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Short Communication

Impact of different crop establishment techniques on growth and yield of drought tolerant rice varieties

Ajay Kumar Paswan, Navnit Kumar and Sumit Sow*

Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Samastipur, Pusa, Bihar 848 125

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****Corresponding author:*** *E-mail: sumitsow19@gmail.com*

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As a staple food, rice (*Oryza sativa* L.) is consumed by 65% of the world's population. From irrigated to rainfed, upland to lowland conditions, it is cultivated under diverse ecological conditions. Since rice has a semi-aquatic phylogenic origin, it is primarily produced in water-intensive systems. Due to climate change and water competition with other crops, cereal crop production is becoming increasingly threatened by water shortages (Chhokar *et al*., 2017). Rice varieties that are drought resistant have been developed in response to the predicted increase in drought in the future. Drought, combined with its strong relationship with the environment, slowed genetic improvement. Climate change mitigation will require an understanding of stress physiology in specific environments (FAO, 2004). The reproductive stage is highly susceptible to drought, particularly during flowering, but even mild droughts can cause considerable damage in other stages as well (Liu *et al*, 2006). There are approximately 50% of rice-growing areas that are irrigated, 34% that are rainfed low-lands, 9% that are rainfed uplands, and 7% that are flooded. The global rice production is largely dominated by irrigated rice (75%) (IRRI, 2007).

During the peak period of farm operation, the lack of irrigation water, insufficient labour and high wages inevitably delayed rice planting. The solution is to seed directly in puddled conditions to mitigate this problem. Direct seeding of rice refers to sowing seeds directly into the field rather than transplanting young plants (Pandey *et al*., 2002). Rice is typically grown in wetlands by planting seedlings in puddled fields. Drought is among the most important constraint adversely affecting yields in rainfed upland conditions. In comparison with non-drought-tolerant varieties, drought-tolerant rice varieties can yield 0.8 to 1.2 t ha^{-1} more. A yield advantage in these 23 million hectares of drought-prone soil will propel poverty-stricken rural communities to be much more productive and provide them with food security. Farmers in drought-prone ecosystems benefit from drought-tolerant rice varieties by reducing their risk of losing crops. To enhance the productivity of the drought prone ecosystem of Bihar, drought tolerant varieties need to be developed and discriminated. In this context, the objective of this study was to evaluate the effect of different establishment methods and drought-tolerant varieties on rice growth and yield under rainfed conditions in eastern India.

An experiment was conducted at the research farm of Dr. Rajendra Prasad Central Agricultural University, Pusa (Bihar) during *kharif* season of 2017. The climate is sub-tropical, greatly influenced by south-west monsoon. A total of 797.3 millimeters of rainfall fell during the cropping period, and maximum temperatures ranged between 32.6 and 37.8 °C. Mean minimum temperatures ranged between 15.3 and 26.4 °C. Maximum relative humidity ranged between 91 to 77%. At the start of the experiment, the soil layer 0 to15 cm was sandy loam with pH 8.2, organic carbon content 0.46%, and available N of 285 kg ha^{-1}, available P_2O_5 of 22.6 kg ha^{-1}, and available K_2O of 161. kg ha^{-1}. Three different establishment methods (direct seeded rice, puddled transplanting, un-puddled transplanting) in main-plot were used in the split-plot design of the experiment and six varieties (Sahbhagi Dhan, Abhishek, Sabour Ardhjal, DRR 42, Swarna Shreya, Rajendra Neelam) in sub-plot with three replications. Each treatment was replicated three times, with a net plot size of 5.0 m x 2.6 m. The treatments were randomized as per procedure given by Cochran and Cox (1962).Several agronomic characteristics of rice plant are observed at different growth stages using the "representative sample" technique. Sampled plants were properly earmarked and tagged for field observation in situ.

With a meter scale, each net plot area consisted of five randomly selected hills tagged and measured in cm. Before heading, the height was measured at 30, 60 and 90 DAS/DAT. Counting the leaves was completed after detaching the leaves from their sheaths and categorizing them into small, medium, and large ones. Using a maximum length-width method for leaf area calculation, multiplied by the correction factor of 0.75 given by Yoshida (1981) for rice. The number of tillers was counted from the hills selected for plant heights during 30 DAS/DAT, 60 DAS/DAT, and 90 DAS/DAT. Plant of five hills from second row of each plot were uprooted and the uprooted plant were washed thoroughly. Thereafter, whole plant sample were sun dried, first. After that plant were oven dried (70^0 C ± 5^0 C) for 48 hours till constant weight was attained. The final dry weight was expressed in g m^{-2}. The formula given by Watson (1952) is based on dry weight gained by a unit area of crop in a unit time expressed as g $m^{-2}day^{-1}$.On the basis of clean and dry grains yield in the net plot area, kg $plot^{-1}$ was converted to t ha^{-1}. In each net plot area, straw was obtained after threshing and weighed after air drying. As a result, the weight of straw obtained was converted into t ha^{-1}. In this study, the analysis of variance was performed by employing the appropriate method (Gomez and Gomez, 1984).

Plant height at 30, 60, 90 DAS/DAT and at harvest were statistically non-significant under the establishment methods studied (Table 1). However, leaf area index (LAI) at 60 and 90 DAS/DAT was found to be statistically significant. Highest LAI (4.86 and 4.28) was observed with puddled transplanting at 60 and 90 DAS/DAT respectively which was significantly higher over other establishment methods. There may be less competition between the main crop and weeds for resources, such as light, nutrients, and moisture, since little water percolates under puddled conditions. A higher LAI was also reported by Baloch *et al.* (2006) for transplanted rice. It was found that puddled transplanting produced significantly more tillers and dry matter at 60, 90 DAS/DAT, as well as at harvest, compared with unpuddled transplanting and direct seeding of rice. The increase in number of tillers and drymatter production under puddled transplanting could be attributed to better moisture regimes in puddled transplanting since puddling reduces percolation of water. Similar results were reported by Kumar *et al.* (2008). In general crop growth rate increased upto 90 days only. This may be ascribed to the increased leaf abscission and senescence during late stages. Crop growth rate was estimated during 0-30, 30-60, 60-90 DAS/DAT and 90 DAS/DAT to harvest and during all the stages it was non-significant except during 60-90 DAS/DAT where maximum CGR (16.12 $gm^{-2}day^{-1}$) was noticed under puddled transplanting. Increased dry matter is the sole reason of significant improvement in crop growth rate. Sharma *et al.* (2006) also reported significant variation on crop growth rate among establishment methods. SabourArdhjal had the highest plant height at all stages, followed by Abhishek and Sahbhagi Dhan. Variations in photosynthetic partitioning may be responsible for variation in plant height among varieties. Uddin *et al.* (2010), Sarkar *et al.* (2013), and Birhane (2013) also reported similar results.

LAI varied significantly among varieties at all stages of observation (Table 1). The variety Sahbhagi Dhan has registered the highest LAI at all the stages of growth which was followed by Sabour Ardhjal. The higher number of tillers under this variety at all the stages of growth might be responsible for greater LAI. Likewise, Murthy *et al.* (2012) reported similar findings. At 90 DAS, puddled transplanting produced the highest number of tillers (273.6 m^{-2}), significantly higher than unpuddled transplanting (248.9 m^{-2}) and direct seeding of rice (247.6 m^{-2}).Correspondingly, at harvest maximum number of tillers (265.0 m^{-2}) was obtained with Sahbhagi Dhan,

Table 1. Effect of different establishment methods and varieties on plant height, Leaf Area Index, number of tillers/m^2, dry matter production, crop growth rate

Treatment	Plant height (cm)				Leaf Area Index				Number of tillers m^{-2}				Dry matter production (g m^{-2})				Crop growth rate (g m^{-2}day^{-1})			
	30 DAS/ DAT	60 DAS/ DAT	90 DAS/ DAT	Harvest	30 DAS/ DAT	60 DAS/ DAT	90 DAS/ DAT	Harvest	30 DAS/ DAT	60 DAS/ DAT	90 DAS/ DAT	Harvest	30 DAS/ DAT	60 DAS/ DAT	90 DAS/ DAT	Harvest	0-30 DAS/ DAT	30-60 DAS/ DAT	60-90 DAS/ DAT	90 DAS/T -Harvest
Establishment Methods																				
M_1	34.5	79.9	107.1	110.0	1.61	4.40	3.87	1.61	130.5	258.5	247.6	240.4	61.6	352.7	797.1	1060.2	2.04	9.70	14.81	10.50
M_2	32.1	86.5	113.6	115.5	1.56	4.86	4.28	1.56	119.0	287.1	273.6	265.8	56.1	384.0	867.7	1154.0	1.89	10.92	16.12	11.45
M_3	31.2	80.8	108.5	111.4	1.51	4.45	3.91	1.51	112.9	160.9	248.9	241.6	53.3	354.7	801.7	1066.3	1.75	10.02	14.91	10.58
SEm±	0.83	2.16	2.10	2.17	0.02	0.07	0.07	0.02	4.19	3.35	4.51	3.62	1.90	6.53	14.55	18.63	0.07	0.25	0.27	0.29
CD (P=0.05)	NS	NS	NS	NS	NS	0.30	0.27	NS	NS	13.5	18.2	14.6	NS	26.3	58.6	75.11	NS	NS	0.08	NS
Varieties																				
V_1	32.8	83.0	110.6	113.1	1.66	4.85	4.27	1.66	138.2	286.2	273.2	265.0	65.2	376.6	851.2	1132.1	2.17	10.34	15.85	11.23
V_2	33.5	84.7	113.1	115.8	1.56	4.56	4.01	1.56	120.7	286.9	256.4	249.0	57.0	371.2	838.8	1115.7	1.86	10.47	15.58	11.07
V_3	35.4	89.4	117.9	120.6	1.61	4.72	4.15	1.61	130.4	278.3	264.9	257.7	61.5	393.5	889.3	1182.7	2.05	11.06	16.51	11.70
V_4	32.3	81.7	108.7	111.2	1.48	4.33	3.81	1.48	107.0	255.1	243.3	236.3	50.5	349.4	789.8	1050.4	1.68	9.96	14.67	10.42
V_5	31.9	80.7	107.3	109.8	1.60	4.70	4.13	1.60	128.5	276.5	263.7	256.0	60.6	356.7	806.2	1072.3	2.02	9.86	14.98	10.64
V_6	29.6	74.9	100.8	103.2	1.45	4.26	3.75	1.45	99.9	247.5	238.6	231.7	47.2	335.3	757.8	1007.9	1.57	9.60	14.08	10.00
SEm±	1.13	2.79	2.94	3.02	0.03	0.09	0.08	0.03	5.74	6.71	6.57	4.75	2.68	8.19	19.50	25.47	0.09	0.28	0.38	0.37
CD (P=0.05)	3.3	8.1	8.5	8.8	0.10	0.27	0.25	0.10	16.7	19.5	19.1	13.8	7.8	23.8	56.6	73.9	0.25	0.82	1.10	1.07
Interaction M × V																				
SEm±	1.96	4.82	5.09	5.23	0.06	0.16	0.15	0.06	9.94	11.62	11.39	8.22	4.64	14.18	33.77	44.12	0.15	0.49	0.66	0.64
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

M_1-Direct seeding of rice; M_2-Puddled transplanting; M_3-Unpuddled transplanting; V_1-Sahbhagi Dhan; V_2-Abhishek; V_3-Sabour Ardhjal, V_4-DRR 42; V_5-Swarna Shreya; V_6-Rajendra Nilam; SEm(±) = Standard error of mean; CD: Critical difference

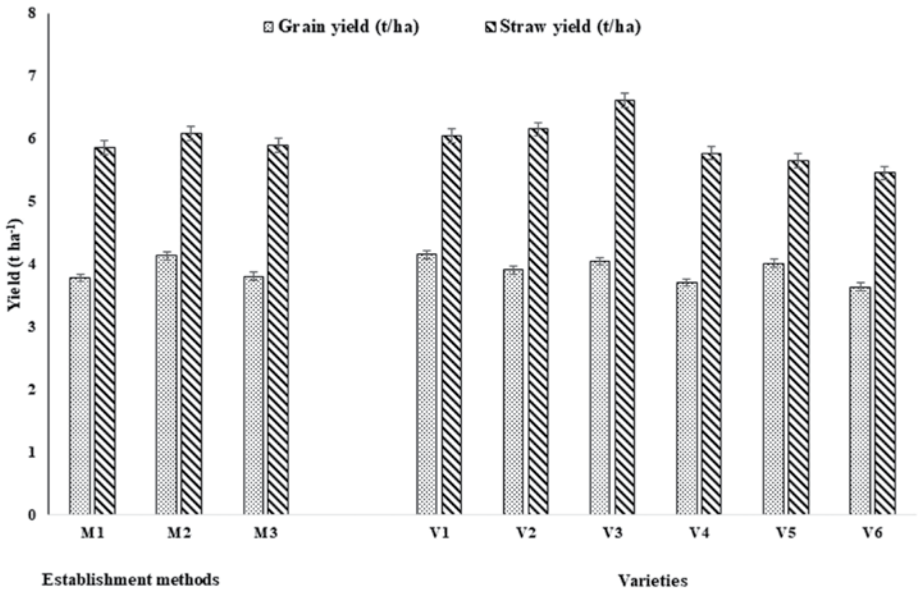

Fig. 1. Effect of different establishment methods and varieties on grain yield (t ha^{-1}) and straw yield (t ha^{-1})

M_1-Direct seeding of rice; M_2-Puddled transplanting; M_3-Unpuddled transplanting; V_1-Sahbhagi Dhan; V_2-Abhishek; V_3-Sabour Ardhjal, V_4-DRR 42; V_5-Swarna Shreya; V_6-Rajendra Nilam

which was statistically at par with Sabour Ardhjal (257.7 m^{-2}) and Sawarna Shreya (256.0 m^{-2}) and significantly superior over rest of the varieties. Sahbhagi Dhan has more tillers due to its ability to adapt to stress conditions with higher water and nutrient use efficiency capabilities, increasing photosynthetic rate and stomatal conductance. These findings are in agreement with those of Baghel*et al.* (2013) and Dinesh *et al.* (2005). Significant variation in dry matter production and crop growth rate was observed among the varieties in all the stages of observation. Sabour Ardhjal recorded higher dry matter production and crop growth rate from 30 days onwards. There is also evidence that Gill *et al.* (2006), Murthy *et al.* (2012), and Sarkar *et al.* (2013) have found similar results.

The highest grain yield was obtained from puddled transplants (4.13 t ha^{-1}), followed by unpuddled transplants (3.80 t ha^{-1}) and direct seeded rice (3.78 t ha^{-1}).In comparison to the other varieties, Sahbhagi Dhan was significantly superior in grain yield. The variety produced 4.15 t ha^{-1}, which was statistically similar to Sabour Ardhjal and Swarna Shreya. According to Sahu *et al.* (2015), puddled transplanting results in higher grain yields than unpuddled transplanting. A similar conclusion was reached by Jha *et al.* (2011) as well.

It can be concluded from these results that puddled transplantation performed significantly better than direct seeding or unpuddled transplanting in terms of plant growth and yield, and Sahbhagi Dhan performed better among different varieties as far as growth and yield were concerned. Hence, for rainfed ecosystem transplantation of drought tolerant rice variety Sahbhagi Dhan under puddled condition may be a viable option for superior growth and yield.

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Compliance with ethical standards: NA

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Authors' contribution:

This article is fully based on M.Sc. research work of the first author (A. Paswan) under the supervision of N. Kumar as major advisor. N. Kumar and A. Paswan conceptualized and designed the experiment. Manuscript has been drafted by S. Sow. All the authors have provided critical feedback in preparation of the manuscript.

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