The Pharma Innovation Journal 2021; 10(10): 1201-1206

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(10): 1201-1206

www.thepharmajournal.com
Received: 16-08-2021
Accepted: 18-09-2021

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Performance of crop establishment methods and stress tolerant rice varieties on growth and yield under rainfed stress-prone upland rice environment of Eastern India

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Abstract
A field experiment was carried out at Banaras Hindu University, Varanasi, Uttar Pradesh, India during *Kharif* seasons of 2017 and 2018 to evaluate the performance of crop establishment methods *i.e*. Puddled transplanted, Direct drill seeding on flat bed, Direct seeding on raised bed-FIRB (furrow irrigated raised bed) and Stress Tolerant Rice Varieties (STRVs) *i.e.* DRR42, DRR44, Sukha dhan 5, Sukha dhan 6, Sarjoo 52 under rainfed stress-prone upland rice environment of eastern India. Result revealed that crop establishment methods and STRVs have significant effect on growth, yield attributes and yield. Direct seeding on raised bed registered significantly higher growth attributes and yield over the conventional method of crop establishment, however its performance was at par with direct drill seeding on flat. Among the tested STRVs, DRR 44 and DRR 42 produced significantly higher growth characters, yield attributes and yield over other varieties. From this experimentation, it can be concluded that establishment of rice by direct seeding on raised bed/direct drill seeding on flat with stress tolerant rice varieties DRR 44/DRR42 should be practiced for better growth, stress tolerance and higher yield under rainfed stress-prone upland rice environment of Eastern India.

Keywords: FIRB, direct drill seeding, puddled transplanting, STRVs

Introduction
Rice (*Oryza sativa* L.) is globally recognized as one of the most important food grain. It is staple food for more than half of the world's population. Worldwide rice covers an area of 161.197 m ha, with an annual production of about 728.18 m t of paddy (IRRI, 2018) [1]. Among the different rice growing countries, India has the largest area (43.5 m ha) but it is the second largest producer (163.52 m t) of rice only after China (203.14 m t). Rice environments in India are extremely diverse and complex, i.e. grown under a wide range of agro-ecological conditions ranging from irrigated, rainfed upland, rainfed lowlands, deepwater and tidal conditions. As major portion (55 per cent) of rice producing area is rainfed, crop often suffer from a variety of stresses like moisture stress, excess moisture/flooding and salinity. In recent years, the area under rice is decreasing due to increased cost on inputs i.e. tillage, transplanting and weeding operations. Simultaneously, non-availability of irrigation water and shortage of labor during peak period of transplanting leads to delay in transplanting causing yield reduction and less profit (Gangwar *et al*., 2008) [3]. The major challenge is to mitigate the potential adverse effects of changing climate so that growth in rice production can be sustained and food security can be achieved. One of the important ways to ensure food security and at the same time provide viable incomes for poor rice farmers in the future is to develop new crop and resource management options like, crop establishment systems and appropriate varieties, that are more tolerant to the adverse effects of a more volatile climate under stress-prone environment (Haefele *et al*., 2010) [6]. As all STRVs do not perform same under different establishment systems, thus site-specific experimentation is required to explore their potential. Hence, to increase the productivity of stress-prone ecosystems, a combination of improved varieties and crop management options that are more tolerant to the adverse climatic effects under stress-prone environment is necessary to ensure food security and to provide higher incomes of resource poor rice farmers (Singh *et al*., 2014) [8]. Considering the importance, therefore, present research was conducted for evaluation of resource conserving crop establishment methods and STRVs for better stress tolerance, enhanced and stable yield,

and higher profitability under rainfed stress-prone upland rice environment.

Materials and Methods

Study area

The present investigation was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (at $25^0$18'N latitude, $88^0$03'E latitude and at an altitude of 75.7 meters above the mean sea level) during *kharif* season of 2017 and 2018. This region falls in semi-arid to sub- humid type of climate and is subjected to extremes of weather conditions *i.e.* extremely hot summer and cold winter. The total rainfall received during the crop growth was 599 mm for the first year (2017) while 778 mm of total rainfall received during second year of experimentation (2018) i.e. more amount of rainfall was received during second year. Fig.1 clearly shows that more uniform distribution of rainfall was observed during the crop growth period in 2018 as compared 2017. The mean monthly maximum temperature ranged from 38.95ºC to 28.08ºC and 37.69ºC to 28.55ºC in 2017 & 2018 respectively whereas, mean monthly minimum temperature during the experimentation ranged from 11.95ºC to 27.05ºC and 26.88ºC to 13.5ºC in 2017 & 2018 respectively (presented in Table.1). The soil of the experimental field was sandy clay loam texture with pH 7.3. It was moderately fertile, being low in available organic carbon (0.33%), available nitrogen (213.66 kg ha^{-1}) and medium in available phosphorus (17.77 kg ha^{-1}) and potassium (218.85 kg ha^{-1}).

Experimental details

The experiment was laid out in split-plot design with three crop establishment methods i.e. puddled transplanted, direct drill seeding on flat bed and direct seeding on raised bed-FIRB (furrow irrigated raised bed) in main plots and five stress tolerant rice varieties (STRVs) *viz*. DRR42, DRR44, Sukha dhan 5, Sukha dhan 6 and Sarjoo52 in sub plots and was replicated thrice (Table. 2).

Nusery raising and sowing

The nursery area was ploughed thrice, levelled and desired seedbed was prepared. Certified seeds of rice varieties DRR42, DRR44, Sukha dhan 5, Sukha dhan 6 and Sarjoo-52 were soaked in water for 12 hours and subsequently sown in the nursery on puddled bed by broadcast method adopting the recommended seed rate of 40 kg ha^{-1}. Field preparation was done with dry ploughing (2 cultivators + levelling) in all crop establishment method. However, puddling was done by wet ploughing (2 cultivators + levelling/churning) in case of conventional puddled transplanting. 27 days old rice seedlings were transplanted to the main field. In case of direct drill seeding on flat, seeding was done with zero till drill machine maintaining the row spacing of 20 cm apart. For direct seeding on raised bed, bed planter was used to prepare the bed of about 15 cm height with 37 cm width and 30 cm furrow. Two rows of rice were seeded on each bed. Seed rate of 40 kg ha^{-1} was used in all establishment methods.

Data collection

Random five plants from each experimental plot were selected and tagged. Plant height (cm) was recorded at different stages with the help of meter scale. The number of tillers from marked area of 0.25 m^{-2} (0.5m × 0.5m quadrant) were counted from two places of each plot at different growth stages of the crop and average of two places were taken and expressed in terms of number of tillers m^{-2}. For recording dry matter accumulation, plants from 0.5 m row length in each plot were cut from the base (border plot area) thenafter samples were dried in sun and then oven dried at 65^0C till the constant weight was achieved. After drying, the samples were weighed for taking dry weight and expressed in g m^{-1}. Leaf area of ten selected leaves was measured by leaf area meter. These leaves were oven dried (at 60–80 °C for 48 h) for getting leaf dry mass. With help of these leaves specific leaf area was calculated. However, for leaf area index measurement plants from 25 cm row length from each plot was randomly selected and were cut from the base. All leaves from the sample were removed and kept for oven drying to get constant weight. Leaf area of this sample was calculated by multiplying specific leaf area of leave with dry weight of sample. Finally leaf area index was calculated by dividing leaf area of sampled area to the ground area covered. The time taken to 50% flowering was recorded based on count from the middle rows of the plot visually. The total number of days taken from seeding to maturity was recorded from each net plot carefully and expressed as days to maturity in numbers. Five panicles were sampled from the tagged plants in each plot. The length of panicle was measured from the base of the panicle to the tip of the top most spikelet. The average of these panicle length were computed and expressed in cm. The number of filled and unfilled spikelets were counted carefully from five selected panicles and then averaged to obtain number of filled and unfilled spikelets $panicle^{-1}$ and expressed in per cent. For recording yield data, Crop was harvested at maturity stage when leaves of plant turned yellow. Produce of each net plot was separately threshed, and grains thus obtained were winnowed, cleaned and weighed. The yield was recorded in g $plot^{-1}$ and converted in Mg ha^{-1}. The biological yield was recorded plot wise and computed to Mg ha^{-1}. The straw yield (Mg ha^{-1}) was recorded plot wise after subtracting grain yield from biological yield after sun drying and computed to Mg ha^{-1}.

Statistical analysis

The data obtained by various observations during the course of investigation were subjected to statistical analysis for determining the significance of difference between the treatments and to draw valid conclusion by adopting appropriate method of 'Analysis of Variance' for split plot design as outlined by Gomez and Gomez (1984) [5]. The level of significance used in 'F' and't' tests was p=0.05. Critical difference values were calculated, wherever 'F' test was found significant.

Result and Discussion

Performance of crop establishment methods and STRVs on growth attributes

The data on different growth attributes were recorded for rice at 90 DAS (Table. 3). Among different crop establishment methods, direct seeding on raised bed (CE3) recorded significantly higher plant height, number of tillers, dry matter accumulation and leaf area index over puddled conventional transplanting (CE1). However, performance of FIRB method was found to be stastically at par with direct seeding on flat during both the year of experimentation. The bed planting method (FIRB) of crop establishment showed more plant height than other methods because it provided better soil conditions and anchorage and hence reduced lodging. Wheras comparatively lower plant height was recorded in case of puddle transplanting (CE1) on account of transplantation shock at early stage. The reason for higher number of tillers might be due to favouable environment in terms of space availability due to border effect, which ultimately resulted in more number of tillers per plant. Direct seeding on raised bed produced maximum dry matter due to higher tiller production and vigorous crop growth than in direct drill seeding on flat and puddled transplanting. These improvements in growth parameter on beds were due to better rooting environment, improved light interception and more efficient nutrient and water use. Similar result had been reported by Lauren *et al*., (2006) [7].

Among different varieties DRR 44 recorded significantly higher plant height, number of tillers, dry matter accumulation, leaf area index at 90 DAS than other tested varieties. However, its performance was at par with DRR 42 in respect to growth attributes during both the years of experiment. Better growth attributes in DRR 44 and DRR 42 might be due to its genetic ability of more tolerance to stress condition which also contributed to good crop stand establishment.

Effect of crop establishment systems and STRVs on 50% flowering, Days to maturity, Panicle length and Fertility percentage of rice

The data pertaining to days to 50% flowering, Days to maturity, Panicle length and Fertility percentage of rice are presented in Table.4. Maximum days to 50 percent flowering and maturity was recorded under puddled transplanting which was significantly higher than other method of crop establishment i.e. direct drill seeding on flat and direct seeding on raised bed during both the years. Direct seeding resulted in early maturity which was mainly due to better root establishment from the day of germination and avoidance of transplanting shock leading up to 10-12 days early maturity than transplanted rice, Similar observation was reported by Gill (2008) [4]. Direct seeding on raised bed recorded highest panicle length and fertility percentage followed by direct drill seeding on flat and puddled transplanting. However, fertility percentage of direct seeding on raised bed was found significantly higher than conventional puddle method of crop establishment. Early flowering and maturity under direct seeding on flat as well as direct seeding on FIRB facilitated to escape the terminal drought stress which resulted in better partioning of grains ultimately resulting to higher fertility percentage.

Significantly early 50% flowering was observed in case of varieties, DRR 42 and DRR 44 as compared to other rice varieties. Sarjoo 52 took more number of days for 50% flowering. Whereas, number of days taken by Sukha dhan 5 for 50% flowering was at par with Sukha dhan 6 (Table. 4). Data pertaining to panicle length and fertility percentage revealed that varieties had significant influence on panicle length. DRR 44 produced significantly higher panicle length over other tested varieties however, remained statistically at par with DRR 42. In case of fertility percentage, DRR 44 had highest fertility percentage but was found at par with DRR 42 and Sarjoo 52 during both the years (Table 4). Yield attributing characters are the function of growth attributes that develop during vegetative phase of plant. Higher values of these yield attributes under DRR 44 were perhaps due to better partitioning of photosynthates from source to sink as result of favourable growing condition, higher grains panicle^{-1}, larger panicles, fertility as well as early maturity which ultimately helped in stress management in rainfed stress-prone upland rice environment. The results are in line with those of Singh *et al*. (2009) [9].

Performance of crop establishment methods and STRVs on yield

The grain and straw yield differed significantly due to crop establishment methods and varieties of rice during both the year of experimentation as presented in Table no.5. Direct seeding on raised bed had produced significantly higher grain and straw yield over the puddled transplanting and was found statistically at par with direct drill seeding on flat. Similar trend was noticed during both the years of experimentation. The reason for higher value of grain, straw and biological yield under direct seeding on raised bed was due to better growth and yield attributes such as panicles m^{-2}, panicle weight, number of grains panicle^{-1} and spikelet fertility percentage. It might be due to favorable border effect in terms of space and resource management, which ultimately helped in facilitating better conversion of photosynthates to yield. Similar results were reported by Bhuyan *et al*. (2012) [2].

Among different STRVs highest grain yield (3.43 & 3.59 Mg ha^{-1}) was recorded in DRR 44 which remained statistically at par to DRR 42 (3.32 & 3.47 t ha^{-1}) but significantly differed from rest of the tested varieties. However, lowest grain yield was recorded in Variety Sukha dhan 5 (2.90 & 3.04 t ha^{-1}) (Table.5). Higher grain under DRR 44 might be due to significantly more panicles m^{-2}, grains per panicle, panicle weight and 1000 grain weight. Yield attributing characters are the function of growth attributes that develop during vegetative phase of plant. Higher values of these yield attributes under DRR 44 were perhaps due to better partitioning of photosynthates from source to sink as result of favorable growing condition, higher grains panicle^{-1}, larger panicles, fertility as well as early maturity which ultimately helped in stress management in rainfed stress-prone upland rice environment.

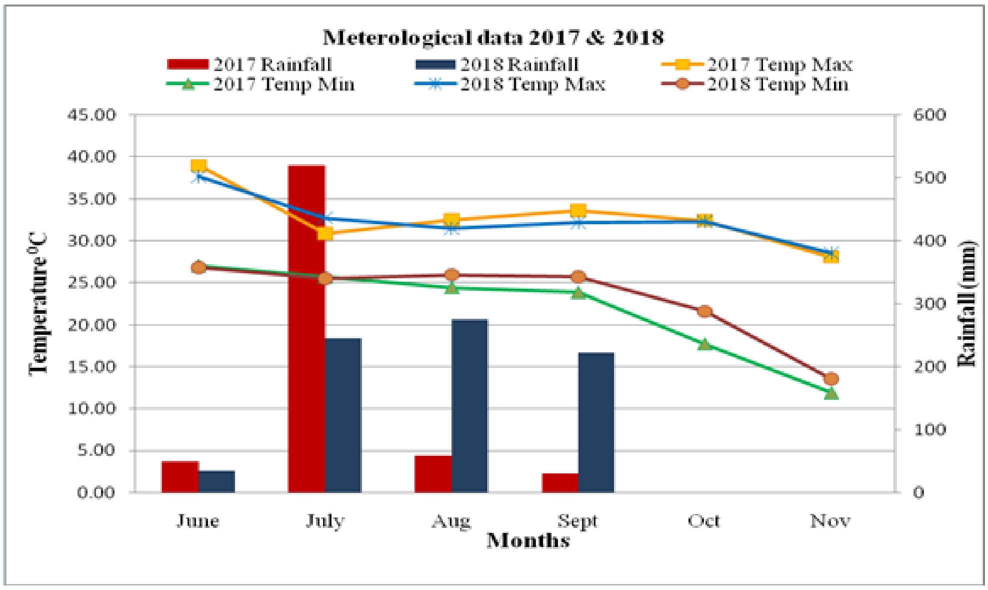

Fig 1: Meteorological parameters during the experimental year 2017 & 2018. Source: Meteorological observatory at the Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi

Table 1: Meterological data of 2017 and 2018

Months	Rainfall (mm)		Maximum Temperature (⁰C)		Minimum Temperature (⁰C)	
	2017	2018	2017	2018	2017	2018
June	48.9	35.7	38.95	37.69	27.05	26.88
July	518.5	245.4	30.86	32.76	25.69	25.54
Aug	57.8	276	32.50	31.48	24.46	25.99
Sept	29.8	223	33.60	32.23	23.89	25.73
Oct	0	0	32.42	32.32	17.77	21.63
Nov	0	0	28.08	28.55	11.95	13.50

Table 2: Treatment detail used during experiment

S. No.	Description	Symbol
	Main plot treatments: 3 (CE - Crop Establishment Methods)	
1.	Puddle transplanting	CE_1
2.	Direct seeding on flat	CE_2
3.	Direct seeding on raised bed (FIRB)	CE_3
	Sub-plots treatments: 5 (STRVs - Stress Tolerant Rice Varieties)	
1.	DRR 42	V_1
2.	DRR 44	V_2
3.	Sukha dhan 5	V_3
4.	Sukha dhan 6	V_4
5.	Sarjoo 52	V_5

Table 3: Performance of crop establishment systems and STRVs on growth attributes of rice (at 90 DAS) under rainfed stress-prone upland rice environment

Treatments	Plant height at 90 DAS (cm)		No. of tillers at 90 DAS		Dry matter accumulation (g m^{-1}) at 90 DAS		Leaf area index at 90 DAS	
	2017	2018	2017	2018	2017	2018	2017	2018
Crop establishment systems (CE)								
Puddle transplanting	97.45	102.69	317.44	325.67	265.35	286.51	4.14	4.22
Direct drill seeding on flat	105.78	105.50	338.37	335.73	271.13	297.38	4.31	4.40
Direct seeding on raised bed (FIRB)	111.49	112.97	346.80	354.27	278.01	309.31	4.44	4.54
SEm±	2.12	2.01	5.69	5.50	2.39	4.32	0.06	0.06
LSD(P=0.05)	8.32	7.91	22.34	21.60	9.39	16.95	0.23	0.23
Varieties (STRVs)								
DRR 42	105.11	108.37	339.44	342.44	289.87	308.11	4.55	4.66
DRR 44	115.71	120.05	358.19	364.22	298.89	317.96	4.76	4.87
Sukha Dhan 5	95.76	99.09	309.93	308.22	245.15	279.60	3.91	3.96
Sukha Dhan 6	105.21	106.58	322.43	330.22	258.03	288.66	4.02	4.12
Sarjoo 52	102.74	101.19	341.02	347.67	265.56	294.34	4.24	4.32
SEm±	2.08	2.50	7.30	7.06	3.06	5.45	0.06	0.06
LSD(P=0.05)	6.08	7.29	21.31	20.62	8.92	15.90	0.18	0.18

Table 4: Effect of crop establishment systems and STRVs on 50% flowering, Days to maturity, Panicle length and Fertility percentage under rainfed stress-prone upland rice environment

Treatments	Days to 50% flowering		Days to maturity		Panicle length		Fertility%	
	2017	2018	2017	2018	2017	2018	2017	2018
Crop establishment systems (CE)								
CE_1: Puddle transplanting	93.9	91.9	126.3	122.4	23.54	24.66	70.76	72.90
CE_2: Direct drill seeding on flat	89.5	87.5	121.0	116.5	23.99	25.13	74.87	76.92
CE_3: Direct seeding on raised bed (FIRB)	88.8	86.8	119.7	115.7	24.31	25.48	76.90	79.14
SEm±	0.2	0.2	0.5	0.3	0.40	0.41	1.15	1.19
LSD (P=0.05)	0.8	0.8	1.8	1.0	NS	NS	4.53	4.68
Varieties (STRVs)								
V_1: DRR 42	87.4	85.4	118.1	114.2	24.79	25.96	76.16	77.96
V_2: DRR 44	88.9	86.9	120.2	115.4	25.68	26.92	77.52	79.87
V_3: Sukha Dhan 5	92.1	90.1	124.1	120.4	22.43	23.51	70.10	72.24
V_4: Sukha Dhan 6	91.0	89.0	122.9	118.9	23.29	24.40	72.52	74.74
V_5: Sarjoo 52	94.1	92.1	126.3	122.0	23.55	24.67	74.59	76.80
SEm±	0.2	0.2	0.3	0.3	0.33	0.36	1.47	1.53
LSD (P=0.05)	0.7	0.7	1.0	0.9	0.98	1.04	4.30	4.45

Table 5: Effect of crop establishment systems and STRVs on yield under rainfed stress-prone upland rice environment

Treatments	Grain yield (Mg ha^{-1})		Straw yield (Mg ha^{-1})		Biological yield (Mg ha^{-1})	
	2017	2018	2017	2018	2017	2018
Crop establishment systems (CE)						
CE_1: Puddle transplanting	3.05	3.17	5.11	5.42	8.16	8.59
CE_2: Direct drill seeding on flat	3.20	3.33	5.37	5.67	8.57	9.00
CE_3: Direct seeding on raised bed (FIRB)	3.31	3.45	5.44	5.80	8.74	9.26
SEm±	0.05	0.05	0.06	0.07	0.11	0.12
LSD (P=0.05)	0.19	0.20	0.25	0.29	0.42	0.46
Varieties (STRVs)						
V_1: DRR 42	3.32	3.47	5.53	5.85	8.85	9.33
V_2: DRR 44	3.43	3.59	5.61	5.99	9.04	9.59
V_3: Sukha Dhan 5	2.90	3.04	4.91	5.27	7.81	8.32
V_4: Sukha Dhan 6	3.05	3.12	5.13	5.33	8.17	8.44
V_5: Sarjoo 52	3.23	3.37	5.34	5.71	8.57	9.08
SEm±	0.05	0.06	0.08	0.09	0.12	0.14
LSD(P=0.05)	0.16	0.16	0.22	0.27	0.36	0.41

Conclusion

Based on the two years experimentation on evaluation of the performance of crop establishment methods and STRVs under rainfed stress-prone upland rice environments, it can be recommended that establishment of rice by direct seeding on raised bed or direct drill seeding with zero till drill on flat alongwith stress tolerant rice varieties DRR 44 or DRR42 should be practiced for better stress tolerance, higher growth and productivity, yield stability and increased profitability in rainfed stress-prone upland rice ecologies of Eastern India.

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