



Effect of Nutrient Management and Rice Establishment Methods on Groundnut (*Arachis hypogaea* L.) in Rice–Groundnut Cropping System

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Abstract

The field experiments were conducted at Agronomy Main Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India during *rabi* (November–March) seasons of 2019–2020 and 2020–2021 to evaluate direct and residual effect of nutrient management and rice establishment methods on phenology, growing degree days, growth, yield and economics of groundnut in rice–groundnut cropping system. The experiments were laid out in split-plot design with three replications. Carryover effect of direct seeding rice favourably influenced the succeeding groundnut crop as compared to that grown after transplanting which had superior growth parameters resulting in 25.7% higher pod yield, oil yield (1.24 t ha⁻¹), gross return (₹ 136612.7 ha⁻¹) and net return (₹ 63965.0 ha⁻¹). Residual effect of organic management to preceding rice significantly increased growth, yield attributes, growing degree days at physiological maturity and net return, resulted in highest pod yield of 2.48 t ha⁻¹ in groundnut which was at par with that grown after INM in rice, but was on an average, 17.0% higher than inorganic practice in rice. INM to groundnut increased yield parameters and economics of the crop resulting in 19.7 and 39.3% higher pod yields than 100% and 75% soil test based fertiliser, respectively. Hence, INM under direct seeding to *kharif* rice benefits the succeeding groundnut crop and direct application of 75% STBN (inorganic)+25% STBN (FYM)+0.2 LR+biofertilisers to groundnut proved beneficial for improving phenology, growing degree days, growth, yield and economics of groundnut in rice–groundnut cropping system.

Keywords: Groundnut, phenology, yield, economics, rice-groundnut system

1. Introduction

Rice based cropping systems are of prime importance in global food production. Groundnut (*Arachis hypogaea* L.) considered as a unique and important legume oil seed crop grown over an area of 28.5 mha with a total production of 46 mt in the whole world. In India groundnut is grown over an area of 4.9 mha with total production of 6.73 mt (Anonymous, 2021). 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 and inclusion of oilseeds and legumes in the cropping system has closer relationship between system productivity, energy and environment (Deep et al., 2018). Rice–groundnut is an important cropping system in Odisha. Both the crops in the system are nutrient exhaustive and sensitive to changing climate.

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Deterioration of soil properties due to improper crop and nutrient management has threatened the productivity and sustainability of the system in the state (Patra et al., 2019).

Organic manures and biofertilizers have carry-over effect on the succeeding crops in rice based cropping systems. Low productivity in groundnut is mainly due to low consumption of fertilizer in spite of prominent nutrient deficiencies and application of manures and fertilizers affects the availability of soil nutrients and soil physical properties of groundnut (Patil et al., 2017 and Mondal et al., 2019). Integrated Nutrient Management (INM) strategy will play significant role in plant nutrition for better crop production (Kamble et al., 2018; Annadurai et al., 2009) and is flexible and minimizes the use of chemicals and improve the soil health (Jana et al., 2020). Application of vermicompost with inorganic fertilizers is effective for improving the soil health and increases yields (Ravikumar et al., 2019 and Ghosh et al., 2021). Method of stand establishment influences the performance of rice crop and has great impact on field preparation and establishment of succeeding *rabi* crop. Transplanting in rice is detrimental to the succeeding non-rice crop due to deterioration of soil physical condition and formation of hard pan at shallow depth through puddling (Bandyopadhyay et al., 2019).

The information on residual effects of rice establishment methods and direct and residual effects of nutrient management practices on groundnut in rice-groundnut system is meagre. Growing degree days (GDD) and photo thermal units (PTU) are good estimators of crop growth stages (Prabhakar et al., 2007). The optimum diurnal air temperature for vegetative growth of groundnut is between 30 and 35°C, whereas, for reproductive growth and final yield is some between 25 and 28°C. High day temperature above 35°C during the reproductive phase reduce dry matter production, proportion of flowers from pegs, number of pods per plant, harvest index and pod yield (Prasad et al., 2001).

Severe drought stress at the vegetative stage and mild drought stress applied at the flowering stage in rice result in 20% and 28% yield loss, respectively (Yang et al., 2019). Variable environmental conditions can greatly influence stand establishment, crop development and yield in groundnut. Low temperature in the early season can also have pronounced effects on the physiology of seedlings, resulting in reduced plant growth and development (Virk et al., 2019). Plant growth ceases when temperature exceeds or drops below a critical minimum. The rise in temperature causes early maturity in crop. Climatic resources and their interactions with agricultural parameters help to increase the crop productivity (Ko et al., 2010). Keeping these above points in view, the present investigation was undertaken to find out direct and residual effect of nutrient management and rice establishment methods on phenology, growing degree days, growth, yield and economics of groundnut in rice-groundnut cropping system.

2. Materials and Methods

The field experiments for groundnut were conducted for two consecutive years during *rabi* (November–March) seasons of 2019-2020 and 2020-2021 at Agronomy Main Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar (20°15' N, 85°52' E, 25.9 m above MSL), Odisha, India. 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⁻¹) and potassium (189.4 kg ha⁻¹) and low in nitrogen (187.5 kg ha⁻¹) 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 STBN (vermicompost)+1/3rd STBN (neem oil cake) and integrated nutrient management (INM)- green manuring+ 50% STBN+100% P₂O₅+100% K₂O] 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% P₂O₅ 100% K₂O] 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 on both the year. The seeds were dibbled and maintained one seed at the spacing of 25 cm x 10 cm at seed rate 125 kg kernel ha⁻¹ at a depth of 5 cm. Soil test based nitrogen, phosphorous and potassium were applied at the rate of 25 : 40 : 40 kg N, P₂O₅ and K₂O ha⁻¹ in the form of urea, di-ammonium phosphate and muriate of potash respectively. The matured groundnut plants were uprooted from the net plot area of each plot separately. The pods were separated from the plants, the soil particles adhering to the mature pods were removed and developed pods were completely dried under the sun for five days. All the growth, yield attributes and yield of both crops were recorded as per standard procedures. Growing degree days (GDD) was calculated by using Peterson equation (1965).

$$\text{Growing degree days} = (T_{\text{max}} + T_{\text{min}}) / 2 - T_{\text{base}}$$

Where, T_{max} and T_{min} are the daily maximum and minimum temperature (°C), and T_{base} is the base temperature (10°C)

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

3. Results and Discussion

3.1. Phenology

Nutrient management and rice establishment methods in rice influenced the phenology of succeeding groundnut (Table 1). The numbers of days for attaining various phenological stages in succeeding groundnut differed with different nutrient



Table 1: Duration and growing degree days of different phonological stages of groundnut in rice–groundnut cropping system under nutrient management and rice establishment methods

Treat- ment	Duration (days)					Growing degree days (°C day ⁻¹)				
	Flower initiation	Peg for- mation	Pod initia- tion	Seed initia- tion	Physiological maturity	Flower initia- tion	Peg for- mation	Pod initia- tion	Seed initia- tion	Physiologi- cal maturity
<u>Rice establishment method</u>										
DSR	30.5	45.8	50.2	64.7	120.6	450.8	660.1	707.2	851.4	1617.8
TPR	31.7	46.6	51.1	65.6	122.7	411.7	566.9	623.0	818.5	1749.2
SEm±	0.14	0.03	0.05	0.06	-	2.5	0.8	0.8	1.1	0.7
CD (p=0.05)	0.44	0.09	0.13	0.17	-	7.9	2.4	2.4	3.5	2.1
<u>Nutrient management in rice</u>										
Inorganic	31.5	46.7	51.2	65.7	121.7	440.5	621.0	671.7	842.4	1658.8
Organic	30.7	45.7	50.2	64.7	121.8	423.8	607.7	659.6	828.8	1711.6
INM	31.0	46.0	50.5	65.0	121.5	429.6	611.9	663.9	833.7	1680.0
SEm±	0.17	0.04	0.05	0.07	-	3.1	1.0	0.9	1.4	0.8
CD (p=0.05)	0.53	0.12	0.16	0.21	-	9.7	3.0	2.9	4.3	2.6
<u>Nutrient management in groundnut</u>										
75% STBF	31.3	46.4	50.9	65.4	122.3	435.4	616.7	667.9	838.1	1695.1
100% STBF	31.1	46.2	50.7	65.2	121.4	431.7	613.7	665.6	835.5	1665.6
INM	30.8	45.9	50.3	64.8	121.5	426.7	610.0	661.8	831.2	1689.8
SEm±	0.04	0.04	0.05	0.07	-	0.8	0.6	0.6	0.7	0.6
CD (p=0.05)	0.12	0.11	0.15	0.20	-	2.4	1.7	1.7	2.1	1.9

management and rice establishment methods. Residual effect of transplanting in rice (TPR) resulted higher crop duration in succeeding groundnut than direct seeding (DSR) and showed higher requirement of days for attaining various phonological stages like flower initiation, peg formation, pod initiation, seed initiation and harvest maturity as compared to DSR. Residual effect of organic management showed the minimum requirement of days to complete various phonological stages of succeeding groundnut up to physiological maturity as compared to INM and inorganic. The results also indicated that residual effect of INM resulted minimum requirement of days of 121.5 followed by organic and inorganic (121.7 and 121.8 respectively). As regards to direct application of treatment to groundnut, integrated use of organic and inorganic sources of nutrients (INM) to groundnut recorded minimum requirement of days to complete various phonological stages followed by organic and inorganic except physiological maturity. This might be due to genetic potentiality of crop and variety which can response

well to the prevailed weather conditions during crop growth enabling to escape possible high temperature stress at later growth stages and efficient utilization of available growing degree days to complete each phonological stages (Kingra and Kaur, 2013; Singh, 2003). Samant and Swain (2020) also reported the similar types of results in rice.

3.2. Growing degree days (GDD)

Effect of nutrient management and establishment methods of rice on heat unit of growing degree days (GDD) was significant at all the phonological stages of succeeding groundnut (Table 1). The lowest heat unit (GDD) requirement was observed in flower initiation and increased in the successive phonological stages peg formation, pod initiation, seed initiation and harvest maturity. Residual effect of DSR showed significantly higher GDD than TPR in all growth stages except harvest maturity which indicated that transplanting stress delayed crop development on the order of 1749.2°C day mean thermal units. Similarly, carry over effect of organic management in

rice required minimum GDD at all the phonological stages of succeeding groundnut followed by INM and inorganic except physiological maturity. Organic recorded the maximum GDD requirement for maturity ($1711.6^{\circ}\text{C day}^{-1}$), followed by INM and inorganic (with a mean of 1680.0 and $1658.8^{\circ}\text{C day}^{-1}$ respectively) at physiological maturity owing to higher life span and efficient utilization of heat as compared to inorganic and INM. Similar findings were reported by Islam and Sikder (2011) in rice under organic and inorganic conditions.

Direct application of 75% STBF to groundnut resulted in the maximum GDD of 1695.1°C followed by 100% STBF and INM might be due to difference in prevailing daily mean temperature in a particular year (Kumar et al., 2020).

3.3. Growth and yield attributes

Carryover effect of DSR favourably influenced the growth and yield attributes in succeeding groundnut crop as compared to that grown after TPR. The leaf area index, seeds pod^{-1} and 100 pod weight was not affected due to rice establishment (Table 2). DSR produced significantly higher plant height (39.5 cm), dry matter accumulation (27.9 g plant^{-1}), nodules plant^{-1} (83.5) and pods plant^{-1} (18.0) and shelling percent (72.5). Besides early maturity, DSR also offers the option to resolve edaphic conflicts between rice and the subsequent non-rice crop and enhance sustainability of the rice-based cropping system and succeeding winter crops (Farooq et al., 2011, Yadav et al., 2018).

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

Treatment	Plant height (cm)	Leaf area index	Dry matter accumulation (g plant^{-1})	Nodules plant^{-1}	Pods plant^{-1}	Seeds pod^{-1}	100 pod weight (g)	Shelling (%)
Rice establishment method								
DSR	39.5	3.29	27.9	83.5	18.0	1.86	88.7	72.5
TPR	36.6	3.13	25.2	81.1	16.0	1.65	88.4	71.3
SEm \pm	0.3	0.12	0.5	0.9	0.12	0.10	0.8	-
CD ($p=0.05$)	0.9	NS	1.5	NS	0.4	NS	NS	-
Nutrient management in rice								
Inorganic	34.7	2.98	24.4	78.0	16.1	1.58	84.8	71.3
Organic	41.5	3.36	28.7	86.8	18.2	1.94	91.6	72.4
INM	38.0	3.29	26.6	82.1	16.6	1.73	89.2	72.1
SEm \pm	0.4	0.15	0.6	1.1	0.15	0.13	0.9	-
CD ($p=0.05$)	1.1	NS	1.8	3.5	0.4	0.37	2.7	-
Nutrient management in groundnut								
75% STBF	31.6	3.03	24.9	76.6	16.1	1.58	84.6	70.9
100%STBF	42.9	3.16	26.9	78.0	16.7	1.74	89.3	71.8
INM	39.6	3.44	27.9	92.3	18.2	1.94	91.7	73.1
SEm \pm	0.3	0.24	0.8	1.6	0.29	0.23	0.4	-
CD ($p=0.05$)	0.8	NS	NS	4.6	0.8	0.64	1.2	-

Residual effect of nutrient management in rice also exerted significant influence on growth and yield attributes of succeeding groundnut crop. Significantly higher plant height (41.5 cm), dry matter accumulation (28.7 g plant^{-1}), nodules plant^{-1} (86.8), pods plant^{-1} (18.2), seeds pod^{-1} (1.94), 100 pod weight (91.6 g) and shelling percent (72.4) were recorded under the residual effect of organic management in the respective years followed by INM and the lowest was with inorganic practice, but no significant effect was noticeable in LAI (Gowthami and Ananda, 2017) .

As regards to direct application of treatment to groundnut, no significance effect was observed in LAI and dry matter

accumulation though their numerical values under integrated use of organic and inorganic sources of nutrients were 3.44 and 27.9 g plant^{-1} respectively. Significantly higher nodules plant^{-1} , pods plant^{-1} , seeds pod^{-1} , 100 pod weight and shelling percent were observed in INM whereas plant height was observed in 100% STBF (Baishya et al., 2014). Similar findings had been recorded in greengram by Mohanty et al. (2014).

3.4. Yield

The nutrient management and rice establishment method had significant influence on pod yield, haulm yield and harvest index of subsequent groundnut (Table 3).

Table 3: Yield and economics of groundnut in rice–groundnut cropping system under nutrient management and rice establishment methods

Treatment	Oil yield (t ha ⁻¹)	Pod yield (t ha ⁻¹)	Haulm yield (t ha ⁻¹)	Harvest index (%)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio
Rice establishment method							
DSR	1.24	2.59	3.59	41.7	136612.7	63965.0	1.66
TPR	0.98	2.06	3.49	36.9	108528.2	36925.3	1.54
SEm±	0.02	0.034	0.053	0.71	-	-	-
CD (<i>p</i> =0.05)	0.07	0.1	0.16	2.2	-	-	-
Nutrient management in rice							
Inorganic	1.00	2.12	3.31	38.4	111580.9	39730.4	1.86
Organic	1.18	2.48	3.65	40.2	130937.2	58558.0	1.06
INM	1.13	2.37	3.66	39.2	125193.3	53047.1	1.88
SEm±	0.03	0.042	0.065	0.82	-	-	-
CD (<i>p</i> =0.05)	0.09	0.12	0.19	2.7	-	-	-
Nutrient management in groundnut							
75% STBF	0.92	1.96	3.43	36.3	103375.3	39115.8	1.57
100%STBF	1.08	2.28	3.57	38.8	120167.4	48161.4	1.60
INM	1.31	2.73	3.62	42.8	144168.7	64058.3	1.64
SEm±	0.05	0.07	0.108	1.30	-	-	-
CD (<i>p</i> =0.05)	0.14	0.2	0.31	3.7	-	-	-

1 US \$=INR 74.53; 72.80 during average of March month of 2020 and 2021

Carryover effect of DSR favourably influenced the succeeding groundnut crop as compared to that grown after TPR resulting in higher oil yield (1.24 t ha⁻¹) and 25.7% higher pod yield (Table 3). The haulm yield and harvest index also showed the similar trends. 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).

Residual effect of organic nutrient management to preceding rice crop in the respective years resulted in the highest oil yield (1.18 t ha⁻¹) and pod yield of 2.48 t ha⁻¹. This was on a par with that grown after INM practice in rice, but was on an average, 17.0 % higher than that grown after inorganic practice in rice owing to availability of continuous and balanced supply of nutrients for a prolonged period due to residual effect of organic to preceding rice which confirm the findings of Prasad et al. (2002).

Integrated use of organic and inorganic sources of nutrients (INM) to groundnut resulting in 19.7 and 39.3% higher pod yield 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 and physico-chemical properties due to FYM, and instant availability of nutrients from inorganic fertilisers (Ibrahim et al., 2017; Singh et al., 2013).

3.5. Economics

The study on economics (Table 3) revealed that DSR fetched higher net returns (₹ 136612.7 ha⁻¹) as compared to TPR. Similarly, The net return value under DSR, on an average, was ₹ 27039.7 ha⁻¹ more than TPR. DSR also improved the B:C to 1.66 as compared to TPR during due to relatively less cost of cultivation in conformity with Bohra and Kumar (2015). Organic management to rice resulted in the higher gross returns, net returns and B:C over INM and inorganic nutrition might be due to higher yield under organic practice. INM to groundnut recorded net returns (₹ 64058.3 ha⁻¹) and B:C (1.64) with increasing the corresponding values by ₹ 24942.5 ha⁻¹ and 0.07 unit over 75% STBF and ₹ 15896.9 ha⁻¹ and 0.04 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) and Chaudhay et al. (2015).

4. Conclusion

Thus, integrated nutrient management practice in conjunction with *dhaincha* green manuring+50% STBN+100% P₂O₅ +100% K₂O under direct seeding to *kharif* rice benefits the succeeding groundnut crop in rice–groundnut system. Direct application of 75% STBN (inorganic)+25% STBN (FYM)+0.2 LR+biofertilisers (*Rhizobium* and PSB) to groundnut crop is the



recommended nutrient management practice for improving phenology, growing degree days, growth, yield and economics of groundnut in rice–groundnut cropping system.

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