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Yield, nutrient uptake, quality and economics of rice (*Oryza sativa* L.) as affected by various crop establishment methods and nitrogen levels

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Abstract
A field experiment was conducted at Agronomy Research farm, College of Agriculture, N. D. University of Agriculture and technology, Kumarganj, Faizabad, U.P. during *kharif* season of 2016-17 to find out the best crop establishment methods and the optimum nitrogen dose for obtaining higher yield of rice. During the experiment, common packages of practices were followed time to time and periodically are observations were recorded on growth and yield for evaluate the treatment effects. The results obtained during the study revealed that grain and straw yield of the different establishment techniques were in the order, SRI method, conventional transplanting method followed by direct seeding method. The highest no. of panicle m^{-2} (447.15), length of panicle (21.20 cm), no. of grains $panicle^{-1}$ (158.03), test weight (24.60 g), straw yield (61.42 q ha^{-1}), grain yield (52.14 q ha^{-1}) and harvest index (45.91%) under SRI method of crop establishment. The nitrogen uptake and its contents in rice (both in grain and straw) were found to be the maximum with SRI method (M_2) while lowest nitrogen uptake and its content contents in rice (both in grain and straw) were found to be with direct seeding method. Among the nitrogen levels tried, the maximum no. of panicle m^{-2} (413.30), length of panicle (22.99 cm), no. of grains panicle $^{-1}$ (166.39), test weight (23.97 g), straw yield (60.23 q ha^{-1}), grain yield (51.25 q ha^{-1}) and harvest index (45.97%) obtained with application of 160 kg N ha^{-1}. The nitrogen uptake and its contents in rice (both in grain and straw) were found to be the maximum with application of 160 kg N ha^{-1}, which was comparable with 120 kg N ha^{-1} While, the lowest uptake and its contents in rice (grain and straw) was associated with 0 kg N ha^{-1}. The highest gross return (Rs. 106698.4), net return (Rs. 72329.7) and B-C ratio (1:2.10) were recorded with M_2N_4 treatment combination (SRI method with application of 160 kg N ha^{-1}). Based on the results obtained, it can be concluded that SRI method is a better establishment method of rice because it produces more yield and gross monetary economic return with 160 kg N ha^{-1} than other methods and nitrogen levels.

Keywords: SRI, conventional transplanting, direct seeding, yield, nitrogen levels

Introduction
"Rice is Life" for millions of people and staple food for more than half of the world's population. Rice is one of the most important food crop of India in terms of area, production and consumer preference. India is the second largest producer and consumer of rice in the world. Rice provides about 700 calories day^{-1} $person^{-1}$ for about 3000 million people living mostly in developing countries (Sangeetha and Baskar, 2015) [13]. Rice production in India crossed the mark of 111.01 million tonnes in 2017-18 with area of 43.50 million ha. The average productivity of rice in India is 2590 kg ha^{-1} (Anonymous, 2017-18) [2]. Its production has to be raised to 160 million tonnes by 2030 with a minimum annual growth rate of 2.35% to meet the future rice requirement (Venkatramani, 2005) [18].
Rice is traditionally grown by transplanting seedlings into puddled soil. Puddling benefits rice by reducing water percolation losses, controlling weeds, facilitating easy seedling establishment, and creating anaerobic conditions to enhance nutrient availability. But, repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers, and forming hard-pans at shallow depths. Traditionally, transplanting seedlings entails lot of expenditure on raising nursery, uprooting and transplanting. A shortage of labour during peak periods increases labour wages and make transplanting operation costly (Mahajan *et al.*, 2009) [10], necessitate the search for an alternative to conventional method of transplanting.
Direct seeding of sprouted seeds in puddle soil (wet seeding) either manually or drum seeding method holds special significance in the present day production systems by saving time, labour and energy. Direct-seeded rice occupies 26% of the total rice area in South Asia (Gupta *et al.*, 2006) [6].

Direct seeded rice (DSR), being a cost effective, consumes less water and labour saving crop establishment method, is becoming popular. DSR is efficient resource conservation technology which saves the labour to the extent of about 40% and water up to 60% (Nainwal *et al*., 2013) [11].

The System of Rice Intensification (SRI) is a new methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients resulting in both healthy soil and plants, supported by greater root growth and the soil microbial abundance and diversity. If SRI were to be applied with the water now being used for rice irrigation, it would be able to increase irrigated area by 50%, leading to 50% increase in rice production (Thakkar, 2005) [17]. Higher yield with fewer inputs, like water, fertilizers, seed, etc. have made SRI attractive and rewarding, particularly for the resource poor small and marginal rice farmers. It is also useful to resource rich larger farmers.

Nitrogen (N) is the most important yield-limiting nutrient for rice. Increased rice production is largely attributed to the increased use of N fertilizer. In rice production, efficient use of N fertilizer is a critical factor in achieving high and stable yield, while minimizing negative effects to the environment. Rice yield per unit area per unit time is dependent on adequate fertilization. Nutrient requirement may, however, differ under various establishment methods. Hence, there is a need to evaluate non-conventional systems of rice crop establishment together with optimal nitrogen dose to realize the production potential of alternate systems of crop establishment.

Materials and Methods

A field experiment was conducted at Agronomy Research Farm of Narendra Deva University of Agricultural and Technology, Kumarganj, Faizabad (U.P.) situated in Faizabad district at 26.47º North latitude and 82.12º East longitudes with an altitude of 113 meters above the mean sea level, during *kharif* season of 2016-17. The experimental site was silt-loam in texture and slightly alkaline in reaction (8.10 pH), low in organic carbon (0.43%) and available nitrogen (160 kg ha^{-1}), medium in available phosphorus (16.5 kg ha^{-1}) and potassium (260 kg ha^{-1}). The experiment was laid out in split-plot design with (A) three crop establishment techniques as main plot treatments *viz*., Conventional transplanting (M_1), SRI (M_2) and Direct seeding (M_3) and (B) five nitrogen levels as sub-plot treatments *viz*., Control (N_0), 40 kg N ha^{-1} (N_1), 80 kg N ha^{-1} (N_2) and 120 kg N ha^{-1} (N_3) and 160 kg N ha^{-1} (N_4) and replicated thrice. The recommended dose of nitrogen as per recommendation, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied through urea, single super phosphate and murate of potash, respectively. Entire P_2O_5 and K_2O was applied basally to all the treatments duly taking into consideration of the phosphorus and potassium content of the organic manure. Nitrogen was applied as per the treatments in 3 split doses of 50% basal and 25% each at active tillering and panicle initiation stages, respectively.

Results and Discussion

Effect on yield and yield attributes

Yield is the ultimate outcome of the crop efficiency as influenced by various management practices is show in Table-1. Environment and input act on the plants which ultimately produce the desirable economic product. This is because of total dry matter production as well as the efficiency of its conversion is amenable to various management practices and processes. The final yield of rice is the result of the successful completion of growth and development activities which in turn depends on the genetic potential of the genotype, the environmental conditions to which it is exposed during the course of its life cycle and agronomic management efficiencies.

The findings of the present study showed that yield attributes *viz.*, panicle length, grains per panicle and number of panicle m^{-2} differed significantly due to crop establishment methods of rice during experimentation except test weight (1000 - grain weight) had non-significant effect.

However, SRI method of rice establishment recorded higher yield attributes compared to conventional transplanting and direct seeded rice during experimentation. This might be ascribed to the availability of more nutrients; light, space, moisture as well as lesser plant competition within row might be also the reason. This impact has made it possible to record more number of tillers m^{-2} with heavier panicles contributing to higher grain yield with SRI method. Higher yield attributes under SRI method were also reported by Krishna *et al.* (2008) [9] and Senthil, (2015) [14].

Among the nitrogen levels, application of 160 kg N ha^{-1} recorded significantly higher panicle length, grains $panicle^{-1}$, number of panicles m^{-2} which is at par with application of 120 and 80 kg N ha^{-1} but test weight had non-significant effect. Increased yield attributes with higher nitrogen application might be due to better growth characters which ultimately resulted in higher production and translocation of photosynthates towards panicles. Higher nutrition to crop leads to better leaf area index development which provided more photosynthetic organs and more photo-assimilates to be accumulated in economic part of crop. Similar findings were reported by Dwivedi *et al.* (2006) [5] and Alagesan and Babu (2011) [1].

Table 1: Yield, nutrient uptake and quality of rice (*Oryza sativa* L.) as affected by various crop establishment methods and nitrogen levels.

Treatments	Yield attributes and yield							Nitrogen and protein content (%) in grain and straw			Nitrogen uptakes by crop (kg ha^{-1})		
	No. of panicle (m^{-2})	Length of panicle (cm)	No. of grains $panicle^{-1}$	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	H.I. (%)	N-content in grain	N- content in straw	Protein content in grain	N -uptake by grain	N - uptake by straw	Total nitrogen uptake by crop
A- Crop establishment techniques													
M_1-C.T.	405.76	20.71	152.88	24.36	45.43	54.72	45.36	1.16	0.444	7.25	52.69	24.29	76.98
M_2- SRI	447.15	21.20	158.03	24.60	52.14	61.42	45.91	1.17	0.448	7.31	61.01	27.51	88.51
M_3-DSR	367.42	17.99	126.43	24.26	36.82	47.71	43.55	1.13	0.440	7.06	40.13	20.99	61.12
S. Em. ±	1.82	0.47	5.40	0.18	0.24	0.12	1.22	0.01	0.004	0.054	0.08	0.05	0.06
CD (P=0.05)	7.13	1.82	21.22	NS	0.95	0.48	NS	0.04	0.015	0.213	0.30	0.19	0.23
B- Nitrogen levels (kg ha^{-1})													
N_O-Control	397.88	16.43	119.92	22.88	36.42	46.24	34.30	1.12	0.431	7.00	42.01	15.91	67.09
N_1- 40	404.15	19.71	143.90	23.10	42.23	52.78	42.10	1.15	0.442	7.19	47.78	20.99	72.38

N_1- 80	408.04	21.35	155.90	23.24	45.58	54.29	45.63	1.17	0.451	7.31	51.95	24.91	76.33
N_1- 120	410.15	22.38	163.39	23.78	47.65	56.32	45.83	1.21	0.454	7.50	55.71	28.60	80.06
N_1- 160	413.30	22.99	166.39	23.97	51.25	60.23	45.97	1.24	0.458	7.75	58.72	31.11	81.99
S. Em. ±	2.79	0.51	2.28	0.50	0.21	0.22	3.87	0.015	0.006	0.02	0.10	0.05	0.10
CD (P=0.05)	8.14	1.47	8.10	NS	0.61	0.64	NS	0.043	0.016	0.268	0.31	0.14	0.30

Table 2: Economics of rice (*Oryza sativa* L.) as affected by various crop establishment methods and nitrogen levels.

Treatment combination	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	Gross Return (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B-C Ratio
M1NO	35.34	46.87	66715.2	32868.9	33846.3	1.03
M1N1	43.56	52.15	79680.0	33477.6	46202.4	1.38
M1N2	46.66	55.36	85615.2	34086.3	51528.9	1.51
M1N3	49.65	58.37	91089.6	34695.0	56394.6	1.63
M1N4	52.57	60.88	95276.0	35303.7	59972.3	1.70
M2N0	44.13	53.56	81889.6	31933.9	49955.7	1.56
M2N1	49.76	58.13	90667.2	32542.6	58124.6	1.78
M2N2	52.05	61.89	95979.2	33157.3	62821.9	1.89
M2N3	55.88	65.13	102157.6	33760	68397.6	2.02
M2N4	57.78	68.39	106698.4	34368.7	72329.7	2.10
M3N0	28.96	39.66	55276.8	28743.9	26532.8	0.92
M3N1	34.86	45.67	65691.2	29352.6	36338.6	1.23
M3N2	37.56	48.83	70382.4	29962.3	40420.1	1.35
M3N3	40.32	51.09	74999.2	30570.0	44429.2	1.45
M3N4	42.60	53.30	79446.4	31178.7	48267.7	1.55

Note: M_1, M_2 and M_3 = Crop establishment methods namely conventional transplanting, SRI and direct seeding of rice and N_0, N_1, N_2, N_3 and N_4 = Different nitrogen levels (0, 40, 80, 120 and 160 kg N ha^{-1}), respectively.

Yield and Harvest index

The findings of the present study showed that grain yield and straw yield was differed significantly due to different crop establishment methods of rice and nitrogen levels during the experimentation. However, SRI method of crop establishment recorded higher grain yield and straw yield compared to conventional transplanting and DSR. This might to be due to SRI method of crop establishment recorded higher growth and yield attributes which would have facilitate better conversion of photosynthates to yield. Similar results were reported by Rajeshwar and Khan (2008) [12] and Sowmyalatha *et al.* (2012) [15].

About Nitrogen levels, application of 160 kg N ha^{-1} followed by 120 kg N ha^{-1} recorded higher grain yield and straw yield. It may be due to the fact that higher level of nitrogen may result in prosperous growth and which ultimately contributed in to the higher biomass accumulation and improve the straw yield to the level of significance. Similar findings were reported by Das *et al*. (2009) [4].

Harvest index is the function of grain yield to the total biological yield (grain + straw). Harvest index influenced non-significantly due to various methods of establishment. The higher harvest index was recorded under SRI method (45.91%), due to higher grain yield of rice per unit biological yield, led higher harvest index. Similar findings have also been reported by Stoop *et al*., (2005) [16] and Hussain *et al*. (2003) [19]. Harvest index also influenced non-significantly due to different nitrogen levels. The higher harvest index was recorded with 160 kg N ha^{-1} (45.97%), due to higher grain yield of rice per unit biological yield, led higher harvest index.

Effect on nitrogen and protein content in crop

Perceptible differences were observed with regard to nitrogen content in grain and straw of crop and protein content in grain among the crop establishment methods tried. Nitrogen content in grain and straw of rice crop as well as protein content in grain were found to be the maximum with SRI method (1.17%), which was comparable with conventional transplanting (1.16%). The lowest was associated with direct seeded rice (1.13%). Among the nitrogen levels, application of 160 kg N ha^{-1} recorded significantly higher nitrogen content in grain (1.24%) and (0.458%) straw while lowest nitrogen content both in grain (1.12%) and straw (0.431%) recorded in control.

Effect on nitrogen uptake by crop

Perceptible differences were observed with regard to nitrogen uptake among the crop establishment methods tried. Nitrogen (61.01 kg ha^{-1}) uptake by grain was found to be the maximum with SRI method (M_2) which was significantly superior over rest of crop establishment methods. The lowest nitrogen uptake by grain (40.13 kg ha^{-1}) was associated with direct seeding (M_3). Different levels of nitrogen had significant effect on nitrogen uptake by grain. It was recorded significantly higher (58.72 kg ha^{-1}) with 160 kg N ha^{-1}) which was superior over rest of treatments. The lowest nitrogen uptake (40.01 kg ha^{-1}) by grain was recorded with control. Similar trends were also reported in nitrogen uptake by straw during experimentation.

The highest total nitrogen uptake of nitrogen (88.51 kg ha^{-1}) by crop (grain and straw) was obtained in SRI methods (M_2) being significantly superior over transplanting and direct seeding techniques of rice establishment. The minimum total nitrogen uptake (61.12 kg ha^{-1}) was recorded in direct seeding method. Similar result was reported by (Barison, 2002) [3]. Among the nitrogen levels, the highest total nitrogen uptake by crop (grain and straw) was recoded with 160 kg ha^{-1} while minimum total nitrogen uptake (67.09 kg ha^{-1}) was recorded in direct seeding method of crop establishment. These results are in close conformity to the findings of Zhang *et al.*, (2003) [8].

Effect on economics of crop

The data presented in table-2 revealed that the cost of cultivation, gross return, net return and B-C ratio varied with crop establishment methods and different nitrogen levels. Among the various treatment combinations, the minimum cost of cultivation (Rs. 28743.93 ha^{-1}) was found without nitrogen (0 kg N ha^{-1}) in conjunction with direct seeding method (M_3), which increased with increase in dose of nitrogen and crop establishment methods. The maximum cost of cultivation (Rs. 35303.76 ha^{-1}) was recorded with 160 Kg N ha^{-1} in conjunction with SRI method due to more investment on nitrogen and cost of production. Gross monetary return is directly related to the value of produce in market. Among the different combinations the lowest gross monetary return of Rs. 26532.87 ha^{-1} was recorded in treatments of 0 kg N ha^{-1} with direct seeding method (M_3). Maximum value of net return Rs. 72329.7 ha^{-1} was recorded with 160 Kg N ha^{-1} in conjunction with SRI method (M_2). In respect of net income and B-C ratio, SRI method (M_2) along with 160 Kg N ha^{-1} showed highest values (Rs. 72329.70 ha^{-1} and 2.10). (Hunger, 2009) [7] also reported similar results.

Conclusion

Based on the results obtained, it can be concluded that SRI method is a better establishment method of rice because it produces more yield and gross monetary economic return with 160 kg N ha^{-1} than other methods and nitrogen levels. However, there is a need to verify results in multi-location trials across the country following diverse soil and climate conditions.

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