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Direct and Residual Effect of Nutrient Management and Rice Establishment Methods on Productivity, Profitability, Nutrient Uptake and Resource Use Efficiency in Rice (*Oryza sativa* L.)-Groundnut (*Arachis hypogaea* L.) Cropping System

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ABSTRACT

Background: Rice and rice based cropping systems are of prime importance in global food production but continuous rice mono cropping and excessive dependence on chemical fertilisers degrade the soil quality, which can be partly solved by changing into rice-legume system.

Methods: The field experiment was conducted during *kharif* and *rabi* of 2019-2020 and 2020-2021 at Odisha University of Agriculture and Technology, Bhubaneswar to evaluate direct and residual effect of nutrient management and rice establishment methods on productivity, profitability, nutrient uptake and resource use efficiency in rice-groundnut system.

Result: Transplanted rice increased the yield attributes of rice in both the years resulting in 6.0-8.1% higher grain yield than direct seeding. Integrated nutrient management (INM) significantly improved the growth and yield of rice as compared to sole organic and inorganic. Carryover effect of direct seeding increased growth and yield of succeeding groundnut. Residual effect of organic in preceding rice increased pod yield of groundnut. INM to groundnut increased yield parameters of the crop resulting in 19.7-20.2 and 38.9-40.0% higher pod yields than 100% and 75% soil test based fertiliser, respectively in both the years. Direct seeding of rice with INM practice in both the crops performed superior in rice-groundnut cropping system.

Key words: Cropping system, DSR, Economics, Groundnut, INM, Nutrient uptake, Resource use efficiency, TPR.

INTRODUCTION

Rice (*Oryza sativa* L.) and rice based cropping systems are of prime importance in global food production. India occupies the world's largest area under rice (44.5 Mha) and is the second highest producer (172.5 Mt paddy) contributing 22% of global rice production. Groundnut (*Arachis hypogaea* L.) is considered as important legume oilseed crop contributing nearly 18% of the total oilseed production in India (2018-19). Continuous rice mono cropping and excessive dependence on chemical fertilisers degrade the soil quality, which can be partly solved by changing into rice-legume cropping system. It is pertinent to suggest suitable rice based cropping system and nutrient management practices in order to get more yield and income with maintaining the soil fertility and inclusion of oilseeds and legumes in the cropping system has closer relationship between cropping system productivity, energy and environment (Deep *et al*., 2018).

Use of high analysis fertilisers debars the crop of availing the micronutrients and balanced fertilization. Organic manures and biofertilizers have carry-over effect on the succeeding crops in rice based cropping systems. Efficient nutrient management through integration of all possible sources of nutrients can fulfill the phasic requirements of crops and increase crop productivity.

Groundnut being a legume-oilseed crop, its nutrients requirement is quite high. Low productivity in groundnut is mainly due to use of imbalanced plant nutrients and application of manures and fertilizers affects the availability of soil nutrients and soil physical properties of groundnut (Salma *et al*., 2018). Method of stand establishment influences the performance of rice crop and has great impact

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on field preparation and establishment of succeeding *rabi* crop. Puddling in TPR results deterioration of soil physical properties which make land preparation becomes difficult and requires more energy to achieve proper soil tilth leading to yield reduction in succeeding *rabi* crop. Keeping these above points in view, the present investigation was undertaken to find out direct and residual effect of different nutrient management and rice establishment methods on productivity, profitability, nutrient uptake and resource use efficiency in rice-groundnut cropping system.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* and *rabi* season of 2019-2020 and 2020-2021 at Agronomy Main Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar under East and South Eastern Coastal Plain Agro-Climatic Zone of Odisha. The soil of the experimental site was acidic in reaction (pH-5.28), loamy sand texture with medium organic carbon (0.57%), phosphorus (15.4 kg/ha) and potassium (189.4 kg/ha) and low in nitrogen (187.5 kg/ha) content. Six treatment combinations comprising of two establishment methods [direct seeded rice (DSR) and transplanted puddled rice (TPR)] and three nutrient management practices [inorganic-100% soil test based fertilizers (STBF), organic-green manuring + 1/3rd soil test based nitrogen (vermicompost) + 1/3rd STBN (neem oil cake) and integrated nutrient management (INM)-green manuring + 50% STBN + 100% P_2O_5 + 100% K_2O] to rice during *kharif* were allotted to the main-plots. Three nutrient management practices *viz.,* 75% STBF (inorganic), 100% STBF (inorganic) and INM [75% STBN (inorganic) + 25% STBN (FYM) + lime 0.2 LR + biofertilisers (*Rhizobium* and PSB) **+** 100% P_2O_5 + 100% K_2O] to groundnut during *rabi* were allotted to the sub-plots in a split-plot design replicated three times at the same site during both the years in rice-groundnut cropping system. Rice (*cv*. Maudamani-CR DHAN 307) and groundnut variety (*cv.* Devi-ICGV 91114) were grown with recommended package of practices. Vermicompost@2.0 t/ha and neem oil cake @0.87 t/ha were applied in rice immediately after layout of the experiment as per treatments. Inorganic nutrient management practices of 100% of STBF @100:40:40 and 25:40:40 kg N:P_2O_5:K_2O/ha were applied in rice and groundnut respectively.

All the growth, yield attributes and yield of both crops were recorded as per standard procedures. The formulae used for calculating different efficiencies were:

Efficiency	Formula
Employment generation efficiency (%)	$\frac{\text{Total mandays employed for the system}}{365} \times 100$
Partial factor productivity (kg REY/kg NPK added)	$\frac{\text{System yield (kg REY/ha)}}{\text{Total addition of NPK in the system (kg/ ha)}}$
Energy use efficiency	$\frac{\text{Energy output (Mj/ha)}}{\text{Energy input (Mj/ha)}}$
Heat use efficiency (g/m^2 /^{o}C day)	$\frac{\text{Total dry matter (g/m}^2\text{)}}{\text{Cumulative growing degree day (^{o}C day)}}$

Available soil nutrient contents were determined following the standard procedures (Jackson, 1973). The data collected from the experiment on various observations of both crops were subjected to statistical analysis as prescribed by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield of rice

Direct seeded rice (DSR) recorded (Table 1) significantly higher plant height and tillers/m^2 over transplanted rice (TPR) in both the years, which might be due to transplanting shock in TPR and higher plant density in DSR. Rice crop under TPR produced more dry matter and comparatively higher leaf area index (LAI), which might be responsible for higher yield attributes in TPR resulting in yield improvement of 8.0 and 6.0% over DSR during 2019 and 2020, respectively. This could be due to better microclimatic condition and improvement in soil physico-chemical properties for better water uptake as well as availability and utilization of nutrients in TPR (Bastola, 2020). Integrated nutrient management (INM) in rice resulted 12.4 and 17.7% higher grain yield over inorganic and organic practice during 2019-20 and 14.0 and 12.8% during 2020-21. Better performance of rice crop with INM had led to increase in plant growth resulting in higher grain yield. Saini *et al.* (2019) opined that beneficial effects of green manuring in crop production should not be evaluated in isolation; however, in integration with chemical fertilizers.

Growth and yield of groundnut

Residual effect of DSR favourably influenced the growth and yield attributes in succeeding groundnut crop as compared to that grown after TPR resulting in 25.6 and 26.2% higher pod yield during 2019-20 and 2020-21, respectively (Table 2). This might be due to deterioration of soil physical condition and formation of hard pan at shallow depth through puddling in TPR which was detrimental to the succeeding non-rice crop (Bandyopadhyay *et al*., 2019).

Significantly higher plant height and per plant nodules, dry matter accumulation, pod weight were recorded under the residual effect of organic nutrient management to preceding rice crop in the respective years which resulted in the highest pod yield of 2367 and 2597 kg/ha during 2019-20 and 2020-21, respectively. This was on a par with that grown after INM practice in rice, but was on an average, 17.4% higher than that grown after inorganic practice in rice

Table 1: Growth, yield attributes and yield of rice in rice- groundnut system under nutrient management and rice establishment methods.

Treatment	Plant height (cm)		Tillers/m^2		Leaf area index		Dry matter accumulation (g/m^2)		Panicles/m^2		Panicle weight (g)		Grain yield (kg/ha)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Rice establishment method														
DSR	126.2	128.4	409.3	415.8	4.56	4.70	1704.7	1751.2	261.1	268.4	3.74	3.75	5259	5481
TPR	117.4	119.4	331.8	339.4	4.67	4.81	1947.5	2022.8	282.7	293.8	4.12	4.19	5684	5808
SEm ±	2.0	2.1	17.2	17.3	0.41	0.43	74.1	74.3	7.0	7.3	0.18	0.17	45	59
C.D. (P=0.05)	6.4	6.5	54.1	54.5	NS	NS	233.5	234.1	NS	23.0	NS	NS	142	185
Nutrient management in rice														
Inorganic	121.9	124.0	364.8	370.7	4.75	4.89	1679.5	1715.2	266.7	275.0	3.43	3.41	5331	5374
Organic	120.4	122.5	350.9	356.5	4.05	4.17	1646.2	1704.2	224.9	230.5	4.23	4.29	5091	5431
INM	123.2	125.2	395.8	405.7	5.05	5.20	2152.6	2241.7	324.0	337.9	4.14	4.20	5992	6128
SEm±	2.5	2.5	21.0	21.2	0.51	0.52	90.8	91.0	8.5	9.0	0.22	0.21	55	72
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	286.0	286.7	26.9	28.2	NS	0.65	174	227

NS- Non-significant at P>0.05

owing to availability of continuous and balanced supply of nutrients for a prolonged period due to residual effect of organic to preceding rice (Prasad *et al*., 2002). INM to groundnut increased the growth and yield parameters resulting in 19.7 and 38.9% higher pod yield during 2019-20 and 20.2 and 40.0% during 2020-21 over 100 and 75% STBF, respectively. This might be owing to increased solubility and availability of N in the rhizosphere due to biofertilisers, improvement of soil pH due to lime, physico-chemical properties due to FYM and instant availability of nutrients from inorganic fertilisers (Singh *et al*., 2013).

System yield in rice-groundnut system

Direct seeding of rice resulted in the system yield of 12.2 and 13.1 t REY/ha, in 2019-20 and 2020-21, respectively, which was 8.0 and 10.1% higher than grown after TPR (Table 3). Rice yield under TPR was 7% higher than DSR, but groundnut produced about 26% higher pod yield when was grown after DSR than TPR. Higher yield as well as higher sale price of groundnut (three times of rice) resulted in higher REY of the system under DSR. INM in rice resulted in, on an average, 12.3% higher system yield than the inorganic practice, but was at par with the organic treatment in one of the two years, because of higher yield of rice under INM (Table 1) and similar yield of groundnut under residual effect of organic and INM practice in preceding rice crop (Table 2) for the reasons stated earlier. Similarly, INM practice in groundnut improved system yield by 12.1 and 21.8% over 100 and 75% STBF, respectively, because of corresponding increase in groundnut yield by 20 and 39% (Table 2) in conformity with Prasad *et al*. (2002).

Nutrient uptake in rice-groundnut system

On an average, DSR resulted in higher uptake of N by the system (252.2 kg/ha), which was 15.6 kg more than TPR but was at par with the latter with respect to uptake of P and K (Table 3). INM in rice exhibited higher uptake of N, P and K by the system, followed by organic and inorganic. Similarly, INM practice in groundnut resulted in higher uptake of N, P and K than 100 and 75% STBF. The uptake of nutrients followed the trend of system yield in conformity with the findings of Samant (2015).

Resource use efficiency in rice-groundnut system

The resource use efficiency indices such as land use efficiency (LUE), employment generation efficiency (EMGE), partial factor productivity (PFP), energy use efficiency (EUE) and heat use efficiency (HUE) of the rice-groundnut system were affected by nutrient management and rice establishment methods (Table 3).

TPR registered higher LUE, EMGE and EUE than DSR in both the years. On the other hand, PFP was higher in DSR (53.9 and 58.0 kg REY/kg NPK added) than TPR, whereas both the establishment methods did not influence the HUE values. This might be ascribed to the variations in duration, man-days requirement, input use and yield of component crops. INM to rice resulted in the highest EMGE 82.3% in both the year and HUE of 1.20 and 1.43 g/m^2/^{o}C

Table 2: Growth, yield attributes and yield of groundnut in rice-groundnut system under nutrient management and rice establishment methods.

Treatment	Plant height (cm)		Nodules/plant at 70 DAS		Dry matter accumulation (g/plant)		Pods/plant		Pod weight/plant (g)		Pod yield (kg/ha)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Rice establishment method												
DSR	39.1	39.9	80.4	86.5	26.3	29.6	16.7	19.3	14.7	17.7	2476	2704
TPR	36.2	37.0	78.1	84.0	23.7	26.7	14.8	17.2	12.9	15.7	1972	2143
SEm±	0.4	0.4	0.87	0.93	0.68	0.70	0.6	0.7	0.5	0.6	45	50
C.D. (P=0.05)	1.2	1.2	NS	NS	2.15	2.20	NS	NS	1.6	2.0	143	158
Nutrient management in rice												
Inorganic	34.4	35.1	75.2	80.8	23.0	25.9	14.9	17.3	12.4	15.1	2033	2198
Organic	41.1	41.9	83.6	89.9	27.0	30.5	16.9	19.6	15.2	18.5	2367	2597
INM	37.6	38.3	79.1	85.0	25.0	28.1	15.4	17.9	13.7	16.6	2272	2475
SEm±	0.5	0.5	1.06	1.14	0.84	0.85	0.7	0.9	0.6	0.8	55	62
C.D. (P=0.05)	1.5	1.5	3.34	3.59	2.64	2.69	NS	NS	2.0	2.4	175	194
Nutrient management in groundnut												
75% STBF	31.3	31.9	73.8	79.4	23.5	26.3	14.9	17.3	12.4	15.1	1880	2039
100% STBF	42.5	43.4	75.1	80.8	25.4	28.4	15.5	18.0	13.7	16.6	2181	2376
INM	39.2	40.0	88.9	95.6	26.2	29.7	16.8	19.5	15.2	18.5	2611	2855
SEm±	0.3	0.3	1.53	1.65	1.12	1.14	0.6	0.7	0.5	0.7	97	108
C.D. (P=0.05)	0.8	0.8	4.47	4.81	NS	NS	NS	NS	1.6	1.9	283	315

Table 3: System yield, nutrient uptake and resource use efficiency in rice-groundnut system under nutrient management and rice establishment methods.

Treatment	System yield (t REY/ha)		Nutrient uptake by the system (kg/ha)						Land-use efficiency (%)		Employment generation efficiency (%)		Partial factor productivity (kg REY/kg NPK added)		Energy use efficiency		Heat use efficiency (g/m^2/^{o}C day)	
			N		P		K											
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Rice establishment method																		
DSR	12.2	13.1	240.9	263.4	38.6	44.7	158.3	166.9	68.7	67.0	73.4	73.4	53.9	58.0	12.3	12.6	1.15	1.28
TPR	11.3	11.9	225.7	247.5	38.2	44.3	159.9	173.7	72.0	70.1	80.0	80.2	49.0	51.1	12.5	13.0	1.00	1.28
SEm±	5.2	0.1	2.16	2.56	0.35	0.53	2.15	2.44	0.02	0.03	0.14	0.16	0.5	0.6	0.11	0.12	0.02	0.02
C.D. (P=0.05)	NS	0.4	6.82	8.05	NS	NS	NS	NS	0.07	0.08	0.43	0.52	1.6	1.8	NS	0.38	0.06	NS
Nutrient management in rice																		
Inorganic	11.1	11.6	219.8	234.8	36.4	40.7	150.5	158.8	69.8	68.0	74.1	73.4	50.3	52.6	10.2	10.4	1.02	1.20
Organic	11.8	12.8	235.3	264.7	37.8	44.5	158.7	171.5	71.1	69.2	73.8	74.6	54.3	58.7	14.6	15.2	1.01	1.21
INM	12.4	13.1	244.9	266.9	40.9	48.3	168.1	180.5	70.2	68.4	82.3	82.3	49.7	52.3	12.5	12.9	1.20	1.43
SEm±	6.4	0.2	2.65	3.13	0.43	0.65	2.63	2.99	0.03	0.03	0.17	0.20	0.6	0.7	0.14	0.15	0.02	0.03
C.D. (P=0.05)	NS	0.5	8.35	9.86	1.34	2.03	8.28	9.42	0.08	0.10	0.53	0.64	2.0	2.2	0.43	0.47	0.07	0.09
Nutrient management in groundnut																		
75% STBF	10.8	11.2	213.4	233.0	35.9	40.6	150.2	157.4	70.8	69.0	76.7	76.4	50.0	52.0	12.8	13.0	1.01	1.19
100% STBF	11.6	12.3	230.4	251.1	37.8	43.6	156.3	167.6	70.1	68.3	76.7	76.6	49.5	52.2	12.9	13.3	1.09	1.28
INM	12.9	13.9	256.0	282.2	41.4	49.2	170.8	185.8	70.2	68.4	76.8	77.4	54.8	59.4	11.5	12.2	1.13	1.37
SEm±	0.3	0.3	4.74	5.53	0.49	0.67	2.94	3.37	0.00	0.01	0.27	0.32	1.2	1.3	0.19	0.22	0.02	0.02
C.D. (P=0.05)	0.8	0.9	13.82	16.14	1.43	1.94	8.59	9.83	0.00	0.04	NS	NS	3.4	3.9	0.55	0.65	0.07	0.07

N- Nitrogen; P- Phosphorous; K- Potassium; NS- Non-significant at P>0.05.

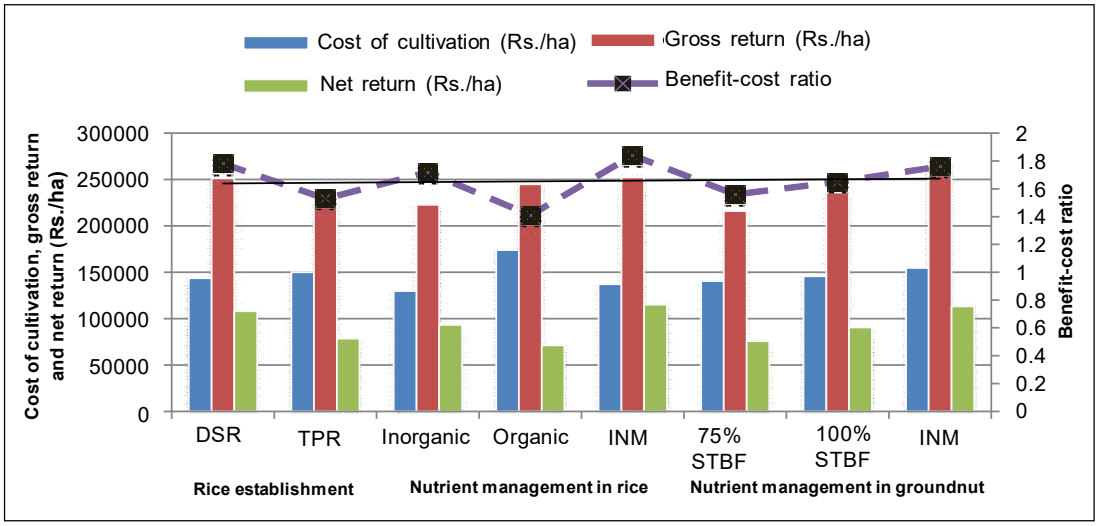

Fig 1: Economics of rice-groundnut system during 2019-20 under nutrient management and rice establishment methods.

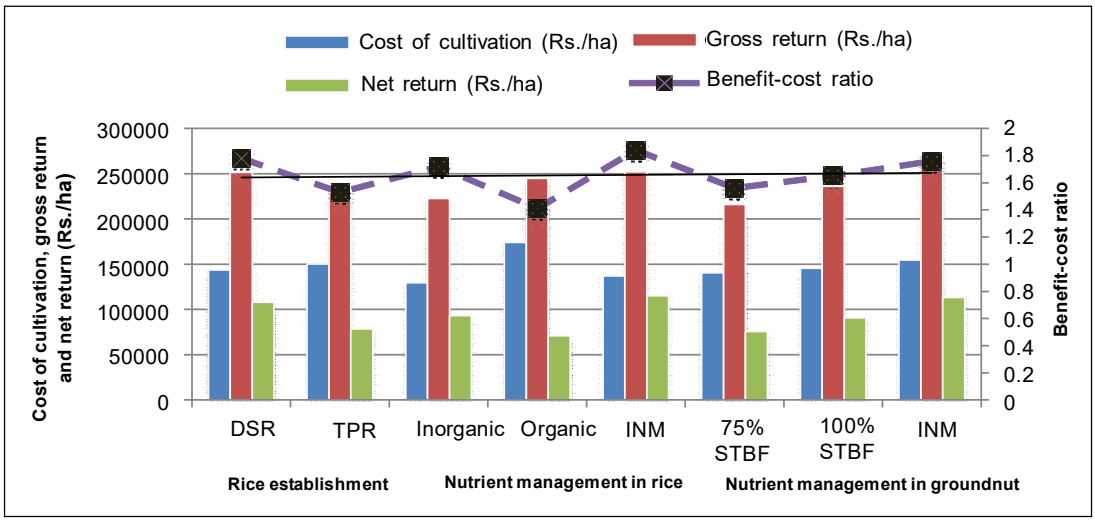

Fig 2: Economics of rice-groundnut system during 2020-21 under nutrient management and rice establishment methods.

day during 2019-20 and 2020-21, respectively. Application of organic sources to rice resulted in higher LUE, PFP and EUE in both the years followed by INM and inorganic in conformity with the findings of Shilpha *et al*. (2018). INM in groundnut crop in the system resulted in higher average values of EMGE, PFP and HUE of the system than 100 and 75% STBF. However, EUE was higher in 100% STBF as compared to INM and 75% STBF (Patra *et al.,* 2018).

Economics of rice-groundnut system

Transplanting in rice resulted in higher cost of cultivation of the system in both the years due to higher cost towards man days, but DSR fetched the maximum gross return owing to higher system yield (Fig 1 and Fig 2). The net return value under DSR, on an average, was Rs.27121/ha more than TPR. DSR also improved the B:C to 1.67 and 1.78 as compared to TPR during 2019-20 and 2020-21, respectively, due to relatively less cost of cultivation in conformity with Bohra and Kumar (2015). But INM to rice resulted in the higher average gross returns, net returns and B:C over organic practice and inorganic nutrition might be due to its higher yield. INM to groundnut incurred in higher cost of cultivation of the system and also fetched higher average system gross returns (Rs.257523/ha), net returns (Rs.103434/ha) and B:C (1.69) increasing the corresponding values by Rs. 45857/ha, Rs. 32143/ha and 0.16 unit over 75% STBF and Rs. 27656/ha, Rs. 18960/ha and 0.09 unit over 100% STBF. This was due to higher system yield under INM, which might have negated the relatively higher cost of organic sources of nutrients in line with the findings of Samant (2015).

CONCLUSION

There is carry over effect of nutrient management and rice establishment methods in rice on succeeding groundnut crop. Integrated nutrient management practice in conjunction with *dhaincha* green manuring + 50% STBN + 100% P_2O_5 + 100% K_2O under direct seeded rice followed by integrated use of 75% STBN (inorganic) + 25% STBN (FYM) + 0.2 LR + biofertilisers (*Rhizobium* and PSB) to succeeding groundnut crop is the recommended nutrient management practice for higher productivity, profitability, nutrient uptake and resource use efficiency of rice-groundnut cropping system.

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