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Effect of crop establishment systems and STRVs on yield and economics of rice under rainfed stress-prone environment

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Abstract
A field experiment was conducted during *Kharif* seasons of 2017 and 2018 at Varanasi, Uttar Pradesh to evaluate the performance of three crop establishment systems *viz*. Puddled transplanted, Direct drill seeding on flat bed, Direct seeding on raised bed-FIRB (furrow irrigated raised bed) and five stress tolerant rice varieties (STRVs) *viz*. DRR42, DRR44, Sukha dhan5, Sukha dhan 6, Sarjoo52 under rainfed stress-prone environment of eastern India. Result revealed that crop establishment methods and STRVs have significant effect on yield. Direct seeding on raised bed recorded significantly higher yield over the conventional method of crop establishment, however was found at par with direct drill seeding on flat. Among all tested STRVs, DRR 44 and DRR 42 produced significantly higher yield over other varieties. Higher net return and B: C was recorded in Direct seeding on raised bed followed by direct drill seeding on flat and puddled transplanted. Among tested varieties higher net return and B: C was produced in DRR 44 followed by DRR42, Sarjoo 52, Sukha Dhan 6 and Sukha Dhan 5. 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 higher yield and net return under rainfed stress-prone environment of eastern Uttar Pradesh.

Keywords: FIRB, direct drill seeding, puddled transplanting

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). 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, i.e. grown under a wide range of agro-ecological conditions ranging from irrigated, rainfed upland, rainfed lowlands, deep water and tidal conditions. Out of 44 m ha of total rice producing area in country, only 45 per cent is irrigated and remaining 55 % is rainfed, out of which 33 per cent is rainfed lowland, 15 per cent is rainfed upland and 7 per cent is flood prone. As major portion (55 per cent) of rice producing area is rainfed, crop often suffer from a variety of stresses. The performance of crop is mainly dependent on the erratic behaviour of south-west monsoon in these rainfed areas. Rice is grown traditionally by transplanting seedlings in puddled soil under favourable rainfed and irrigated lowland condition. Manual transplanting method of rice cultivation is still most common although, it is time consuming, laborious (about 30 man days ha^{-1}) cause drudgery to laborers and costly operation and also results in non uniform and inadequate plant stand. It also deteriorates soil health as puddling leads to the formation of a hard pan at shallow depth. Due to delay in monsoon rains, there is insufficient water for puddling land and prepare for transplanting. It forces farmers to leave their land uncultivated in these cases. This alarming situation is limiting the scope for rice cultivation. The situation is worst in rainfed ecosystems of rice cultivation where drought and submergence occur in the same season at different growth stages of the plant or, in different seasons, thus creates more complex environment. Therefore the need of hour is to search for some alternate methods of rice production which require less water, can adopt under stress environment and does not affect the yield potential of the varieties. Direct seeding method of rice production is one of the methods which refer to the process of growing a rice crop from seeds sown in the main field rather than by transplanting rice seedlings from the nursery. Direct seeded rice (DSR) has many benefits over transplanting. In addition to higher economic returns, DSR have better crop stand due to absence of transplanting shock, with less labour and water requirement.

Other resource conservation techniques of rice establishment is direct seeding on furrow irrigated raised bed (FIRB).

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, varieties etc. that are more tolerant of the adverse effects of a more volatile climate under stress-prone environment (Haefele *et al*., 2010) [6]. A few short duration stress tolerant rice varieties (STRVs) such as Sukha dhan 1, Sahbhagi dhan, DRR 44, DRR 42, BRRI dhan 56, Sukha dhan 2 and Sukha dhan 3 developed by IRRI through conventional breeding, has shown excellent performance in India, Bangladesh and Nepal. Under severe drought, when the yield of control varieties (e.g. IR 64) collapsed, these lines (stress tolerant) could still yield around 0.8-1.0 t ha^{-1} and, under normal conditions, they are as good as or better than the current popular rice varieties being grown in these areas (Dar *et al*., 2014) [4].

Identification of appropriate crop establishment and STRVs is urgently needed for better stress tolerance, enhanced yield stability and profitability under rainfed stress-prone environment. Hence keeping these points in view the present experiment was conducted.

Materials and Methods

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 (2018). The highest rainfall (139.8 mm) and (154.8 mm) was recorded during the 30th and 34th standard meteorological week during first and second year, respectively.

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}). The experiment was laid out in split-plot design with three crop establishment systems i.e. puddled transplanted, direct drill seeding on flat bed, 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, Sarjoo52 in sub plots and was replicated thrice. The allocation of treatments among main plots and sub plots was done randomly. The experimental plot size was 19.8 m^2 with length of 4.5 m and 4.4 m width. Treatments were separated by 0.5 m plot border and 1m replication border. The same land was used during both the years of experiment. A uniform dose of 50 kg P and 50 kg K ha^{-1} and 5 kg Zn ha^{-1} was applied to all treatments. 100 kg of N was applied in split doses as per requirement of crop stages. One-third nitrogen was applied as basal application and the remaining two-third nitrogen were applied in two equal splits at active tillering and panicle initiation stage of the crop. Sources of N, P and K were Urea, Di-ammonium phosphate and Muriate of potash, respectively. Only pre-sowing irrigation was provided for good and uniform crop establishment. However, during second year in addition to pre-sowing irrigation one life saving irrigation was given immediately after the seeding during dry spell for proper seedling emergence.

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. 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 kg plot^{-1} and converted in t ha^{-1}. The straw yield (kg ha^{-1}) was recorded plot wise after subtracting grain yield from biological yield after sun drying and computed to t ha^{-1}. Harvest index was calculated from economic yield (grain) and biological yield (grain + straw) by using the following formula given by Singh and Staskofif (1971) [8].

The economics of various treatments were computed separately by taking into account the existing price of inputs and produce. The investment on fertilizers, labours, and power for performing different operations such as Ploughing, weeding, irrigation, harvesting, threshing and winnowing etc. were worked out per ha as per rate prevalent at the Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U., Varanasi. The cost of cultivation was taken into account for calculating economics of treatments and expressed as gross return (Rs. ha^{-1}), net return (Rs. ha^{-1}) and Benefit: Cost. The yield of rice crop was converted into gross return in ha^{-1} on the basis of current price of the grain and straw. The net return was computed by subtracting cost of cultivation (Rs. ha^{-1}) from gross return (Rs. ha^{-1}). The benefit cost ratio (BCR) was calculated by simply dividing net return (Rs. ha^{-1}) to the cost of cultivation (Rs. ha^{-1}).

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

Effect of crop establishment systems and STRVs on yield and harvest index on rice

The findings of the present study showed that grain yield and straw yield differed significantly due to crop establishment methods and varieties of rice during both the year of experimentation. It was observed from the data that different methods of rice establishment markedly influenced the grain and straw yield of rice. Direct seeding on raised bed had produced significantly higher grain and straw yield over the puddled transplanting and it was found statistically at par with direct drill seeding on flat. However, harvest index was not significantly influenced due to crop establishment methods and varieties. Direct seeding on raised bed had maximum harvest index followed by direct drilling on flat, whereas puddle transplanting attained lowest harvest index (Table.1). Similar trend was noticed during both the years of experimentation. Higher value of grain yield, straw yield and harvest index under Direct seeding on raised bed might be due to the reason that crop under direct seeding on raised bed recorded better growth and yield attributes such as panicles m^{-2}, panicle weight, number of grains $panicle^{-1}$ and spikelet fertility percentage 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) [3].

Among varieties highest grain and straw yield was recorded in DRR 44 (3.43 & 3.59 t ha^{-1}) 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}). Data related to harvest index revealed that highest harvest index was obtained in DRR 44 (37.93& 37.47 %) but was found non significant and remained statistically at par with other varieties in both the years (Table.1). 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 environment.

Table 1: Effect of crop establishment systems and STRVs on yield and harvest index of rice

Treatments	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest index	
	2017	2018	2017	2018	2017	2018
Crop establishment systems (CE)						
Puddle transplanting	3.05	3.17	5.11	5.42	37.32	36.93
Direct drill seeding on flat	3.20	3.33	5.37	5.67	37.34	36.97
Direct seeding on raised bed (FIRB)	3.31	3.45	5.44	5.80	37.79	37.28
S.Em±	0.05	0.05	0.06	0.07	0.22	0.25
LSD(P=0.05)	0.19	0.20	0.25	0.29	NS	NS
Varieties (STRVs)						
DRR 42	3.32	3.47	5.53	5.85	37.45	37.22
DRR 44	3.43	3.59	5.61	5.99	37.93	37.47
Sukha Dhan 5	2.90	3.04	4.91	5.27	37.10	36.61
Sukha Dhan 6	3.05	3.12	5.13	5.33	37.28	36.92
Sarjoo 52	3.23	3.37	5.34	5.71	37.66	37.09
S.Em±	0.05	0.06	0.08	0.09	0.24	0.24
LSD(P=0.05)	0.16	0.16	0.22	0.27	NS	NS

Effect on crop establishment systems and STRVs on Economics of rice

The economics of different treatments are presented in Table 2. The cost of cultivation on crop establishment method indicated that it was maximum under conventional puddle transplanting and minimum under direct drill seeding on flat. The cost of cultivation varied mainly due to differences in land preparation and labour involved for sowing and transplanting whereas for varieties cost of cultivation remained same. As equal amount of seed was used for sowing and seed cost was same. Data revealed that highest Gross return, net return and B:C was obtained for direct seeding on raised bed establishment system followed by direct drill seeding on flat where as minimum under puddled transplanting method. Lowest net return and benefit: cost ratio was recorded under Puddled transplanting because of comparatively higher cost of production and lower yield. Similar finding were concluded by Bhushan *et al*. (2007). Among varieties, DRR 44 recorded maximum gross return, net return and B: C followed by DRR 42, Sarjoo 52, Sukha dhan 6 while minimum with Sukha dhan 5 (Table 2). Higher net return and B:C was assessed with DRR 44 due to higher grain and straw yield on account of better stress management and growth and yield parameters. Similar finding were reported by Nirmala *et al*. (2019) [7].

Table 2: Effect of crop establishment systems and STRVs on economics of rice

Treatments	cost of cultivation		Gross returns		Net return		B:C	
	2017	2018	2017	2018	2017	2018	2017	2018
Crop establishment systems (CE)								
Puddle transplanting	36233.5	37765.5	67672	74504	31438	40044	0.87	1.08
Direct drill seeding on flat	31900	32844	71066	78087	39166	48077	1.23	1.46
Direct seeding on raised bed (FIRB)	32300	33244	72998	80766	40698	50428	1.26	1.52
S.Em±	-	-	986	1100	986	1131	0.03	0.03
LSD(P=0.05)	-	-	3873	4319	3873	4442	0.12	0.13
Varieties (STRVs)								
DRR 42	33477.8	34617.8	73529	81231	40051	49740	1.21	1.46
DRR 44	33477.8	34617.8	75563	83880	42085	52464	1.27	1.54
Sukha Dhan 5	33477.8	34617.8	64605	71730	31128	39946	0.94	1.17
Sukha Dhan 6	33477.8	34617.8	67750	73181	34273	41422	1.03	1.21
Sarjoo 52	33477.8	34617.8	71444	78906	37967	47343	1.15	1.39

S.Em±	-	-	1105	1248	1105	1291	0.03	0.04
LSD(P=0.05)	-	-	3226	3643	3226	3769	0.10	0.11

Conclusion
Based on the evaluation of crop establishment systems and STRVs, 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 stress tolerance, higher yield stability and net return under rainfed stress-prone environment of Eastern Uttar Pradesh.

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