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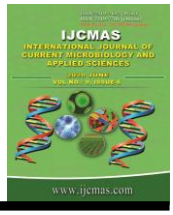

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Effect of Different Establishment Methods and Varieties of Rice (*Oryza sativa* L.) on Growth, Yield, NPK uptake and Soil Fertility after Harvest in Mollisols

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A B S T R A C T

The present investigation was carried out with four establishment methods (wet-direct seeded (Wet DSR), direct seeded aerobic (DSR-aerobic), direct seeded on furrow irrigated raised bed (DSR on FIRB) and conventional transplanting (TPR)) in main plots and eight rice cultivars (Pant Dhan 23, Pant Dhan 24, Pant Shankar Dhan 1, Pant Shankar Dhan 3, Pusa Basmati 1, Pusa 1121, Govind and Pant Dhan 26) in sub-plots in split-plot design. Results showed that TPR produced 4.3 % higher dry matter than Wet DSR. TPR produced 7.63 and 10.75 % higher grain yield than Wet DSR and DSR-aerobic, respectively. Available primary nutrients (N, P and K) as well as their uptake were higher under TPR than other establishment methods. Among varieties, maximum dry matter accumulation and grain yield was observed with Pant Shankar Dhan 3. N and K uptake was the maximum with Pant Dhan 23 while total P uptake was the maximum with Pant Shankar Dhan 3. Higher available P and K were associated with Pusa Basmati 1 and Pusa 1121, and Pant Dhan 23, respectively.

Introduction

Rice is the staple cereal crop of India (Meena *et al.*, 2019) and conventional transplanting is the most adopted rice establishment method among farmers (Singh *et al.*, 2015a) but it needs large quantity of irrigation water ranging from 1,500 and 3,000 mm (Sharma *et al.*, 2002, Singh *et al.*, 2002). Declining water resources coupled with increased demand from other sectors for water have emphasized the need of alternate rice production technology with less water (Singh *et al.*, 2017).

The different alternate rice establishment methods such as wet-direct seeded, direct seeded-aerobic and direct seeding on furrow irrigated raised bed (FIRB) are also important as they save water but with yield penalty.

In wet-direct seeded rice, seeds are either broadcasted or sown in line using drum seeder. Direct seeding of rice is one of the methods of rice cultivation, which refers to the process of establishing rice crop from seeds sown in the field rather than transplanting rice (TPR) seedlings from the nursery where as aerobic rice cultivation is a practice of direct drilling of seeds in rows and maintaining aerobic conditions of the field under limited water availability (Singh *et al.*, 2015b). Growing demand of rice can met by selection of high yielding varieties. However, there are diverse types of rice cultivars (hybrids, high yielding varieties and basmati rice) with different duration which are grown in different areas due to their suitability and consumer demand. Additionally, short duration varieties are also selected to increase the cropping intensity (Khush 2001). Keeping these facts in view, the present investigation was carried out to study the behaviour of hybrid, high yielding, basmati and short duration varieties under different establishment methods.

Materials and Methods

The field experiment was carried out during *kharif* season of 2015 in A_2 block at N. E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The soil of the experimental field was silty loam in texture, slightly alkaline in reaction (pH 7.7), high in organic carbon (0.92 %) and low in available nitrogen (232 kg ha^{-1}), medium in available phosphorus (21 kg ha^{-1}) and available potash (212 kg ha^{-1}). The experiment was laid out in split-plot design with four establishment methods namely wet-direct seeded (Wet DSR), direct seeded aerobic (DSR-aerobic), direct seeded on furrow irrigated raised bed (DSR on FIRB) and transplanted (TPR) in main plots and eight rice cultivars including two high yielding varieties (Pant Dhan 23 and Pant Dhan 24), two hybrids (Pant Shankar Dhan 1 and Pant Shankar Dhan 3), two Basmati varieties (Pusa Basmati 1 and Pusa 1121) and two high yielding short duration varieties (Govind and Pant Dhan 26) in sub-plots taking three replications. Seed rate of different varieties used under different establishment methods is given in Table 1. In DSR-aerobic and DSR on FIRBs, seeds were sown in manually opened furrows at a distance of 20 cm while for Wet DSR, pre-germinated seeds were broadcasted. However, for TPR, 24 days old seedlings were transplanted in puddled field keeping 2 seedlings $hill^{-1}$ at a spacing of 20 cm x 20 cm. The recommended dose of fertilizer *i.e.* 120-60-40 N-P_2O_5-K_2O was used to raise the experimental crop. For Wet DSR, DSR-aerobic and DSR on FIRB, 25 % N plus full dose of P and K was applied before seeding through urea (46 % N), NPK mixture (12: 32: 16) and muriate of potash (60 % K_2O). Rest 75 % N was applied in two splits at active tillering (50 % N) and panicle initiation (25 % N) stage. For TPR, half of the recommended dose of nitrogen was applied basally and the remaining half was applied in two equal splits, each at active tillering and panicle initiation stage. Flood method of irrigation was followed and pre-sowing irrigation was given for seed bed preparation and soil moisture was maintained near saturation at sowing to milking stage in Wet DSR, DSR-aerobic and DSR on FIRB. While in TPR, up to seedling establishment, a thin film of water (2-3 cm) was maintained and then plots were continuously flooded to maintain a ponded layer of 5-6 cm depth during the vegetative stage and after panicle initiation, 2-3 cm depth of water was maintained and plots were drained 15 days before harvest. Pendimethalin @ 1 kg a.i. ha^{-1} was mixed in 750 litre water and was sprayed next day of sowing as pre-emergence and bispyribac sodium @ 0.25 kg a.i. ha^{-1} in 750 to 1000 litre of water was sprayed at 15-20 days after sowing (DAS) as

pre-emergence in DSR-aerobic and DSR on FIRB methods and pretilachlor @ 0.75 kg a.i. ha^{-1} in 750 to 1000 litre of water was sprayed at 6 DAS as pre-emergence in wet direct seeded method and 1-3 days after transplanting (DAT) in transplanted plots to control the weeds. Two weedings were done at 20 and 40 days after sowing by removing weeds manually using a *khurpi*. Zn deficiency (*Khaira*) was controlled by spraying 0.5 % zinc sulphate with 0.25 % slaked lime twice at 15 and 25 days after emergence. Fe deficiency in DSR plots was controlled by spraying $FeSO_4$ @ 0.5 % at 20 days after emergence. There was mild incidence of stem borer which was controlled timely by applying cartap hydrochloride (Calden-G) @ 20 kg ha^{-1}. Grain yield from net plot area was adjusted to 14 % moisture. Recommended agronomic practices were followed to raise the experimental crop. Nitrogen content in grain and straw samples were analysed by micro Kjeldahl method. Phosphorus content was determined by Vanado molybdo phosphoric acid yellow colour method and potassium content by flame photometer (Jackson, 1973). Nutrient (N, P and K) uptake by grain and straw for individual treatment was calculated by multiplying grain and straw yield with respective nutrient content (Nanda *et al.,* 2016) and were added to get total N, P and K uptake. After the harvest of rice crop, soil samples were collected from 0-15 cm depth for each plot and were shade dried and passed through 2 mm sieve.

Soil samples were analysed for available N, P and K by standard methods (Subbiah and Asija 1956, Olsen *et al.,* 1954, Jackson 1973, respectively). The data recorded were analyzed following standard statistical analysis of variance (Gomez and Gomez 1984). Wherever the interaction between establishment methods and rice varieties found significant was presented in a separate two way table.

Results and Discussion

Growth attributes and phenology

Number of tillers m^{-2}, dry matter accumulation, days to 50 % flowering and days to maturity were influenced significantly due to different establishment methods (Table 2). Plant height did not vary with establishment methods but highest plant height was recorded under transplanted establishment methods. Wet DSR produced significantly higher number of shoots m^{-2} than rest of the establishment methods. The more number of shoots m^{-2} in wet-direct seeded and direct seeded-aerobic method is attributed to closer spacing of sprouted seeds which increased the number of plants m^{-2} (Xiang *et al.,* 1999). However, TPR accumulated highest dry matter which was *at par* with wet direct seeded but was significantly superior over direct seeded methods.

Maximum increment in dry matter accumulation in transplanted method might be due to increased amount of photosynthate accumulation, nutrient availability and soil moisture than closely spaced rice plants under rest of the establishment methods. Transplanted establishment method took more number of days to 50 % flowering and days to maturity as compared to other establishment methods. Both direct seeded-aerobic and direct seeded on FIRB took 91 and 121 days to 50 % flowering and days to maturity, respectively which was significantly lower than transplanted method but was *at par* with wet direct seeded.

This finding is supported by a study in which direct seeding of sprouted seeds reduced the duration of rice than under transplanting (Rana *et al.,* 2014). Earlier study suggested that phenological characters (days taken to 50 % flowering and days to maturity) of a particular rice variety vary with season,

nutrient management practice (Nanda *et al.,* 2018) and method of establishment (Rana *et al.,* 2014). Early flowering and maturity in direct seeding methods in the present investigation is attributed to absence of transplanting shock.

Number of tillers m^{-2}, dry matter accumulation, days to 50 % flowering and days to maturity were significantly affected by varieties. Maximum plant height was noticed with variety Pusa basmati 1 which was *at par* with Pusa 1121. Among the different varieties, Pant Dhan 23 recorded significantly highest number of tillers m^{-2} as compared to all other varieties except Pant Shankar Dhan 3, Pant Dhan 24, Pusa 1121 and Pant Shankar Dhan 1.

Variation in plant height and number of tillers m^{-2} might be due to their ability to effectively utilize natural resources *viz.* photoperiod, solar radiations as well as absorb more nitrogen from soil through roots for the synthesis of protoplasm which is responsible for rapid cell division which may increase plant shape and size or due to genetic character of the variety (Gautam *et al.,* 2008). Significantly higher plant dry matter accumulation was recorded in variety Pant Shankar Dhan 3 (1271 g m^{-2}) which was *at par* with variety Pant Dhan 24 and Pant Dhan 23. Higher dry matter accumulation in Pant Shankar Dhan 3 variety might be due to more vegetative growth period for development of more tiller and greater leaf area which lead to production of greater photosynthates which caused production of more dry matter. This corroborates the finding of earlier study (Ghadekar *et al.,* 1988). Highest days taken to 50 % flowering and days to maturity were found associated with variety Pusa Basmati 1 which was comparable with Pant Shankar Dhan 3 and Pusa1121, and Pant Shankar Dhan 3, regarding days taken to 50 % flowering and days to maturity, respectively.

Grain yield

Grain yield was significantly influenced due to different establishment methods and varieties and the interaction effect was also significant (Table 3). Highest grain yield was recorded under TPR (52.71 q ha^{-1}) which was statistically *at par* with Wet DSR (48.97 q ha^{-1}) but significantly higher than DSR-aerobic and DSR on FIRBs. This confirms the finding of a study in which transplanted rice gave higher grain yield than direct seeded rice (Chauhan *et al.,* 2015). Among the varieties, Pant Shankar Dhan 3 gave highest grain yield (56.27 q ha^{-1}) which was significantly greater than rest of the varieties tested except for Pant Dhan 24. Better performance of hybrid and high yielding varieties might be due to better growth and partitioning of photosynthates to reproductive parts (Singh *et al.,* 2017). Highest grain yield (64.58 q ha^{-1}) was obtained in Pant Shankar Dhan 3 variety under TPR which was significantly superior over all other combinations of establishment methods and varieties except for Pant Dhan 24 in TPR (61.98 q ha^{-1}) which was comparable with it.

Nutrient uptake

Different establishment methods had significant effect on nitrogen, phosphorus and potassium uptake by straw and their total uptake by rice crop (Table 4). Maximum nitrogen, phosphorus and potassium uptake by grain (56.6, 11.1 and 22.92 kg ha^{-1}, respectively) and straw (36.6, 2.63 and 41.34 kg ha^{-1}, respectively) and their total uptake (106.8 kg ha^{-1}, 14.6 kg ha^{-1} and 120.3 kg ha^{-1}, respectively) were found in TPR. Puddling in transplanted rice limits percolating water in the field and retains a saturated soil profile, which inhibits nitrification (prevent oxidation of NH_4^+). So leaching loss would have been checked and more nitrogen might have retained in ammonical form leading to more

nitrogen availability under transplanted condition which favoured higher nitrogen uptake (Kirk *et al.,* 1994). More phosphorus uptake by rice under transplanted establishment method might be due to greater phosphorus availability and more grain and straw yield. The higher uptake of potassium in transplanted method might be due to higher nutrient concentration under puddled conditions by the formation of slurry type of structure which restricted water and nutrient losses to the lower depth and provided better opportunity for diffusion and uptake of nutrients and proliferation of roots with in the deep puddled layer (Greenland 1981).

Higher total (grain + straw) N, P and K uptake by rice in transplanting method than semi-dry establishment method has also been observed (Kanthi *et al.,* 2014). Significantly higher total N, P and K uptake by transplanted rice than direct seeded-aerobic rice has also been reported (Singh *et al.,* 2015a).

Different varieties had significant effect on nitrogen, phosphorus and potassium uptake by grain, straw and their total uptake by rice except phosphorus uptake by grain. Maximum nitrogen uptake by grain (57.4 kg ha^{-1}), straw (40.2 kg ha^{-1}) and total uptake by rice (97.8 kg ha^{-1}) was found with variety Pant Dhan 23. Variety Pant Shankar Dhan 3 recorded maximum phosphorus uptake by grain (10.62 kg ha^{-1}) and total phosphorus uptake (15.5 kg ha^{-1}) while maximum phosphorus uptake by straw (2.68 kg ha^{-1}) was recorded in variety Pant Dhan 23, Pant Dhan 24 and Pant Shankar Dhan 1.

Highest potassium uptake by grain (22.93 kg ha^{-1}) and total potassium uptake by rice (128.7 kg ha^{-1}) was found in variety Pant Dhan 24 and potassium uptake by straw (42.18 kg ha^{-1}) was found highest in variety Pant Dhan 23. These results are in accordance with a study in which the maximum NPK uptake was recorded with variety Krisnaveni which was higher than other varieties *viz.* Surya, Sambha Mahsuri and Swanamukhi (Srilaxmi *et al.,* 2005).

Available nutrients in soil

Different establishment methods caused significant variation with regard to available nitrogen, phosphorus and potassium in soil after the harvest of rice crop (Table 5). Significantly higher available nitrogen, phosphorus and potassium in soil were obtained under TPR, which were comparable with Wet DSR with respect to available nitrogen and phosphorus. Higher available nitrogen, phosphorus and potassium in transplanted establishment method as compared to other establishment methods might be due to puddling effect in transplanted method which allows destruction of soil aggregates, dispersion of soil particles and greater amount of water to penetrate into the field. These all factors might have led to better nutrient availability under TPR as a result of improved chemical properties (Gangwar *et al.,* 2008).

Different varieties had significant influence on available phosphorus and potassium in soil after the harvest of rice crop (Table 5). Available P in soil due to variety Pusa Basmati 1 and Pusa 1121 (21.14 kg ha^{-1}) recorded maximum available phosphorus in soil which were at par with rest of the varieties except Govind and Pant Dhan 26. Available potassium in soil was found to be significantly higher where variety Pant Dhan 23 was grown than due to all other varieties. The higher available nitrogen, phosphorus and potassium were found where hybrid and high yielding varieties were grown. This might be due to the vigorous root system of these varieties which enhances activity of microbes in the rhizosphere and increase the availability of nutrient in soil solution.

Table.1 Details of seed rates of varieties under different establishment methods

	Seed rate (kg ha^{-1})			
Varieties	Wet DSR	DSR-aerobic	DSR on FIRB	TPR
Pant Dhan 23	40	40	25	30
Pant Dhan 24	40	40	25	30
Pant Shankar Dhan 1	30	30	20	20
Pant Shankar Dhan 3	30	30	20	20
Pusa Basmati 1	35	35	20	25
Pusa 1121	35	35	20	25
Govind	40	40	25	30
Pant Dhan 26	40	40	25	30

Table.2 Effect of establishment methods and varieties on growth attributes at harvest and phenology of rice

Treatment	**Plant height (cm)**	**Number of tillers m^{-2}**	**Dry matter accumulation (g m^{-2})**	**Days to 50 % flowering**	**Days to maturity**
Establishment method					
Wet DSR	108	291	1153	92	122
DSR-aerobic	106	269	1099	91	121
DSR on FIRB	108	202	892	91	.121
TPR	110	220	1203	95	125
SEm±	0.10	4.4	26.4	0.28	0 .59
CD (P=0.05)	NS	15.4	91.4	1.0	2.06
Varieties					
Pant Dhan 23	108	262	1200	95	125
Pant Dhan 24	108	257	1254	95	126
Pant Shankar Dhan 1	105	247	1065	88	118
Pant Shankar Dhan 3	107	260	1271	98	128
Pusa Basmati 1	111	221	939	99	129
Pusa 1121	110	255	960	96	126
Govind	106	233	914	84	114
Pant Dhan 26	106	229	1096	87	117
SEm±	0.73	7.0	27.7	0.75	0.61
CD (P=0.05)	2.09	20.0	78.51	2.1	1.73

Table.3 Effect of establishment methods and varieties on grain yield of rice

	Grain yield (Q/ha)					
	Wet DSR	DSR-aerobic	DSR on FIRB	TPR	Mean	
Varieties						
Pant Dhan 23	54.86	53.64	44.62	58.92	53.01	
Pant Dhan 24	59.36	55.90	43.75	61.98	55.25	
Pant Shankar Dhan 1	50.86	48.78	35.24	53.64	47.13	
Pant Shankar Dhan 3	58.26	55.38	46.84	64.58	56.27	
Pusa Basmati1	38.54	38.71	31.77	40.52	37.39	
Pusa 1121	43.57	42.70	32.29	44.44	40.75	
Govind	37.50	36.64	35.07	43.42	38.16	
Pant Dhan 26	48.78	48.95	36.18	54.16	47.02	
Mean	48.97	47.59	38.22	52.71		
CD (P=0.05) value						
Establishment methods				1.61		
Varieties				2.70		
Two varieties at same establishment method				5.40		
Two establishment methods at same variety				5.29		

Table.4 N, P and K uptake by grain and straw and their total uptake by rice as influenced by various establishment methods and varieties

Treatment	**N uptake**			**P uptake**			**K uptake**		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Establishment method									
Wet DSR	56.0	36.3	92.3	10.1	2.58	12.7	22.75	41.13	63.88
DSR-aerobic	55.0	34.8	89.8	10.1	2.57	12.7	22.45	40.96	63.41
Direct on FIRB	53.9	34.4	88.3	9.91	2.57	12.5	22.42	40.85	63.27
TPR	56.6	36.6	93.2	11.1	2.63	13.7	22.92	41.34	64.26
SEm±	0.62	0.25	2.04	0.50	0.13	0.13	0.23	0.07	1.80
CD (P=0.05)	NS	0.87	7.07	NS	0.44	0.47	NS	0.23	6.2
Varieties									
Pant Dhan 23	57.4	40.2	97.8	10.51	2.68	13.1	22.92	42.18	65.10
Pant Dhan 24	56.9	38.0	94.9	9.74	2.68	12.4	22.93	41.74	64.67
Pant Shankar Dhan 1	56.0	38.0	94.2	10.2	2.68	12.8	22.73	41.59	64.32
Pant Shankar Dhan 3	55.7	36.0	95.9	10.62	2.56	13.2	23.11	41.48	64.59
Pusa Basmati 1	55.0	35.3	90.3	10.11	2.55	12.7	22.78	41.14	63.92
Pusa 1121	54.1	34.0	88.1	9.97	2.56	12.5	22.34	40.94	63.28
Govind	53.9	32.2	86.1	9.81	2.50	12.3	21.78	39.50	61.28
Pant Dhan 26	54.0	32.6	86.6	9.51	2.49	12.0	21.43	39.97	61.40
SEm±	0.61	0.58	2.41	0.67	0.13	0.27	0.26	0.25	3.42
CD (P=0.05)	1.73	1.65	6.8	NS	0.36	0.77	0.73	0.72	9.7

Table.5 Available N, P and K in soil as influenced by various establishment methods and varieties

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Wet-direct seeded	230.8	20.93	182.4
Direct seeded-aerobic	230.3	20.21	182.4
Direct seeded on FIRB	226.2	19.45	182.4
Transplanted	233.8	21.03	183.5
SEm±	0.9	0.12	0.14
CD (P=0.05)	3.1	0.41	0.47
Pant Dhan 23	233.8	20.71	183.5
Pant Dhan 24	230.6	21.10	182.9
Pant Shankar Dhan 1	230.2	20.76	183.0
Pant Shankar Dhan 3	229.9	20.76	182.5
Pusa Basmati 1	229.9	21.14	182.0
Pusa 1121	228.4	21.14	181.6
Govind	231.5	19.93	181.1
Pant Dhan 26	229.8	19.58	181.0
SEm±	1.30	0.20	0.30
CD (P=0.05)	NS	0.56	0.48

Transplanting establishment method recorded greater dry matter, higher NPK uptake and was associated with higher NPK availability in soil than other establishment methods. Also transplanted rice produced higher grain yield than Wet DSR, DSR-aerobic and DSR on FIRB. In a water scarce condition, Wet DSR is also a possible alternative to transplanted rice in order to achieve higher grain yield. Pant Shankar Dhan 3 was superior in terms of grain yield than other varieties and can safely be taken under various establishment methods to realize higher yields.

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