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Influence of irrigation management practices on performance of rice under different crop establishment methods in eastern indo-gangetic plains of India

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Abstract
Evolution of crop establishment methods on the performance of rice under different irrigation management was done at crop research centre, Pusa, Bihar during *kharif* season of 2017. The experiment was setup in split plot design with three irrigation management as main plot and four methods of crop establishment as sub plot. The treatments were replicated thrice during the experiment. Main plot treatments were continuous submergence throughout crop growth, Saturation maintenance up to P.I. and (5±2cm) after P.I. and alternate wetting and drying (5 cm irrigation at 3 DADPW) up to P.I. and (5±2cm) after P.I. whereas sub plot treatments were and normal transplanting, direct wet seeding on puddled soil, direct dry seeding and broadcasting on un-puddled soil in sub plots. The results showed that the different irrigation practices were not having significant impact on crop growth rate (CGR), dry matter accumulation, Leaf area Index, water productivity and grain yield except nutrient uptake. The maximum N uptake by grain, straw and crop was recorded with continuous submergence throughout crop growth which was statistically at par with saturation maintenance up to PI and (5±2cm) after P.I. In case of uptake of P and K by grain, straw and crop, the maximum was recorded in continuous submergence throughout crop growth which was significantly superior to alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI and saturation maintenance upto PI and (5±2cm) after PI . The impacts of different crop establishment methods on these parameters were found to be significant. The maximum LAI and plant dry matter was observed with normal transplanting which was significantly superior to direct wet seeding on puddled soil, direct dry seeding and broadcasting on un-puddled soil at all the stage of the crop. However, same trend was observed for CGR in latter stages. The maximum grain yield (40.53 q/ha) was recorded with normal transplanting which was significantly superior other treatments in the experiments.

Keywords: Crop establishment, irrigation, nutrient uptake, water productivity

Introduction
Rice is one of the most important cereal crops of *kharif* season. Rice is cultivated worldwide over an area of about 160.68 million ha^{-1} with an annual production of about 650.19 million tonnes. In India rice is cultivated over an area of about 39.16 million hectares with an annual production of about 85.59 million tonnes (Anonymous, 2016). The scarcity of water for agriculture production is becoming a major problem in many countries, particularly in word's leading rice-producing countries like China and India (Prasad *et. al.*, 2001). Its cultivation in India is predominantly practiced under transplanting method that involves raising, uprooting and transplanting of seedlings. This technique requires continuous ponding of water (Pathak *et. al.*, 2011). To avoid these difficulties several other methods of rice cultivation have been developed so far. Farmers of Bihar are facing problems in rice establishment through transplanting because of higher production costs particularly due to shortages of labours, water and escalating fuel prices. The rice cultivation is mostly monsoon dependent in this state, which in turn is extremely erratic in onset, distribution, intensity and cessation. Late monsoon usually delays seedlings raising and transplanting operations thus resulting in lower yield. In such circumstances, direct seeding comprising of drum seeding, broadcasting of either dry or sprouted seeds under puddled condition may be an alternative to transplanting in boosting the rice production. Alternate wetting and drying (AWD) irrigation is water saving technique in rice production and is an important adaptation strategy under changing climatic scenario where water scarcity may become more prevalent. Under AWD, fields are subjected to intermittent flooding where irrigation is interrupted and water is allowed to subside until the soil reaches a certain moisture level, after which the field is again flooded. Keeping these points in view the present investigation was undertaken to evaluate the comparative effects of different

irrigation management practices and crop establishment methods on performance of rice.

Materials and Method

A field experiment in split plot design with three treatments of irrigation management practices *i.e.* I_1-Continuous submergence throughout crop growth, I_2-Saturation maintenance up to PI and (5±2cm) after PI and I_3- Alternate wetting and drying (5 cm irrigation at 3 DADPW) up to PI and (5±2cm) after PI as main plot treatments and four methods of establishment *i.e.* E_1- Normal transplanting, E_2- Direct wet seeding on puddled soil, E_3- Direct dry seeding and E_4- Broadcasting on un puddled soil in sub plots was carried out in *kharif* season of 2017 at Crop Research Centre, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. The experimental site was situated in Samastipur district of North Bihar on the Southern and Western bank of the river *Burhi Gandak* at 25° 59' North latitude and 85°48´ East longitude with an altitude of 52.92 meters above mean sea level. It has sub-tropical and sub humid monsoon climate. The average rainfall of the area is 1276.1 mm out of which nearly 1026.0 mm is received during the monsoon between June and September. The test cultivar was *Abhishek.* The soil of experimental plot was sandy loam in texture, alkaline in reaction (pH-8.5), low in available N 154 kg/ha, P2O5 19.21 kg/ha and K2O 121.00 kg/ha. The crop was fertilized with 120:60:40:25 kg/ha N-P-K-Zn. Application of fertilizers was done at recommended stage. Five plants from each second row were randomly selected for the study of dry matter. The samples were washed, sun dried after that, dried in an oven at 70°C ± 5° C for 48 hours till constant weight was attained. Finally, the dry matter yield was converted into g/sq. m. This study was made at 30, 60, 90 DAS and at harvest. Samples collected at harvest were used for uptake study. The crop growth rate was calculated for the periodical observation in relation to dry matter production per meter, using the following formula.

$$\text{CGR (g/m2/day)} = \frac{W2 - W1}{T2 - T1}$$

Where

W2 = Dry weight in g/m^2 at the end of the period.
W1 = Dry weight in g /m^2 at the start of the period.
T2 - T1 = Length of period in days.

The amount of irrigation applied was measured through Parshall flume. Water productivity was calculated for each irrigation treatments and expressed in Rs/m^3. The formula for calculating water productivity is

$$\text{Water productivity} = \frac{\text{Net returns (Rs/ha)}}{\text{Total water consumed in m3/ha including effective rainfall}}$$

No incidence of diseases and pests occurred during the crop season. Harvesting was done manually with the help of sickles. Before harvesting sample plants were taken separately and tagged for postharvest studies. Data was analysed as per standard statistical procedures.

Result and Discussion

Dry matter production (g/m2)

Influence of irrigation management practices was found to be non-significant at all growth stages of crop (Table 1). However, maximum dry matter production (1008.66 g/m^2) at harvest was recorded with continuous submergence throughout crop growth and minimum with alternate wetting and drying (5 cm irrigation at 3 DADPW) upto P.I. and (5±2 cm) after PI (916.22 g/m^2). Within crop establishment methods, maximum plant dry matter (1096.56 g/m^2) at harvest was observed with normal transplanting which was significantly superior to direct wet seeding on puddled soil (953.07 g/m^2), direct dry seeding (935.42 g/m^2) and broadcasting on un-puddled soil (832.11 g/m^2). This might be due to the fact that photosynthetic activities of the plants are well reflected in their dry matter production. It is a cumulative effect of various growth factors *viz.* plant height, number of tillers/m^2 and numbers of leaves and crop dry matter is directly proportion to biological yield (Anbumani *et al.* 2004) [1].

Table 1: Performance of crop as affected by different treatments

Treatments	CGR(g/m2/day)		Dry Matter Production (g/m^2)				LAI (DAS)		Water Productivity (Rs/m^3)	Grain yield (q/ha)
	30-60 DAS	60-90 DAS	90-harvest	60	90	Harvest	60	90		
Irrigation management										
I1-Continuous submergence throughout crop growth.	10.39	14.09	8.34	335.56	758.38	1008.66	4.85	4.26	3.60	37.22
I2-Saturation maintenance upto PI and (5±2cm) after PI.	9.67	13.11	7.76	312.06	705.25	937.99	4.49	3.95	3.96	34.53
13-Alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI.	9.44	12.80	7.58	304.82	688.89	916.22	4.37	3.85	4.41	33.65
S.Em±	0.27	0.35	0.23	8.69	19.23	26.14	0.10	0.09	0.23	0.78
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crop establishment methods										
E1-Normal transplanting	11.37	15.32	9.07	364.81	824.47	1096.56	5.27	4.64	5.19	40.53
E2-Direct wet seeding on puddled soil	9.82	13.32	7.88	317.07	716.58	953.07	4.56	4.01	3.17	35.09
E3-Direct dry seeding	9.64	13.07	7.74	311.20	703.32	935.42	4.47	3.93	4.17	34.38
E4-Broadcasting on un-puddled soil	8.51	11.63	6.88	276.83	625.65	832.11	3.97	3.49	3.45	30.53
S.Em±	0.41	0.57	0.37	13.31	30.36	41.25	0.15	0.13	0.32	1.14
CD (P=0.05)	1.23	1.69	1.09	39.54	90.22	122.57	0.44	0.39	0.94	3.39

Table 2: Nutrient uptake (kg/ha) by grain, straw and crop as affected by different treatments

Treatments	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Irrigation management									
I1- Continuous submergence throughout crop growth.	40.97	29.85	70.81	10.13	7.86	17.98	8.40	69.08	77.48
I2 - Saturation maintenance upto PI and (5±2cm) after PI.	37.72	26.81	64.53	9.15	6.97	16.12	7.56	63.69	71.24
I3 -Alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI.	36.13	24.98	61.11	8.69	6.64	15.32	7.18	61.73	68.90
S.Em±	0.86	0.85	1.70	0.22	0.23	0.44	0.18	2.04	2.21
CD (P=0.05)	3.39	3.33	6.68	0.88	0.89	1.72	0.69	NS	NS
Crop establishment methods									
E1-Normal transplanting	44.91	31.82	76.73	11.53	8.82	20.35	9.35	76.16	85.51
E2-Direct wet seeding on puddled soil	38.46	27.37	65.84	9.26	7.11	16.36	7.81	65.10	72.91
E3-Direct dry seeding	37.30	26.35	63.65	8.88	6.83	15.71	7.41	62.83	70.24
E4-Broadcasting on un-puddled soil	32.41	23.30	55.71	7.62	5.86	13.48	6.27	55.24	61.50
S.Em±	1.25	1.38	2.62	0.32	0.37	0.67	0.25	3.31	3.56
CD (P=0.05)	3.72	4.11	7.79	0.94	1.09	2.00	0.75	9.84	10.58

Crop growth rate

Crop growth rate was influenced by various growth parameters as well as biochemical and physiological activities of plant. Irrespective of irrigation treatments CGR increased up to 60-90 DAS and there after decreased up to harvest. It may be due to accumulation of photosynthate through photosynthesis during period of crop and then it was distributed towards the root and shoot. This result was in close conformity to Kumar *et al.* (2015) [7]. Among the crop establishment methods, the highest CGR (15.32 g/m^2/day) was observed with normal transplanting at 60-90 DAS which was significantly superior to direct wet seeding on puddled soil (13.32 g/m^2/day), direct dry seeding (13.07 g/m^2/day) and broadcasting on un-puddled soil (11.63 g/m^2/day).

Leaf area index

Leaf area Index did not vary significantly due to the influence of different irrigation treatments. As it was due to adequate supply of moisture which favoured more number of large sizes leaves at all the irrigation management treatments. Similar results were observed by Kumar *et al.,* (2015) [7]. Different crop establishment methods significantly influenced LAI. The maximum LAI (4.64) was observed at 90 DAS with normal transplanting which was significantly superior to direct wet seeding on puddled soil, direct dry seeding and broadcasting on un-puddled soil. This might be due to the facts that plants were at specific distance in normal transplanting and the competition between the plants were minimum thus, crop enjoyed favourable conditions with respect to light, space and nutrients etc. Similar view was expressed by Majeed *et al.,* (2017) [8].

Grain Yield (q/ha)

Rice grain yield with different irrigation management treatments did not varied significantly. Grain yield was obtained maximum with continuous submergence throughout crop growth (37.22 q/ha) which was closely followed by saturation maintenance upto P.I. and (5±2cm) after PI (34.53 q/ha) and alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI (33.65 q/h). This might be due to the fact that photosynthesis activities were not affected due to sufficient availability of soil moisture in all the irrigation management treatments throughout the growing period (Sathish *et. al.,* 2017) [12]. Among the different crop establishment methods exerted a significant effect on grain yield. The maximum grain yield (40.53 q/ha) was recorded with normal transplanting, which was significantly superior to direct wet seeding on puddled soil (35.09 q/ha), direct dry seeding (34.38 q/ha) and broadcasting on un-puddled soil (30.53 q/ha). This may be due to the fact that planting distance ensures air circulation, water and light to the plant the performance is increased. Similar results were obtained by Sahu *et al.,* (2015) [11].

Water Productivity

Water productivity was not significantly influenced due to irrigation management. Though Water productivity with alternate wetting and drying (5cm irrigation at 3 DADPW) upto P.I. and (5±2cm) after P.I. was found to be maximum (4.41/m^3) and minimum (3.60/m^3) at continuous submergence throughout crop growth. This might be due to less water requirement in case of alternate wetting and drying condition. Gangwar *et al.,* (2008) [5] confirmed the similar result. Different crop establishment methods had significant effect on water productivity. Among the various treatments normal transplanting (5.19 /m^3) recorded the maximum water productivity which was significantly superior to direct wet seeding on puddled soil (3.17 /m^3), direct dry seeding (4.17 /m^3) and broadcasting on un-puddled soil (3.45 /m^3). This might be due to high water application in transplanted rice and comparatively higher net returns were obtained. Kulkarni (2011) [6] also confirmed the same result.

Nutrient Uptake

Nutrient uptake is the function of total biomass production and nutrient content in the biomass (Table 2). The maximum N uptake by grain and straw were 40.97 kg/ha and 29.85 kg/ha with continuous submergence throughout crop growth which was statistically at par with saturation maintenance upto PI and (5±2cm) after PI and was significantly superior to alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2cm) after PI. In case of different establishment methods the maximum N uptake by grain and straw were 44.91 kg/ha and 31.82 kg/ha with normal transplanting which was significantly superior to direct wet seeding on puddled soil, direct dry seeding and broadcasting on un-puddled soil. The maximum P uptake by grain (10.13 kg/ha) was obtained with continuous submergence throughout crop growth which was significantly superior over rest of the treatments. In case of different establishment methods the maximum P uptake was recorded with normal transplanting (11.53 kg/ha) which was significantly superior to direct wet seeding on puddled soil (9.26 kg/ha), direct dry seeding (8.88 kg/ha) and broadcasting on un-puddled soil (7.62 kg/ha). There was significant effect of irrigation management on total N and P uptake by rice crop. N uptake was significantly

higher (70.81 kg/ha) with continuous submergence throughout crop growth as compared to alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI but was statistically at par with saturation maintenance upto PI and (5±2cm) after PI. P uptake was significantly higher with Continuous submergence throughout crop growth (17.98 kg/ha) as compared to other treatments. There was no any significant effect on total K uptake due to different irrigation management. This might be due to higher nutrient content in grain and straw. Similar finding was reported by Yadav (2014) [13]. Greater amount of N, P and K uptake was due to higher yield and higher number of irrigation which was conducive for higher uptake of nutrient by the plants. Similar observation was found by Chapagain (2010) [4]. Within crop establishment treatments, the maximum uptake was recorded with normal transplanting (76.73, 20.35 and 85.51) kg/ha which was significantly superior to direct wet seeding on puddled soil (65.84, 16.36 and 72.91) kg/ha, direct dry seeding (63.65, 15.71 and 70.24) kg/ha and broadcasting on un-puddled soil (55.71, 13.48 and 61.50) kg/ha because normal transplanting increased nutrient availability, easy seedling establishment, and creating anaerobic condition to enhance nutrient availability. Chandrapala (2010) [3] confirmed the similar results.

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