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Productivity and profitability of greengram (*Vigna radiata* l.) as influenced by rice crop establishment and nutrient management practices in rice-greengram cropping system

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ABSTRACT

A field experiment was conducted in North Central Plateau Zone of Odisha to evaluate the residual effect of three rice establishment methods (SRI, drum seeding and conventional transplanting) and three nutrient management practices [RDF (80:40:40 N: P_2O5: K_2O kg ha^{-1}), 50% R.D.F. + 50% R.D.F. through organic sources (based on nitrogen requirement) i.e. INM and 100% RDF through organic management (OM)] and direct effect of three nutrient management practices viz. RDF (20:40:40 N: P_2O_5: K_2O kg ha^{-1}), 50% RDF + biofertlizer (BF) and no fertilizer on performance of greengram in a rice-greengram cropping system during rabi seasons of 2009-10 and 2010–11. The design was split plot in kharif and split-split plot in rabi with treatments replicated thrice. Methods of rice establishment did not influence the performance of subsequent greengram. OM in rice being at par with INM exhibited the highest yield (852 kg ha^{-1}), net return (Rs. 23554 ha^{-1}) and return Rs.$^{-1}$ invested (2.56). 50% RDF + BF application to greengram increased seed yield (930 kg ha^{-1}) by 10.7 and 64.9% over RDF and no fertilizer, respectively. It also recorded the highest nutrient uptake and harvest index, net return (Rs.26980 ha^{-1}) and return Rs.$^{-1}$ invested (2.80).

Keywords: Bio-fertilizer, drum seeding, green gram, nutrient management, SRI

India is the largest producer as well as consumer of pulses in the world, contributing 25.5 per cent of the total global production (GOI, 2013). However, per capita availability of pulses in the country declined from 41.6 g in 1991 to 34 g in 2010. Projected pulse requirement for the year 2030 is 32 million tonnes which necessitates annual growth rate of 4.2 per cent. To meet the projected requirement, there is need to increase the productivity to 1361 kg ha^{-1} and about 3.0 million ha additional area has to be brought under pulses besides reducing the post-harvest losses (IIPR, 2011).

Greengram (*Vigna radiata* L.) is the third important pulse crop of India grown in nearly 8 per cent of the total pulse area of the country next to chickpea and pigeonpea. In Odisha, greengram is cultivated in an area of 0.833 million ha with a production of 0.397 million tonnes and productivity of only 476 kg ha^{-1} (OAS, 2012-13). It is grown mainly in *rabi* and summer seasons after harvest of rice. Rice-greengram cropping system is the most important cropping system *in vogue* in North Central Plateau Zone of Odisha. The information on residual effects of rice crop establishment methods and direct and residual effects of nutrient management practices in rice-greengram sequence on greengram is meagre, therefore present experiment was conducted.

MATERIALS AND METHODS

Field experiments were conducted at the Instructional farm of Krishi Vigyan Kendra, Shyamakhunta, Mayurbhanj (21° 56' N, 86° 46' E and 50 m AMSL) under North Central Plateau Agro-climatic Zone of Odisha during the year 2009-10 and 2010-11. The soil of the experimental site was sandy clay loam in texture having pH 5.63, organic carbon 0.46% available N 221 kg ha^{-1}, available P 10.4 kg ha^{-1} and available K 139.3 kg ha^{-1}. The *rabi* crop of greengram received 52 mm rainfall in two days during 2009-10 and 26.5 mm rainfall in five days during 2010-11. The *kharif* rice crop received nine treatments consisted of combinations of three rice crop establishment methods in *viz.,* system of rice intensification (SRI), direct sowing of pre-germinated paddy seeds under puddled conditions by drum-seeder (DS) and conventional transplanting (CT) as main plot and three nutrient combinations *viz.,* recommended dose of fertilizer *i.e.* 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} (RDF), integrated nutrient management (INM) *i.e.* 50% of R.D.F. through inorganic fertilizers + 50% of R.D.F. through organic sources (based on nitrogen requirement) and organic management (OM) *i.e.* 100% of R.D.F. through organic sources (based on nitrogen requirement) as sub plot. The residual effects of *kharif* treatments as well as direct effect of three nutrient management practices *viz.,* RDF (20 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}), 50% RDF + Biofertlizer (seed inoculation of *Rhizobium* and PSB @ 500g ha^{-1} each) and no fertilizer application were evaluated on greengram as sub-sub plot during *rabi* seasons of 2009-10 and 2010-11. The design of the experiment was spilt plot in *kharif* and split-spilt plot during *rabi* season with three replications each. In *rabi* season, each *kharif* sub-plot was divided into three sub-sub plots to accommodate the three nutrient management practices.

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The organic sources comprised of 50% nitrogen requirement through FYM, 25% through vermicompost and remaining 25% through neem oil cakes. The N content of FYM, neem oil cake and vermicompost used were 0.48, 3.89 and 1.24 during 2009 and 0.48, 3.84 and 1.14 during 2010, respectively. The P_2O_5 content was 0.24, 0.88 and 0.41 during 2009 and 0.26, 0.84 and 0.48 during 2010 for FYM, neem oilcake and vermicompost, respectively. Similarly the K_2O content was 0.45, 1.02 and 0.60 during 2009 and 0.47, 0.98 and 0.58 during 2010 for FYM, neem oil cake and vermicompost respectively.

Greengram seeds of variety *'PDM-54'* inoculated with *Rhizobium* and PSB cultures @ 25 g each per kg of seed as per the treatment were sown with a row spacing of 25 cm continuously in line with a seed rate of 25 kg ha^{-1} after harvest of rice crop. A pre-sowing irrigation was given before cultivating the field. All the chemical fertilizers were applied basally through urea, diammonium phosphate and muriate of potash. Plant to plant spacing was maintained at 10 cm by thinning the additional plants after 10 days of sowing. Ten plants selected randomly from each sub-sub plot were marked for recording biometric observations. The matured pods were plucked manually from the plants in net plot area for recording the economic yield plot-wise. The pods were sun dried for 3-4 days and threshed manually. The seed and haulm yield were recorded plot-wise after reduction of moisture content to 8%. The net return (gross return – cost of cultivation) and return $Rs.^{-1}$ invested (gross return/cost of cultivation) were calculated on the basis of prevailing market price of different inputs and outputs. The N, P and K analysis in plant materials were done by micro-kjeldahl, vanadomolybdate acid yellow colour and flame photometric method, respectively (Jackson, 1973). The N, P and K uptake by seed and haulm were calculated separately by multiplying the respective yields with corresponding nutrient contents. Nutrient harvest index (grain nutrient uptake/total nutrient uptake) was expressed as percentage.

RESULTS AND DISCUSSION

The plant height, number of primary branches $plant^{-1}$, pods $plant^{-1}$, number of seeds pod^{-1} and 1000-seed weight was not affected due to rice crop establishment methods (Table 1). However, residual effect of nutrient management practices in rice exerted significant influence on number of primary branches $plant^{-1}$, pods $plant^{-1}$ and number of seeds pod^{-1}. Significantly higher mean number of branches $plant^{-1}$ (3.5), pods plant-1 (18.1) and number of seeds pod^{-1} (10.1) was recorded under the residual effect of sole organic nutrition followed by INM.

As regards to application of direct treatments to greengram, the treatment 50% RDF + BF recorded significantly higher plant height, number of primary branches $plant^{-1}$, pods $plant^{-1}$, number of seeds pod^{-1} and 1000-seed weight whereas no fertilizer treatment recorded the least values of growth and yield attributes (Table 1). Similar findings have been recorded in chickpea by Pramanik and Bera (2012).

The rice crop establishment methods did not exert any significant influence on yield and economics of subsequent greengram crop (Table 2). However, application of sole organic nutrition and INM in rice being *at par* recorded significantly higher seed and haulm yield of succeeding greengram over RDF in both the years. As per pooled data, the seed yield under residual effect of organic nutrition (852 kg ha^{-1}) was more by 10.1% and 20.5% over the residual effect of INM and RDF, respectively. Also, organic nutrition applied to *kharif* rice recorded the highest harvest index (26.26%) during the second year only, which remained *at par* with INM and the latter recorded comparable harvest index with RDF. The superior performance of residual effect of organics alone or in combination with inorganic fertilizers might be ascribed to prolonged availability of nutrients in this case as compared to sole fertilizer application. Similar observations of higher yield of succeeding crop of groundnut with application of 100% nitrogen through FYM to preceding rice being comparable with supply of 50 per cent nitrogen each through FYM and chemical fertilizer, but significantly superior to 100% nitrogen through chemical fertilizer and non-supply of nitrogen to preceding crop of rice have been reported by Kumari and Reddy (2011).

Greengram responded significantly to the application of chemical fertilizer in combination with biofertiliser. 50% RDF + BF treatment recorded the highest seed (930 kg ha^{-1}) and haulm yield (2596 kg ha^{-1}). Significantly lowest seed and haulm yield was recorded with no fertilizer during both the years. Similar findings of higher yield of greengram have been reported by Panigrahi *et al.*, (2012) and Math *et al.,* (2012). The increase in yield due to biofertilzer inoculation may not be solely due to N fixation or phosphate solubilization, but because of several other factors such as release of growth promoting substances, control of plant pathogens and proliferation of beneficial organisms in the rhizosphere. Solubilizers of inorganic phosphates in the soil (PSB) make them available to the crop and result in better yield (Charyulu *et al.,* 1985). However, both RDF and 50% RDF + BF being comparable to each other produced higher harvest index than no fertilizer. This suggested that under optimal nutrient supply irrespective of source, the plants were equally effective in synthesis and translocation of photosynthates from source to sink. The poor performance of greengram under no fertilizer application suggested that the plants could not get the required quantity of nutrients matching its demand.

Table 1: Effect of rice crop establishment and nutrient management practices in rice –green gram cropping system on growth and yield attributes of green gram

Treatments	Plant height (cm)			Primary branches plant^{-1} (No.)			Pods plant^{-1} (No.)			Seeds pod^{-1} (No.)			1000-seed weight (g)		
	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled
Crop establishment methods in rice															
SRI*	46.5	48.9	47.7	3.2	3.5	3.3	16.0	18.4	17.2	9.6	9.9	9.8	31.06	31.68	31.37
DS	46.8	50.5	48.6	3.2	3.7	3.4	16.4	19.0	17.7	9.8	10.0	9.9	31.36	32.14	31.75
CT	45.4	47.9	46.6	3.1	3.3	3.2	15.6	18.0	16.8	9.4	9.7	9.5	30.84	31.30	31.07
SEm(±)	**0.84**	**1.17**	**0.72**	**0.10**	**0.08**	**0.06**	**0.33**	**0.41**	**0.26**	**0.21**	**0.20**	**0.15**	**0.33**	**0.32**	**0.23**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management in rice															
RDF*	45.1	48.6	46.9	2.9	3.30	3.1	15.3	17.5	16.4	9.3	9.5	9.4	30.62	31.23	30.93
OM	47.0	49.9	48.4	3.3	3.67	3.5	16.8	19.5	18.1	9.9	10.2	10.1	31.53	32.16	31.85
INM	46.5	48.7	47.6	3.2	3.52	3.3	15.9	18.4	17.1	9.6	10.0	9.8	31.11	31.73	31.42
SEm(±)	**0.59**	**1.11**	**0.63**	**0.07**	**0.09**	**0.06**	**0.26**	**0.26**	**0.19**	**0.13**	**0.12**	**0.09**	**0.31**	**0.35**	**0.23**
LSD (0.05)	**NS**	**NS**	**NS**	**0.2**	**0.3**	**0.2**	**0.8**	**0.8**	**0.5**	**0.4**	**0.4**	**0.3**	**NS**	**NS**	**NS**
Nutrient management in green gram															
RDF**	46.5	49.2	47.8	3.4	3.7	3.5	16.8	18.9	17.9	9.7	10.1	9.9	31.30	31.93	31.61
50% RDF + BF	48.8	52.2	50.5	3.5	3.9	3.7	17.7	20.1	18.9	10.2	10.4	10.3	31.82	32.46	32.14
No fertilizer	43.3	45.8	44.5	2.6	2.8	2.7	13.5	16.3	14.9	8.9	9.1	9.0	30.14	30.74	30.44
SEm(±)	**0.85**	**0.89**	**0.62**	**0.10**	**0.11**	**0.08**	**0.32**	**0.45**	**0.28**	**0.20**	**0.18**	**0.13**	**0.35**	**0.38**	**0.26**
LSD (0.05)	**2.4**	**2.5**	**1.7**	**0.3**	**0.3**	**0.2**	**0.9**	**1.3**	**0.8**	**0.6**	**0.5**	**0.4**	**1.01**	**1.09**	**0.73**

Note: **SRI = System of rice intensification; DS = Drum seeding; CT = Conventional transplanting; RDF* (Recommended dose of fertilizer) = 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; OM = Organic management(50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM = Integrated nutrient management(1/2 RDF + ½ OM); RDF** (Recommended dose of fertilizer) =20 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; BF = Bio-fertilizers (Rhizobium and PSB seed inoculation)*

Table 2: Effect of rice crop establishment and nutrient management practices in rice–green gram cropping system on yield, harvest index and economics of green gram

Treatments	Seed yield (kg ha^{-1})			Haulm yield (kg ha^{-1})			Harvest index (%)			Net return (Rs.)			Return Rs. invested		
	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled	2009-10	2010-11	Pooled
Crop establishment methods in rice															
SRI*	736	821	779	2194	2324	2259	24.86	25.87	25.37	18351	22161	20256	2.22	2.47	2.35
DS	775	867	821	2287	2394	2341	25.12	26.35	25.74	20135	24210	22173	2.34	2.61	2.47
CT	694	774	734	2077	2240	2159	24.84	25.47	25.16	16457	20052	18254	2.09	2.33	2.21
Sem(±)	**21.26**	**28.43**	**17.75**	**56.73**	**75.71**	**47.30**	**0.137**	**0.226**	**0.132**	**957**	**1279**	**799**	**0.06**	**0.08**	**0.05**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management in rice															
RDF*	668	746	707	2034	2158	2096	24.57	25.56	25.07	15333	18813	17073	2.02	2.25	2.14
OM	802	902	852	2342	2495	2419	25.26	26.26	25.76	21331	25778	23554	2.41	2.71	2.56
INM	734	814	774	2182	2305	2244	24.99	25.88	25.44	18280	21833	20056	2.22	2.45	2.34
Sem(±)	**29.31**	**31.80**	**21.62**	**71.13**	**80.59**	**53.75**	**0.244**	**0.173**	**0.149**	**1317**	**1430**	**972**	**0.09**	**0.10**	**0.07**
LSD (0.05)	**90**	**98**	**63**	**219**	**248**	**157**	**NS**	**0.53**	**NS**	**4056**	**4407**	**2837**	**0.27**	**0.29**	**0.19**
Nutrient management in green gram															
RDF**	791	888	840	2322	2474	2398	25.38	26.34	25.86	19085	23395	21240	2.15	2.41	2.28
50% RDF + BF	879	981	930	2519	2673	2596	25.80	26.76	26.28	24724	29236	26980	2.65	2.95	2.80
No fertilizer	534	593	564	1716	1811	1764	23.65	24.60	24.13	11134	13792	12463	1.85	2.06	1.96
SEm(±)	**23.32**	**25.03**	**17.11**	**59.37**	**60.98**	**42.55**	**0.360**	**0.234**	**0.215**	**1045**	**1124**	**767**	**0.07**	**0.08**	**0.05**
LSD (0.05)	**67**	**72**	**48**	**170**	**175**	**120**	**1.03**	**0.67**	**0.61**	**2996**	**3223**	**2163**	**0.20**	**0.22**	**0.14**

Note: **SRI = System of rice intensification; DS = Drum seeding; CT = Conventional transplanting; RDF* (Recommended dose of fertilizer) = 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; OM = Organic management(50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM = Integrated nutrient management(1/2 RDF + ½ OM); RDF** (Recommended dose of fertilizer) =20 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; BF = Bio-fertilizers (Rhizobium and PSB seed inoculation)*

Table 3: Effect of rice crop establishment and nutrient management practices in rice greengram cropping system on nutrient content, uptake and harvest index of greengram (pooled data of two years)

Treatment	Nutrient content (%)						Nutrient uptake (kg ha^{-1})						Nutrient harvest index (%)		
	N		P_2O_5		K_2O		N		P_2O_5		K_2O		N	P_2O_5	K_2O
	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm			
Crop establishment methods in rice															
SRI*	4.080	0.571	0.769	0.113	1.134	1.454	29.41	11.94	5.56	2.36	8.18	7.92	70.79	69.84	20.97
DS	4.134	0.574	0.757	0.111	1.160	1.499	31.52	12.43	5.77	2.40	8.82	8.17	71.36	70.23	21.17
CT	4.044	0.564	0.739	0.107	1.111	1.413	27.59	11.32	5.06	2.15	7.57	7.21	70.70	69.84	20.91
SEm(±)							**0.645**	**0.328**	**0.179**	**0.073**	**0.263**	**0.713**	**0.185**	**0.243**	**0.111**
LSD (0.05)							**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management in rice															
RDF*	4.023	0.559	0.737	0.108	1.136	1.437	26.35	10.84	4.83	2.09	7.29	6.92	70.62	69.49	20.62
OM	4.153	0.582	0.775	0.113	1.158	1.480	32.86	13.05	6.14	2.53	9.13	8.67	71.21	70.36	21.35
INM	4.082	0.567	0.753	0.110	1.110	1.450	29.30	11.80	5.42	2.29	8.15	7.71	71.02	70.06	21.07
SEm(±)							**0.945**	**0.324**	**0.169**	**0.064**	**0.242**	**0.522**	**0.240**	**0.203**	**0.171**
LSD (0.05)							**2.76**	**0.94**	**0.49**	**0.19**	**0.71**	**NS**	**NS**	**NS**	**NS**
Nutrient management in green gram															
RDF**	4.113	0.576	0.763	0.112	1.136	1.463	31.92	12.76	5.93	2.47	8.83	8.40	71.37	70.46	21.34
50% RDF + BF	4.188	0.585	0.776	0.113	1.158	1.483	35.96	14.01	6.68	2.72	9.96	9.41	71.84	70.89	21.79
No fertilizer	3.957	0.548	0.725	0.106	1.110	1.421	20.64	8.91	3.78	1.72	5.78	5.49	69.64	68.57	19.91
SEm(±)							**0.746**	**0.308**	**0.167**	**0.062**	**0.238**	**0.483**	**0.257**	**0.235**	**0.238**
LSD (0.05)							**2.10**	**0.87**	**0.47**	**0.18**	**0.67**	**1.36**	**0.73**	**0.66**	**0.67**

Note: **SRI = System of rice intensification; DS = Drum seeding; CT = Conventional transplanting; RDF* (Recommended dose of fertilizer) = 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; OM = Organic management(50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM = Integrated nutrient management(1/2 RDF + ½ OM); RDF** (Recommended dose of fertilizer) = 20 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}; BF = Bio-fertilizers (Rhizobium and PSB seed inoculation)*

The study on economics revealed that there was no significant effect of methods of rice crop establishment on net return and return Rs.$^{-1}$ invested in greengram (Table 2). The highest net return and return per rupee invested was obtained from the residual effect of organic nutrition which was significantly superior to residual effect of RDF but remained *at par* with residual effect of INM during both the years. As per pooled analysis, the residual effect of organic nutrition remained significantly superior to all other treatments and it increased the mean net return (Rs. 23554 ha^{-1}) by 17.4% and 37.9% over that of INM and RDF, respectively.

As regards to application of direct treatments to greengram, the pooled analysis of two years data revealed that 50% RDF + BF noted the highest net return (Rs.26980 ha^{-1}), which was significantly superior to application of RDF (Rs.21240 ha^{-1}) and no fertilizer application (Rs.12463 ha^{-1}). Similarly the return per rupee invested calculated under the treatment 50% RDF + BF (2.80) was higher by 22.8% and 42.8% over that obtained with application of RDF and no fertilizer.

The nutrient content, uptake and nutrient harvest index of greengram did not vary due to residual effect of different rice establishment methods (Table 3). However, the residual effect of nutrient management practices in rice caused significant variations in nutrient content in seeds and haulm as well as nutrient uptake and their utilization by seeds of greengram. It was the sole organic nutrient management in rice which registered highest N, P and K content in seeds of greengram. The uptake of all three nutrients N, P and K by both seed and haulm of greengram were found to be the highest under residual effect of organic nutrient management in rice being *at par* with INM. However, the residual effect of nutrient management practices of rice did not show significant variation for nutrient harvest index of greengram.

Application of 50% RDF + BF in greengram showed higher seed nitrogen content over that obtained with the use of RDF and no fertilizer. The plants receiving no fertilizer recorded by far the least concentrations of nutrients. Similar trend was noticed with P and K content (Table 3). The slight improvement in nutrient contents under the treatments where biofertilizer was applied might be due to their prolonged uptake as a result of proliferation of beneficial organisms in the rhizosphere as stated earlier and slow release from sources which prevented nutrient loss as in case of inorganic sources. Uptake of N, P and K was the highest under 50% RDF + BF as these are positively correlated with biological yields. This might also have been influenced by the beneficial effect of biofertilizers on root rhizosphere and production of efficient root nodules. It was observed that the nutrient harvest index for N, P and K was the highest with 50% RDF + BF which was at par with RDF, but both were significantly superior to no fertilizer application. It suggested that both inorganic as well as integration of inorganic and biofertilizers are equally efficient in partitioning of photosynthates to fruiting bodies in greengram.

Thus it is concluded that application of either organic nutrition or INM to *kharif* rice benefits the succeeding greengram crop in a rice-greengram sequence. Direct application of 50% recommended dose of fertilizer along with biofertiliser seed treatment to greengram is more productive and profitable in North Central Plateau Zone of Odisha.

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