



Residual Effect of Integrated Nutrient Management on Nodulation, Yield, Quality and Available Nutrient Status in Soil after Harvest of Greengram

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SM and RKP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SNJ and KNM managed the analyses of the study. Author BS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i4831258

Editor(s):

(1) Dr. Chen Chin Chang, Hunan Women's University, China.

Reviewers:

(1) Ariel M. Alcones, Apayao State College, Philippines.

(2) Raghvendra Pratap Singh, Uttaranchal University, India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/66004>

Original Research Article

Received 24 October 2020

Accepted 29 December 2020

Published 31 December 2020

ABSTRACT

A field study was carried out during *rabi* seasons in 2017-18 and 2018-19 after harvest of rice to reveal the residual effect of integrated nutrient management on nodulation, yield, quality and available nutrient status in soil after harvest of greengram at Instructional Farm of College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar. The maximum number of root nodules/plant at 30 DAS and 45 DAS in greengram (5.86, 6.19 and 12.49 and 12.94 in 2017 and 2018 respectively) were recorded in the subplot treatment of 75% RDF+ rhizobium + PSB and lowest values were obtained in 75% RDF treatment. Similarly in main plot, residual effect of 50% RDF+50% RDN through FYM showed significantly higher number of root nodules/plant during both the years of study which remained at par with 75 % RDF+ Green manuring. Lowest values were obtained from only RDF treatment. Residual effect of 50 % RDF+50 % RDN through FYM showed significantly higher protein % (24.2 and 24) and protein yield (194.3 and 196.2) during both the years of study which remained at par with 75 % RDF+ Green manuring treatment. Residual effect of 75 % RDF+ Green manuring treatment recorded higher increase in soil organic carbon (4.87 g/kg), available N(225.7 kg/ha), Available P (26.2 kg/ha) and available K (296.0 kg/ha) than all other treatment combinations. The residual treatment 50% RDF+25% RDN through FYM recorded

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the lowest values of soil nutrient status after harvest of greengram. Similarly the sub plot treatment receiving 75% RDF+ *Rhizobium*+ PSB recorded significantly higher soil organic carbon (4.67 g/kg), available N(217.1 kg/ha), Available P (22.8 kg/ha) and available K (291.8 kg/ha) than 100% RDF and 75% RDF.

Keywords: Greengram; INM; *Rhizobium*; PSB; nodulation; nodule dry weigh; soil organic carbon.

1. INTRODUCTION

Green gram (*Vigna radiata* L. Wilezek) is one of the most important pulse crops grown in India. Green gram is short duration, drought tolerant pulse crop which also commonly known as "Mungbean. Greengram is an excellent source of high quality protein. Its seed contains 24.7% protein, 0.6% fat, 0.9% fiber and 3.7% ash as well as sufficient quantity of calcium, phosphorus and important vitamins. Due to its supply of cheaper protein source, it is designated as "poor man's meat". It also contains high quality of lysine (4600 mg/g N) and tryptophan (60 mg/g N) and consumed as whole grain or as well as in the form of dal for table purposes. Greengram is supposed to be easily digestible, hence, is preferred by patients. The sprouted seeds of greengram are rich in ascorbic acid (vitamin C), riboflavin and thiamine [1]. It is grown usually as rained crop and can also be grown as pre-monsoon and late monsoon crop. In India it occupies 3.5 million ha area with a production of 2.1 million tonnes with the average yield 495 kg/ha (Anon., 2019). Rice-greengram cropping system is the most important cropping system in vogue of Odisha. In Odisha, greengram is generally grown in rice fallow area after harvest of rice in *rabi* season. In Odisha, greengram is grown in area of 768 thousand ha with productivity of 470 kg ha⁻¹ (Anon, 2014). The productivity of this crop is very low because of its cultivation on marginal and sub marginal lands of low soil fertility where little attention is paying to adequate fertilization [2]. As traditional practices followed by farmers in Odisha, there is no or very little fertilizers applied to greengram crop sown after harvest of rice. The crop is only grown using residual soil moisture and residual soil fertility after harvest of *kharif* crop. Although, chemical fertilizer are playing a crucial role to meet the nutrients need of the crop, the imbalance and continuous use of chemical fertilizers has adverse effect on soil physical, chemical and biological properties thus affecting the sustainability of crop production, besides causing environmental pollution. Besides, persistent nutrient depletion is posing a greater threat to the sustainable agriculture [3]. Consumption of

chemical fertilizers will also be quite a limiting factor of agricultural production in future. Because of escalating energy cost, chemical fertilizers are not available at affordable price to the farmers. Reliance on the increased use of chemical fertilizers and associated hazards put back attention on organic sources which are effective in promoting soil health and productivity of the crop with quality produce [4]. On the other hand, use of organics alone does not result in spectacular increase in crop yields, due to their low nutrient status. Therefore, integrated management of chemical fertilizers and organic may be an important strategy for sustainable production of crops. This may not only improve the efficiency of chemical fertilizers along with their minimal use in crop production besides providing stability in crop production with higher crop yield and improving available major and minor nutrients [5]. In context of bio fertilizers, positive effect of PSB and Plant Growth Promoting Rhizobacteria (PGPR) on legume rhizobia symbiosis particularly in the early events and synergism between these organisms might increase competitiveness and efficiency of rhizobium inoculation in pulse crops [6,7]. *Rhizobium* inoculation can increase the grain yield of most of the pulse crops to the tune of 10 to 15% [8]. Also co-inoculation of phosphate solubilizing bacteria has been found to improve nodulation, nitrogen fixation and yield of legumes by increasing phosphorus availability [9]. Therefore, it becomes imperative to test role of bio fertilizers and inorganic fertilizers as a source of nutrients in greengram with using residual fertility and soil moisture after harvest of rice. Keeping these points in view, the present investigation was designed to study residual effect of integrated nutrient management on greengram.

2. MATERIALS AND METHODS

The field study was carried out during *rabi* (winter) seasons in 2017-18 and 2018-19 after harvest of rice to study the residual effect of integrated nutrient management on nodulation, yield, quality and available nutrient status in soil after harvest of greengram. The experiment was

conducted at Instructional Farm of College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar (20° 15' N, 85° 52' E, 25.9 m above mean sea level and about 64 km away of the Bay of Bengal), Odisha. The station comes under the East and South Eastern Coastal Plain Agro-climatic Zone of Odisha. The soil of the experimental field was sandy loam in texture (alfisol). The soil has good water holding capacity with good internal drainage. The soil is characterized by slightly acidic in reaction (pH 5.66), low in organic carbon (3.82 g kg⁻¹), low in available nitrogen (199.3 kg ha⁻¹), medium in c phosphorus (17.3 kg ha⁻¹) and medium in available potassium (269.1 kg ha⁻¹) as depicted in Table 1. During *kharif* (rainy) season of both the experimental years short grain aromatic rice (Nua Acharamati variety) was grown in random block design in plot size of 11 m × 9m comprising 6 treatments viz. 100% Recommended Dose of Fertilizer, 75% Recommended Dose of Fertilizer +25% Recommended Dose of Nitrogen through Farm Yard Manure, 50% Recommended Dose of Fertilizer + 50% Recommended Dose of Nitrogen through Farm Yard Manure, 50% Recommended Dose of Fertilizer +25% Recommended Dose of Nitrogen through Farm Yard Manure, 75% Recommended Dose of Fertilizer + Green manuring and 50 % Recommended Dose of Fertilizer + Green manuring. During rabi season of both the years, green gram var. IPM-02-03 was grown in split plot design in plot size of 3.5 m × 3.0 m taking nutrient management in rice as main plot and three nutrient management practices viz. 100% Recommended Dose of Fertilizer, 75% Recommended Dose of Fertilizer, 75 % Recommended Dose of Fertilizer + *Rhizobium* and Phosphorus solubilizing bacteria as sub plots. Recommended dose of fertilizers 20:40:40 kg /ha (N: P₂O₅ :K₂O) were applied as per treatments as basal dose at the time of sowing in furrows at 30 cm apart in at the depth of 10 cm. The required quantity of rhizobium cultures, i.e. @ 200 g culture per 10 kg seed was mixed to 10% sugar solution to form slurry. The culture of Phosphorus solubilizing bacteria 200 g per 12 kg fine soil was well mixed with the help of hand and then applies to as per treatment details.

The number of root nodules of five randomly selected plants from 3.5 m × 3m plot size was recorded in each plot at 30 and 45 DAS. Plants were uprooted carefully and after washing root nodules were separated from the roots, counted, weighted and recorded. After counting the number of root nodules per plant, nodules were

dried at 70 °C for two days and dry weight was recorded and expressed on per plant basis. Nitrogen content in the grain of greengram was estimated by Kjeldahl method (Jackson, 1967), and the protein per cent in the grain was calculated by multiplying the nitrogen content with a factor 6.25.

$$\text{Protein yield (kg/ha)} = \text{Protein content (\%)} / 100 \times \text{seed yield (kg/ha)}$$

Surface soil samples (0-30 cm depth) were collected from each plot after the crop harvest and composite samples were analysed for organic carbon, available nitrogen, phosphorus and potassium as per standard procedures. All the data obtained were statistically analysed using the F-test [10]. Critical difference (CD) values at P=0.05 were used for determine the significance of differences between mean values of treatments.

3. RESULTS AND DISCUSSION

3.1 Effect on Nodulation

The maximum number of root nodules /plant at 30 DAS and 45 DAS in greengram (5.86, 6.19 and 12.49 and 12.94 in 2017 and 2018 respectively) were recorded in the subplot treatment of 75% RDF+ rhizobium + PSB and lowest values were obtained in 75% RDF treatment. Similarly in main plot, residual effect of 50% RDF+50% RDN through FYM showed significantly higher number of root nodules/plant during both the years of study which remained at par with 75% RDF+ Green manuring. Lowest values were obtained from only RDF treatment. Such positive benefits of nutrient combination have also been by Gupta [11]. This fact is also supported with better nodulation pattern and nodulation rating with *Mesorhizobium* inoculation as compared to control. Residual effect of 50% RDF+50% RDN through FYM showed significantly higher nodule dry weight (63.49, 67.97 and 139.6 and 144.8 mg/plant in 2017 and 2018 respectively) (Table 2). Similarly the subplot treatment 75% RDF+ *rhizobium* + PSB showed significantly higher nodule dry weight than 100% RDF and 75% RDF. These results were in conformity of the findings [12,13,2].

3.2 Effect on Yield Parameters

Among the main plot treatments, residual effect of 50% RDF+50% RDN through FYM showed significantly higher seed yield (798 and 815

kg/ha), stover yield (1993 and 1922 kg/ha) and harvest index (28.5 and 29.7%) during both the years which remained at par with 75% RDF+ Green manuring treatment. Lowest values were obtained from 100% RDF treatment only. Similarly the sub plot treatment receiving 75% RDF+ *rhizobium*+ PSB recorded significantly maximum seed yield (684 and 710 kg/ha), stover yield (1784 and 1749 kg/ha) and harvest index (27.6 and 28.8 %) (Table 3) during both the years of study. The increased green gram seed yield might be due to addition of FYM and dhaincha to rice and *Rhizobium* and PSB to preceding rabi greengram resulting in improvement in soil structure which reduced the soil crust and also serves as a source of energy for soil microflora which resulted in better root nodulation and nitrogen fixation. The combined inoculation of rhizobium + PSB with fertilizers enhanced the yield attributes of greengram (Yadav et al., 2007). These results are in confirmatory with Dhakal et al. [2], Sudhagar Rao et al. [14] Bhadu et al. [15] and Rajkhowa et al. (2000).

3.3 Effect on Quality Parameters

Residual effect of 50% RDF+50% RDN through FYM showed significantly higher protein % (24.2 and 24) and protein yield (194.3 and 196.2) during both the years of study which remained at par with 75%RDF+ Green manuring treatment. Lowest values were obtained from 100% RDF treatment only (21.6 and 21.7 and 110.5 and 117.4 respectively) (Table 4). Among sub plot treatments, treatment receiving 75% RDF+ *rhizobium*+ PSB recorded significantly maximum protein % (23.2 and 23.3) and protein yield (161.2 and 165.8) than 100% RDF and 75% RDF treatments. Increased nutrient content with dual inoculation with rhizobium and PSB were observed in greengram by Sharma et al. (2006);

Singh et al. (2013) The higher protein yield in these treatments might be due to the fact that better availability of all the nutrients to the green gram plants through both organic and inorganic sources resulting into higher seed yield, which reflected into maximum protein yield. On the contrary, lowest protein yield was noticed in 100% RDF which might be due to lower seed yield on account of reduced growth and development due to imbalance nutrition of the crop.

3.4 Effect on Soil Nutrient Status after Harvest of Greengram

Residual effect of 75 % RDF+ Green manuring treatment recorded higher increase in soil organic carbon (4.87 g/kg), available N (225.7 kg/ha), Available P (26.2 kg/ha) and available K (296.0 kg/ha) than all other treatment combinations. The residual treatment 50% RDF+25% RDN through FYM recorded the lowest values of soil nutrient status after harvest of greengram. Similarly the sub plot treatment receiving 75% RDF+ *Rhizobium*+ PSB recorded significantly higher soil organic carbon (4.67 g kg⁻¹), available N (217.1 kg ha⁻¹), available P (22.8 kg ha⁻¹) and available K (291.8 kg ha⁻¹) than 100% RDF and 75% RDF. This might be due to the residual effect of green manuring which slowly releases nutrient to soil and produces organic acids which helps in better nutrient mineralization and solubilisation which ultimately increases nutrient availability in soil. Legume crops add large amount of organic residues through leaf fall and rhizodeposition and the intermediate acids produced during organic residue decomposition also solubilize fixed forms of nitrogen and phosphorus in soil resulting in increased available nitrogen and phosphorus. These results are in confirmatory with Dhakal et al. [2].

Table 1. Chemical composition of the soil (0-15cm) at the experimental site

Composition	Value	Method employed
pH (1:2.5:: soil: water)	5.66	Glass electrode Beckman's electronic pH meter (Jackson, 1973)
Electrical Conductivity (dS m ⁻¹) (1:2.5:: soil: water)	0.13	Conductivity meter (Jackson, 1973)
Organic carbon(g kg ⁻¹)	3.82	Walkley and Black method(Jackson, 1973)
Available N (kg ha ⁻¹)	199.3	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha ⁻¹)	17.3	Bray's -1 method (Jackson, 1973)
Available K (kg ha ⁻¹)	269.1	Neutral normal ammonium acetate method(Jackson, 1973)

Table 2. Effect of INM on number of nodules/plant and dry weight of nodules/plant (mg/plant) at 30 and 45 DAS

Treatments	No. of nodules/plant				Dry weight of nodules/plant (mg/plant)			
	30 DAS		45 DAS		30 DAS		45 DAS	
	2017	2018	2017	2018	2017	2018	2017	2018
Nutrient management in rice								
RDF	4.29	5.01	9.78	10.17	42.23	49.86	100.09	101.10
75% RDF+25% RDN through FYM	5.49	5.91	11.39	12.14	53.58	58.52	118.92	121.13
50% RDF+50% RDN through FYM	6.50	6.83	13.51	14.06	63.49	67.97	139.68	144.89
50% RDF+25% RDN through FYM	3.95	4.31	8.56	8.89	40.22	40.90	85.30	89.08
75% RDF+ Green manuring	6.46	6.73	12.68	13.01	64.63	66.03	126.87	129.19
50% RDF+ Green manuring	5.33	5.50	9.58	10.30	52.98	54.88	100.34	103.07
S.E(m) ±	0.18	0.16	0.74	0.26	1.86	2.55	2.87	5.33
C.D. (0.05)	0.58	0.51	2.33	0.82	5.88	8.03	9.05	16.79
Nutrient management in greengram								
100% RDF	5.39	5.80	10.81	11.13	53.29	57.18	113.04	114.77
75% RDF	4.76	5.16	9.45	10.22	46.64	50.23	96.76	100.29
75% RDF+ <i>Rhizobium</i> + PSB	5.86	6.19	12.49	12.94	58.64	61.67	125.80	129.17
S.E(m) ±	0.11	0.09	0.56	0.16	1.12	1.18	1.68	3.6
C.D. (0.05)	0.32	0.27	1.63	0.48	3.27	3.45	4.91	10.51

Table 3. Effect of INM on yield parameters of greengram

Treatment	Seed yield (kg/ha)		Stover yield (kg/ha)		Harvest index (%)	
	2017	2018	2017	2018	2017	2018
Nutrient management in rice						
RDF	511	539	1477	1411	25.6	27.6
75% RDF+25% RDN through FYM	611	629	1685	1612	26.6	28.0
50% RDF+50% RDN through FYM	798	815	1993	1922	28.5	29.7
50% RDF+25% RDN through FYM	479	495	1462	1324	24.5	27.1
75% RDF+ Green manuring	702	733	1816	1811	27.8	28.7
50% RDF+ Green manuring	521	558	1570	1563	24.9	26.5
S.E(m) ±	23.52	21.62	44.37	33.71	0.45	0.49
C.D. (0.05)	74.11	68.14	139.8	106.21	1.43	1.56
Nutrient management in greengram						
100% RDF	606	620	1685	1603	26.3	27.7
75% RDF	520	554	1532	1468	25.1	27.3
75% RDF+ <i>Rhizobium</i> + PSB	684	710	1784	1749	27.6	28.8
S.E(m) ±	7.08	8.34	23.37	16.36	0.29	0.32
C.D. (0.05)	20.68	24.33	68.20	47.74	0.85	0.93

Table 4. Effect of INM on quality parameters of greengram

Treatments	Protein %		Protein yield (kg/ha)	
	2017	2018	2017	2018
Nutrient management in rice				
RDF	21.6	21.7	110.5	117.4
75% RDF+25% RDN through FYM	22.9	23.2	140.2	146.1
50% RDF+50% RDN through FYM	24.2	24.0	194.3	196.2
50% RDF+25% RDN through FYM	20.5	20.7	98.7	102.8
75% RDF+ Green manuring	23.8	23.7	168.1	173.9
50% RDF+ Green manuring	21.6	22.2	112.6	124.1
S.E(m) ±	.14	0.08	6.05	5.16
C.D. (0.05)	0.44	0.25	19.16	16.26
Nutrient management in greengram				
100% RDF	22.5	22.5	137.5	141.0
75% RDF	21.6	22.1	113.5	123.4
75% RDF+ <i>Rhizobium</i> + PSB	23.3	23.2	161.2	165.8
S.E(m) ±	0.11	0.06	1.95	2.13
C.D. (0.05)	0.31	0.18	5.68	6.21

Table 5. Available soil status after harvest of greengram during Rabi 2018-19

Treatment	OC (g/kg)	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)
Nutrient management in rice				
RDF	4.41	210.5	20.4	288.3
75% RDF+25% RDN through FYM	4.53	218.8	21.5	291.6
50% RDF+50% RDN through FYM	4.76	221.2	24.5	292.0
50% RDF+25% RDN through FYM	4.29	200.7	19.6	285.7
75% RDF+ Green manuring	4.87	225.7	26.2	296.0
50% RDF+ Green manuring	4.46	213.6	20.9	290.8
S.E(m) ±	0.02	0.28	0.09	0.20
C.D. (0.05)	0.05	0.9	0.29	0.64
Nutrient management in greengram				
100% RDF	4.53	215.0	22.1	291.3
75% RDF	4.46	213.1	21.7	289.1
75% RDF+ <i>Rhizobium</i> + PSB	4.67	217.1	22.8	291.8
S.E(m) ±	0.01	0.27	0.07	0.14
C.D. (0.05)	0.03	0.77	0.20	0.42

4. CONCLUSION

From the above experiment it was concluded that residual effect of 50% RDF+50% RDN through FYM to rice increased the nodulation and all the yield attributes in greengram than all other treatment combinations. The residual effect of 75 % RDF+ green manuring increased the available nutrient status in soil after harvest than other treatment combinations. Therefore this treatment combination can be advised to the farming community for achieving higher productivity in rice-greengram cropping system while maintain status of soil fertility.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

I am thankful to Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar for providing the logistical support for conducting Ph.D research at Instructional Farm, OUAT, Bhubaneswar.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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