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Influence of nutrient management and establishment methods on yield and economics of rice in calcareous soils of Bihar

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Abstract
The present investigation was carried out at Research Farm, Dr. Rajendra Prasad Central Agricultural University Pusa, Bihar during *kharif* 2018 on calcareous sandy loam soil. The experiment was laid-out in a split-plot design (SPD). The main-plot treatments included three crop establishment methods, viz. puddled transplanted rice (M_1-TPR), wet direct-seeded rice (M_2-DSR-wet) and dry direct-seeded rice (M_3-DSR-dry). In sub-plots, five different nutrient management methods were T_1 (100% STCR Based Dose of Fertilizer + $ZnSO_4$ @ 25 kg ha^{-1}), T_2 (75% DF + 25% STCR based Recommended Dose of Nitrogen through Vermicompost), T_3 (100% STCR based Recommended Dose of Nitrogen through Vermicompost), T_4 (100% DF + 50% STCR based Recommended Dose of Nitrogen through Vermicompost) and T_5 (50% DF + 25% STCR based Recommended Dose of Nitrogen through Vermicompost) were replicated thrice under each method. The results found that the plant height, yield attributing characters(number of tillers per meter square, number of panicles per meter square, filled grains per panicles and test weight) and yield recorded significantly higher values under transplanted rice with T_4 (100% DF + 50% STCR based Recommended Dose of Nitrogen through Vermicompost) recording significantly higher values among different nutrient management systems. The economics of all the cultivation practices recorded higher B:C ratio (0.73) and net returns (₹ 34684 ha^{-1}) under DSR-wet with T_1 (100% STCR Based Dose of Fertilizer + $ZnSO_4$ @ 25 kg ha^{-1}) giving farmers an alternative method for rice production.

Keywords: Transplanted rice, direct sown rice, vermicompost, rice

Introduction
Rice (*Oryza sativa* L.) is one of the most important cereal crops and it is a staple food of more than 70 per cent of world's population (Yadav and Singh, 2006) [22].Rice occupies 11 per cent of world agricultural land. Asia dominates the world in rice production as it accounts for about 90 per cent of world's rice area and 92 per cent of production (Pandey *et al.*, 2010) [13]. India is the second largest producer and consumer of rice in the World and India shares around 21 per cent of global rice production. The area under rice crop in our country is about 43.19 M ha with a production of 110.15 MT and productivity of 2550 kg ha^{-1} (Directorate of Economics and Statistics, 2017).
Several long-term experiments all over India indicated a decrease in rice productivity due to continuous use of chemical fertilizers. Integrated nutrient management (INM) aims to improve soil health and sustain high level of productivity and production (Prasad *et al.*, 1995) [16]. Sharma (2002) reported increased yield and nutrient use efficiency in rice with application of organics. Organics supply nutrients at the peak period of absorption, and also provide micro nutrients and modify soil- physical behaviour as well as increases the use efficiency of applied nutrients (Pandey *et al.*, 2007) [14].
In India, transplanting is the common method of establishing rice crop. However, this method is not much profitable due to several reasons such as labour shortage, power crisis and water shortage due to late release of water into the canals, higher cost of cultivation and delayed monsoon showers. This forced to identify alternate methods of rice cultivation without reduction in yield in addition to saving energy, water and time. Further, rice production under current inputs and technology fails to meet the projected demand (Leeper, 2010) thus; there is

an urgent need to increase rice productivity per unit area in the world. Drum seeding is one of the alternative methods to transplanting, as it reduces labour requirement and rice establishment performs as good as transplanting method at many places (Yadav and Singh, 2006) [22]. Hence, the aim of this investigation was to evaluate alternate methods of rice establishment at par in yield and economics to transplanted rice.

Materials and Methods

Field experiment was carried out during *Kharif* seasons in 2017-18 at Research Farm, Dr. Rajendra Prasad Central Agricultural University**,** situated in Samastipur district of Bihar at an altitude of 52.0 m and between 25.98^0 N latitude and 85.67^0 E longitudes.The soil of experimental field was calcareous sandy loamin texture class (56.84%Sand, 31.35 % silt and 11.79% clay) and alkaline in reaction (pH 8.6). It was moderately fertile, medium in soil organic carbon content (0.62 %), electrical conductivity (EC) 0.35 dSm^{-1}, low in available nitrogen (184.82 kg/ha), medium to high in available phosphorus (26.63 kg/ha) and medium in available potassium (134 kg/ha).

The experiment was laid-out in a split-plot design (SPD). The main-plot treatments included three crop establishment methods, viz., puddled transplanted rice (M_1-TPR), wet direct-seeded rice (M_2-DSR-wet) anddry direct-seeded rice (M_3-DSR-dry) In sub-plots, five different nutrient management methods were T_1 (100% STCR Based Dose of Fertilizer + $ZnSO_4$ @ 25 kg ha^{-1}), T_2 (75% DF + 25% STCR based Recommended Dose of Nitrogen through Vermicompost), T_3 (100% STCR based Recommended Dose of Nitrogen through Vermicompost), T_4 (100% DF + 50% STCR based Recommended Dose of Nitrogen through Vermicompost) and T_5 (50% DF + 25% STCR based Recommended Dose of Nitrogen throughVermicompost) were replicated thrice under each method.

Results and Discussion

Plant growth and yield attributes

Plant Height

Plant height (Table-1) was significantly influenced by different establishment methods of rice crop as well as nutrient management. Plant height was significantly higher under M_1-Transplanted rice (102.2 cm) followed by M_2-DSR-wet (100.5 cm) and M_3-DSR-dry (99.6 cm). The maximum plant height in transplanted rice might be due to the reason that plant to plant and row distance were maintained leading to less competition among the plants and deep penetration of roots causing higher nutrient uptake and plant growth. Similar results were also reported by Mahajan *et al*., (2004) [10], Hardev *et al*., (2014) [5] and Kumhar *et al*., (2016) [9]. Among treatmentsThe maximum plant height (102.6 cm) was recorded under treatments $T_4$and T_2(102 cm)was at par withT_4-75% DF + 25% RDN while $T_4$was significantly superior to T_1 -100% DF (100.8 cm),T_3 -100% RDN (99.4 cm) and T_5 -50% DF + 25% RDN (98.8cm). Organic manure with chemical fertilizers performed better in increasing the plant height compared to the application of fertilizer alone. The enhancement in growth with increase in fertility was due to rapid conversion of synthesized photosynthates into protein to form more protoplasm, thus increasing the number and size of cell, which might have increased the plant height.

The highest (351) number of tillers per meter square was recorded under M_1-Transplanted rice and M_2-DSR-wet (348) was found to be at par with it. The number of tillers per meter square under M_3-DSR dry (333) recorded significantly lower value as compared to the other two methods of establishment. The different nutrient management systems also had significant effect on number of tillers per meter square. The treatment T_4-100% DF + 50% RDN recorded significantly higher (361) number of tillers per meter square as compared to T_3-100% RDN and T_5-50% DF + 25% RDN having 326 & 325 tillers per meter square respectively, while treatments T_1-100% DF (349) &T_2-75% DF + 25% RDN with 349 & 357 number of tillers per meter square respectively were at par to treatment T_4-100% DF + 50% RDN. Similar result was recorded by Kumar and Balusamy, (2017) [7].

The panicles m^{-2} revealed significant influence on this yield attribute of rice due to establishment methods. The higher number of panicles m^{-2} was found under M_1-Transplanted rice (335) while M_2-DSR-wet (325) was at par with it and significantly superior to M_3-DSR-dry (321) which may be due to better utilization of all the available native growth resources and the translocation of photosynthates from source to sink. Similar results have also been reported by Rajiv, (2013) [17], Ghasal *et al.*, (2014) [3] and Kumhar *et al*., (2016) [9]. Nutrient management also indicated significant effect on number of panicles m^{-2}. The maximum number of panicles m^{-2} was recorded under T_4-100% DF + 50% RDN (347). The treatmentT_2-75% DF + 25% RDN (335) was at par to T_4 while treatments T_1-100% DF, T_3-100% RDNand T_5-50% DF + 25% RDN with 326,310 & 318 number of panicles m^{-2} respectively were significantly lower as compared to treatmentT_4.It may be due to the fact that organic manure solubilized the nutrients and enhanced the soil properties, resulting in enhanced nutrition of crop plants due to organic manure application. Similar results were also reported by Chaudhari and Suri, (2014) [2].

The establishment methods did not have significant influence on number of unfilled grains panicle^{-1}. Though maximum number of unfilled grains panicle^{-1} was found under M_3-DSR-dry (18) followed by M_2-DSR-wet (16) and M_1-Transplanted rice (15). Similar results were reported by earlier worker Kumhar *et al*., (2016) [9]. On the other hand nutrient management had significant effect on unfilled grains per panicle with treatment T_5 (50% DF + 25% RDN) recording highest (22) unfilled grains per panicle which was significantly higher over all other treatments. The treatments T_1, T_2, T_3 and T_4 recorded 15, 15, 16 & 14number of unfilled grains per panicle respectively and were at par to each other.

The filled grains per panicle (Table-1) varied significantly with regard to crop establishment methods. The M_1-Transplanted rice recorded highest (114) number of filled grains per panicle which was significantly superior to M_2-DSR-wet (109) and M_3-DSR-dry (107) methods. However, M_2-DSR-wet and M_3-DSR-dry were at par to each other. Fertility of spikelets and development of grains depend on environmental factors such as nutrients, moisture and light. Wider spacing facilitated all these and caused higher filled grains per panicle under transplanted rice. Similar results were also reported by earlier worker Kumhar *et al*., (2016) [9]. Nutrient management also had significant effect on filled grains per panicle. Treatment T_4-100% DF + 50% RDN recorded significantly higher (115) filled grains per panicle and treatment T_1-100% DF (111) & T_2-75% DF + 25% RDN (113) were at par with T_4 while treatments T_3-100% RDN (105) and T_5-50% DF + 25% RDN (106) recorded significantly lower filled grains per panicle respectively. Similar result was also reported by Kumar and Balusamy, (2017) [7].

The 000' grain weight (Table-1) was significantly affected due to both, different establishment methods of rice crop and nutrient management systems. Higher test weight was obtained under M_1-Transplanted rice (22.54 g) which was significantly superior to M_2-DSR-wet (22.23 g) and M_3-DSR-dry (22.08 g). Higher thousand grain weight (M_1) may be attributed to the adequate availability of nutrients, its higher uptake and partitioning led to bold and heavier grains in rice crop. Similar result was observed by Kumhar *et al*., (2016) [9]. Under different nutrient management systems, treatment T_4-100% DF + 50% RDN recorded significantly higher (23.16 g) thousand grain weight as compared to all other treatments. It was found that treatments T_3-100% RDN (22.91 g) was at par to T_4-100% DF + 50% RDN while treatments T_1-100% DF (21.58 g), T_2-75% DF + 25% RDN (22.38 g) and T_5-50% DF + 25% RDN (21.41 g) were significantly lower. However, the value of thousand grain weight recorded for T_1-100% DF and T_5-50% DF + 25% RDN were at par to each other, while treatment T_2-75% DF + 25% RDN was significantly higher to both the treatments. This proved that integration of nutrients performed better as compared to inorganics and organics alone. Similar result was recorded by Kumar and Balusamy, (2017) [7].

Table 1: Growth and yield attributes of rice as influenced by nutrient management and crop establishment methods

Establishment methods of rice crop	Plant Height (cm)	Tillers m^{-2}	Panicles m^{-2}	Unfilled Grains $panicle^{-1}$	Filled Grains $panicle^{-1}$	Test Weight (g)
M_1-Transplanted rice	102.2	351	335	15	114	22.54
M_2-DSR-wet	100.5	348	325	16	109	22.23
M_3-DSR-dry	99.6	333	321	18	107	22.08
S.Em±	0.37	1.97	2.46	0.87	1.09	0.06
CD (0.05)	1.5	8	10	NS	4.4	0.27
Nutrient Management						
T_1-100% DF	100.8	349	326	15	111	21.58
T_2-75% DF + 25% RDN	102.0	357	335	15	113	22.38
T_3-100% RDN	99.4	326	310	16	105	22.91
T_4-100% DF + 50% RDN	102.6	361	347	14	115	23.16
T_5-50% DF + 25% RDN	98.8	327	318	22	106	21.41
S.Em±	0.42	7.20	6.45	0.88	2.05	0.15
CD (0.05)	1.2	21	19	2.6	6.0	0.47

Grain and straw yield

The grain yield (Table – 2) was significantly influenced by different establishment methods as well as nutrient management systems. The maximum grain yield was recorded under M_1-Transplanted rice (51.0 q ha^{-1}) which was significantly superior to M_2-DSR-wet (48.5 q ha^{-1}) and M_3-DSR-dry (46.2 q ha^{-1}). Also, M_2-DSR-wet was significantly superior to M_3-DSR-dry. The higher grain yield was recorded under transplanted rice due to more number of panicles, filled grains per panicle and test weight as recorded in this experiment and also the availability of more light, space, nutrients and moisture as puddling also restricts percolation losses. Similar results under transplanting method were also reported by Mallareddy and Padmaja, (2013) [11], Jaiswal and Singh, (2001) [6] and Kumar *et al*., (2018) [8].

The less yields in dry direct seeded rice might be ascribed to lower number of filled grains per panicle and thousand grain weight recorded in this experiment (Singh *et al*., 2016) and also higher loss of water by the mode of seepage and percolation might have caused leaching of nitrogen with percolating water leading to reduced growth. Similar results were also recorded by Ram *et al*., (2006).The different nutrient management systems also affected the grain yield significantly. Treatment T_4-100% DF + 50% RDN (52.1 q ha^{-1}) recorded significantly higher grain yield while treatments T_1-100% DF (48.9 q ha^{-1}) and T_2-75% DF + 25% RDN (49.7 q ha^{-1}) were at par with it and yielded significantly more grains as compared to treatments T_3-100% RDN (47.1 q ha^{-1}) &T_5-50% DF + 25% (44.9 q ha^{-1}). The grain yields recorded for treatments T_3-100% RDN& T_5-50% DF + 25% were at par to each other. This might be due to improvement in nutrient supply with more organics, which improved the soil physico-chemical and biological properties by providing essential food to microbes (Sutaliya and Singh, 2005) [21]. Organics also provided balanced supply of all the essential nutrients, in synchronization with crop needs, uptake and thus result in significantly higher grain yield over inorganic fertilizers (Ghosh, 2007) [4]. Similar result was recorded by Kumar and Balusamy, (2017) [7].

The data of straw yield of rice as influenced by different establishment methods andnutrient management are presented in Table-2. The maximum straw yield was observed under M_1-Transplanted rice (60.8 q ha^{-1}) which was significantly superior over M_3-DSR-dry (56.3 q ha^{-1}) while remaining statistically at par with M_2-DSR-wet (58.5 q ha^{-1}). The straw yield recorded under M_3-DSR-dry was at par to M_2-DSR-wet. This could be due to superior accumulation of photosynthates all over vegetative growth. Similar observations were recorded by Kumhar *et al.*, (2016) [9]. The straw yield as affected by different nutrient management systems revealed that all treatments varied significantly. Maximum straw yield was recorded under treatments T_4-100% DF + 50% RDN (62.7 q ha^{-1}) followed by T_2-75% DF + 25% RDN (60.1 q ha^{-1}) which was at par with T_4-100% DF + 50% RDN. Both these treatments were significantly superior to the other treatments. It was observed that treatment T_1-100% DF (58.3 q ha^{-1}) was at par with treatment T_2-75% DF + 25% RDN and yielded significantly more straw as compared to treatments T_3-100% RDN (57.0 q ha^{-1}) &T_5-50% DF + 25% RDN (54.5 q ha^{-1}). The straw yields recorded under treatments T_3-100% RDN& T_5-50% DF + 25% RDN were found to be at par to each other and significantly lower to other treatments. The results revealed that the application of organic manures with 50% and 100% DF registered higher straw yield of rice than 100% RDF alone. Reddy *et al.*, (2004) [19] found that significant effects of combined application of manures and fertilizers on straw yield. Similar result was recorded by Kumar and Balusamy, (2017) [7]. It is noteworthy that though additional amount of organics in T4 caused higher grain and straw yield but T2 was found to be at par with it leading to reduction in the use of chemical fertilizers which would lower the cost of production and maintain good soil health for a longer period of time.

Table 2: Grain and straw yield, cost of cultivation, net returns and benefit-cost ratio of growing rice under the influence of different nutrient management systems and crop establishment methods

Establishment methods of rice crop	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	Cost of cultivation (` ha^{-1})	Gross Returns (` ha^{-1})	Net Return (` ha^{-1})	B:C Ratio
M_1-Transplanted rice	51.0	60.8	65,265	94,734	29,468	0.51
M_2-DSR-wet	48.5	58.5	55,590	90,275	34,684	0.73
M_3-DSR-dry	46.2	56.3	57,662	86,196	28,533	0.58
SEm±	0.42	0.59	-	717	717	0.014
CD (0.05)	1.71	2.38	-	2,892	2,892	0.06
Nutrient Management						
T_1-100% DF	48.9	58.3	43,163	90,893	47,730	1.12
T_2-75% DF + 25% RDN	49.7	60.1	52,761	92,561	39,800	0.76
T_3-100% RDN	47.1	57.0	83,774	87,769	3,995	0.05
T_4-100% DF + 50% RDN	52.1	62.7	67,479	96,970	29,491	0.44
T_5-50% DF + 25% RDN	44.9	54.5	50,355	83,815	33,460	0.67
SEm±	1.28	1.21	-	1,825	1,825	0.033
CD (0.05)	3.76	3.56	-	5,358	5,358	0.10

Economics

The returns from cost of cultivation (Table–2& Fig.1) revealed that there was a significant difference in gross returns due to different establishment methods of rice. The maximum gross returns were recorded under M_1-Transplanted rice (₹ 94734 ha^{-1}) which was significantly superior over M_2-DSR-wet (₹ 90275 ha^{-1}) and M_3-DSR-dry (₹ 86196 ha^{-1}). Similar results were found by Mallareddy and Padmaja, (2013) [11], Pasha *et al.*, (2012) [15] and Kumar *et al.*, (2018) [8].
Under nutrient management, treatment T_4-100% DF + 50% RDNreported highest gross returns(₹ 96970 ha^{-1})because of higher grain and straw yield recorded in this treatmentwhich was significantly superior to rest of the treatments except T_2-75% DF + 25% RDN (₹ 92561 ha^{-1}). Bejbaruha *et al.*, (2009) [1] reported similar results.
However, the data on net returns revealed significant variation among different rice establishment methods. Maximum net returns were found under M_2-DSR-wet (₹ 34684 ha^{-1}) which was significantly superior over M_1-Transplanted rice (₹ 29468 ha^{-1}) and M_3-DSR-dry (₹ 28533 ha^{-1}). Net returns were higher in M_2-DSR-wet than M_1-Transplanted rice because it saved the expenditure incurred on nursery raising, uprooting and transplanting. Mallareddy and Padmaja, (2013) [11], Pasha *et al.*, (2012) [15] and Kumar *et al.*, (2018) [8] also reported similar results.The effect of nutrient management caused significant effect on net returns and maximum net returns was recorded under T_1-100% DF (₹ 47730 ha^{-1}) which was significantly superior over rest of the treatments and minimum net returns was found under T_3-100% RDN (₹ 3995 ha^{-1}). Net return was higher under T_1-100% DF because of low cost of chemical fertilizer at same level of nutrients compared to organic manure. Similar results were found by Bejbaruha *et al.*, (2009) [1].
The data on benefit cost ratio revealed significant effectdue to different rice establishment methods. Higher benefit-cost ratio was found under M_2-DSR-wet (0.73) which was significantly superior over DSR-dry (0.58) and M_1-Transplanted rice (0.51). M_2-DSR-wet recorded higher benefit-cost ratio due to less weed competition compared to M_3-DSR-dry and also saved expenditure incurred on nursery raising, uprooting and transplanting. These results are in conformation with Mallareddy and Padmaja, (2013) [11], Pasha *et al.*, (2012) [15] and Kumar *et al.*, (2018) [8]. Nutrient management also indicated significant effect on benefit cost ratio. The highest B: C ratio was recorded under T_1-100% DF (1.12) which was significantly superior over rest of the treatments and lowest B: C ratio was found under T_3-100% RDN (0.05). Similar results were in found by Bejbaruha *et al.*, (2009) [1].

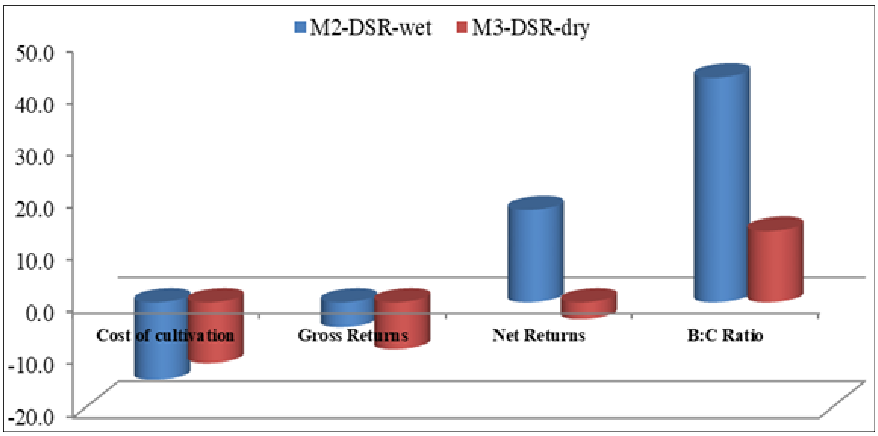

Fig 1: Percent increase or decrease in different economic properties DSR-wet and DSR

Conclusion

It may be concluded from the results of this investigation that among three methods of crop establishment, the transplanted method still performed better in terms of yield attributing character, grain and straw yield. However, the experiment also indicated that the DSR-wet method could also be a better option as it reduces the cost of cultivation thus increasing the cost-benefit ratio vis-à-vis maintaining soil fertility. The nutrient management systems gave an insight in to the experiment with T_4-100% DF + 50% RDN performing better than other treatments but at the cost of extra dose of nutrients which might increase the cost of cultivation. At the same time treatment T_2-75% DF + 25% RDN with reduced cost of cultivation and adequate balance of nutrients also performed better, was either at par or sometimes superior for certain yield parameters giving the farmersa better cost effective alternative for higher yields along with sustenance of soil health.

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