hybrid dhan3 produced the highest number of grains $panicle^{-1}$ and heaviest 1000-grain weight which ultimately contributed to highest grain yield. Due to the interaction between crop establishment method and variety grain yield was not significantly influenced. Numerically the highest grain yield (6.21 t ha^{-1}) was produced in puddle transplanting × BRRI dhan28 treatment, while the lowest grain yield (2.80 t ha^{-1}) was produced in dry direct seeding × BRRI dhan28 treatment (Table 5). Higher number of chaffy grains under dry direct seeding as compared to puddle transplanting was reported by Akhgari and Kaviani (2011) which effects in lowering the yield under dry direct seeding.

Functional relationship between LAI, total dry matter and grain yield of *Boro* rice

A positive linear relationship of LAI and total dry matter with grain yield of *boro* rice indicated that higher the LAI and total dry matter, the higher the grain yield. In Figures 3 and 4, the regression equation indicates that an increase in LAI and total dry matter would lead to an increase in the grain yield of *boro* rice. The functional relationships were significant at $p \leq 0.05$. The functional relationship for LAI can be determined by the regression equation Y = 0.1168x + 2.9607 (R^2 = 0.6528). The functional relationship revealed that 65% of the variation in yield could be explained from the variation in LAI. Again for relationship between total dry matter and grain yield. The functional relationship can be determined by the regression equation Y = 0.0225x – 2.8033 (R^2 = 0.6673). The functional relationship revealed that 66% of the variation in yield could be explained from the variation in total dry matter.

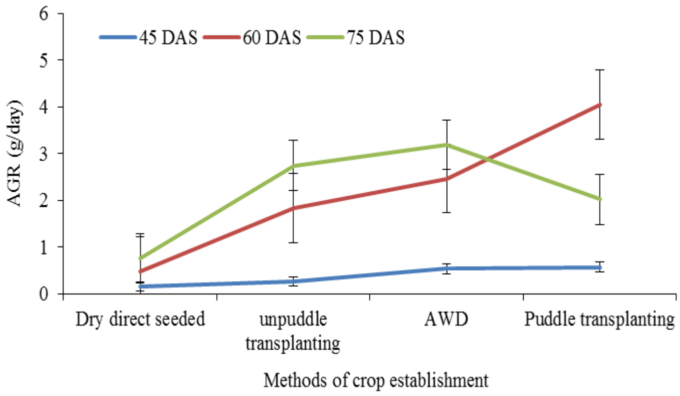


Figure 1. *AGR influenced by crop establishment methods.*

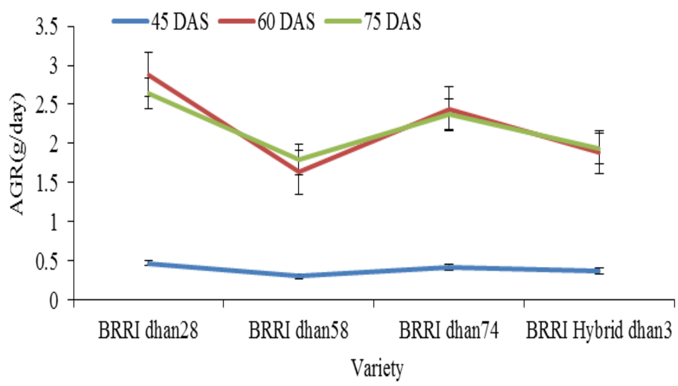


Figure 2. *AGR influenced by different rice varieties.*

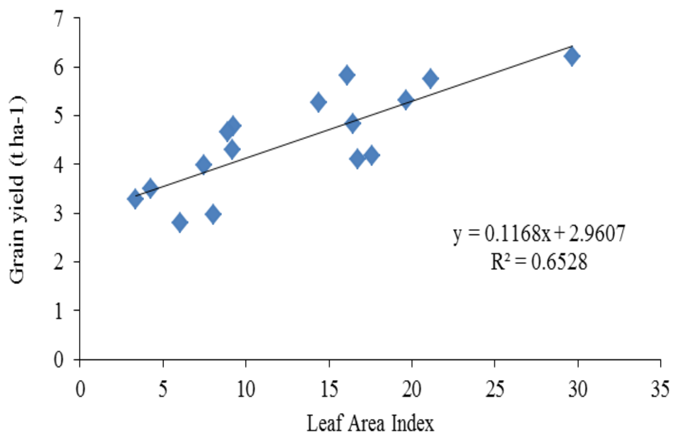


Figure 3. *Functional relationship between LAI and grain yield of boro rice at 75 DAT.*

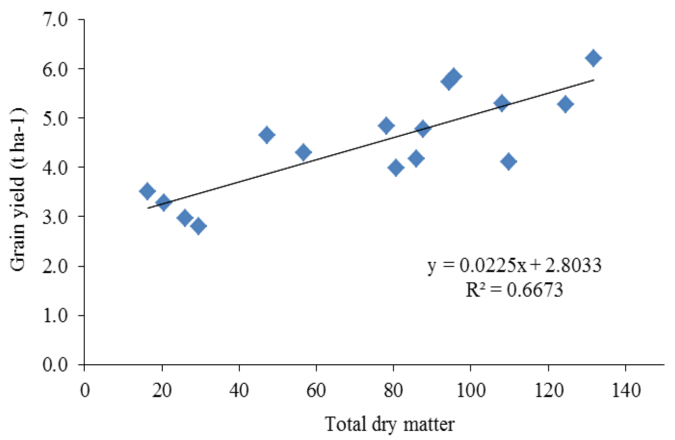


Figure 4. *Functional relationship between total dry matter and grain yield of Boro rice at 75 DAT.*

Conclusion

With detailed data on growth dynamics, physiological performance and yield, the study has strong evidence that yield strongly correlates with leaf area index and total dry matter. Thus, LAI and total dry matter can be simple and powerful predictors for rice yield. Therefore, in order to meet the projected rice demand of the nation in near future, puddle transplanting with BRRI dhan28 can be a feasible because of having the high values of physiological and yield contributing parameters which ultimately contribute in increasing the crop productivity.

REFERENCES

Akhgari, H. and Kaviani, B. (2011). Assessment of direct seeded and transplanting methods of rice cultivars in the northern part of Iran. *African Journal of Agricultural Research*, 6: 6492-6498.

Alam, M.M., Ali, M.H., Hasanuzzaman, M., Nahar, K. and Islam, M.R. (2009). Dry matter partitioning in hybrid and inbred rice varieties undervariable doses of phosphorus. *International Journal of Sustainable Agriculture*, 1: 10-19.

BBS (Bangladesh Bureau of Statistics) (2017). Monthly Statistical Bulletin, Ministry of Planning. Government of the People's Republic of Bangladesh. Dhaka. pp. 49-69.

BBS (Bangladesh Bureau of Statistics) (2018). Monthly Statistical Bulletin, Ministry of Planning. Government of the People's Republic of Bangladesh. Dhaka. pp. 49-69.

Belder, P., Bouman, B.A.M., Cabangona, R., Guoanc, L., Quilangd, E.J.P., Yuanhuae, L., Spiertzb, J.H.J. and Tuong, T.P. (2004). Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia. *Agricultural Water Management*, 65: 193–210.

Bhardwaj, R., Singh, M.K., Singh, C.S. and Singh, A.K. (2018). Efficacy of crop establishment methods on yield and economics of rice (*Oryza sativa* L.) under puddled condition. *International Journal of Current Microbiology and Applied Sciences*, 73: 625-631.

Bouman, B., Lampayan, R. and Tuong, T. (2007). Water management in irrigated rice coping with water scarcity. International Rice Research Institute Publication, Los Banos, Philippines. pp. 41-60.

Devkota, K.P., Yadav, S., Khanda, C.M., Beebout, S.J., Mohapatra, B.K., Singleton, G.R. and Puskur, R. (2020). Assessing alternative crop establishment methods with a sustainability lens in rice production systems of Eastern India. *Journal of Cleaner Production*, 244: 118835.

Fageria N.K. and Baligar V.C. (2011). Lowland rice response to nitrogen fertilizer. *Communications in Soil Science and Plant Analysis*, 32: 1405-1429.

FRG (2012). Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215.274pp.

Ghasal, P.C., Dharam, B., Yadav, A., Ved, P. and Verma, R.K. (2014). Productivity and profitability of rice varieties under different methods of establishment. *Annals Agricultural Research*, 35: 298-303.

Gomez, M.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. John Willey and Sons. New York, Chichester, Brisbane, Toronto. pp. 97-129, 207-215.

Hunt, R. (1978). Plant Growth Analysis. Studies in Biology, No. 96. Edward Arnold (Publishes) Limited, 41. Bedford Square, London.

Jana, K., Mallick, G.K., Das, S.K., Biswas, B., Kundu, M.K., Koireng, R.J. and Puste, A.M. (2017). Evaluation of potential rice (*Oryza sativa* L.) genotypes with different levels of N under rainfed shallow lowland situation. *Archives of Agriculture and Environmental Science*, 2(3): 202-205.

Julfiquar, A.W., Jamil, M., Kulsum, U. and Ali, M.H. (2009). Development of Hybrids in Public Sector Research, Paper presented at the National Seed Fair, Bangladesh-Chaina friendship conference centre, Dhaka.

Khush, G.S. (2001). Green revolution: the way forward. *Nature Reviews Genetics*, 2 (10): 815–22

Kour, S., Sajaan, S., Gaikwad, D.S., Kumar, A. and Neetu (2018). Impact of different sowing methods on growth and yield attributes of direct-seeded rice (*Oryza sativa*.) in alluvial soils of Punjab, India. *Plant Archives*, 18(2): 1385-1390.

McDonald, A.J., Kumar, V., Poonia, S.P., Srivastava, A.K. and Malik, R.K. (2019). Taking the climate risk out of transplanted and direct seeded rice: Insights from dynamic simulation in Eastern India. *Field Crops Research*, 239: 92-103.

Pathak, H., Saharawat, Y.S., Gathala, M. and Ladha, J.K. (2011). Impact of resource-conserving technologies on productivity and green-house gas emission in rice-wheat system. *Greenhouse Gas Science technology*, 1: 126-127.

PRIO (2013). Water scarcity in Bangladesh: Transboundary rivers, conflict and cooperation report, Peace Research Institute Oslo, Hausmanns Gate 7, Norway. ISBN 978-82-7288-485-6.

Radford, P.J. (1967). Growth analysis formulae-their use and abuse. *Crop Science*, 7: 171-175

Sharma, A.P. and Singh, S.P. (1994). Genotypic variation in photosynthesis and yield components in rice. *Indian Journal of Plant Physiology*, 37:188-189.

Singh, A.K., Chudhury, B.U. and Bouman, B. (2003). Effects of rice establishment methods on crop performance, water use, and mineral nitrogen. In "Water-Wise Rice Production" (B.A.M. Bouman, H. Hengsdijk, B. Hardy, P.S. Bindraban, T.P. Tuong, and J.K. Ladha, Eds.). pp. 223–235. Proceedings of a Thematic Workshop on Water Wise Rice Production, 8–11 April 2002 at IRRI Headquarters in Los Banos, Philippines.

Singh, P., Agrawal, M. and Agrawal, S.B. (2009). Evaluation of physiological, growth and yield responses of a tropical oil crop (*Brassica campestris* L. var. Kranti) under ambient ozone pollution at varying NPK levels. *Environmental Pollution*, 157: 871-880.

UNDP and FAO (1988). Land Resources Appraisal of Bangladesh For Agricultural Development Report No. 2. Agro-ecological Regions of Bangladesh. United Nations Development Programme and Food and Agricultural Organization, Rome., Italy. pp. 212-221.

Watson, D.J. (1958). The dependence of net assimilation rate on leaf-area index. *Annals of Botany*, 22(85): 37–54.

Yadav, A., Dharam B., Malik, R.K., Gill, G., Kamboj, B.R., Dahiya, S.S., Lathwal, O.P. and Garg, R.B. (2009). Scope of direct seeded rice in Haryana. In: Proceeding of National Workshop "Scope and Problem of Direct Seeded Rice" organized be Dept. of Agronomy, PAU, Ludhiana 16th Sept. 2009, pp. 26-37.

Yamakawa, H., Hirose, T., Kuroda, M. and Yamaguchi, T. (2007). Comprehensive expression profiling of rice grain filling related genes under high temperature using DNA microarray. *Plant Physiology*, 144: 258-277.

Zain, N.A.M., Ismail, M.R., Puteh, A., Mahmood, M. and Islam, M.R. (2014). Impact of cyclic water stress on growth, physiological responses and yield of rice (*Oryza sativa* L.) grown in tropical environment. *Ciencia Rural*, 44: 2136-2141.