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Review/Overview

Direct and residual effects of fertilizers and biofertilizers on yield, nutrient uptake and economics of groundnut (*Arachis hypogaea*)–rice (*Oryza sativa*) cropping system

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ABSTRACT

A two-year field experiment was conducted during the winter (*rabi*) and rainy (*kharif*) seasons of 2010–12 at Deodhe, Ratnagiri (Maharashtra), to study the direct and residual effects of different doses of fertilizers and biofertilizers on yield, nutrient uptake and economics of groundnut (*Arachishypogaea*L.)–rice (*Oryza sativa* L.) cropping system. Increasing dose of fertilizers up to 125% recommended dose of fertilizers (RDF) significantly increased pod yield by 79.7% and haulm yield by 63.5% of groundnut over the control. Uptake of N, P and K by groundnut also improved significantly with successive increase in doses of fertilizers up to 125% RDF. Succeeding rice showed significant response to residual fertilizer levels up to 100% RDF in grain yield and up to 125% in straw yield and registered 16.9 and 25.4% increase over the control respectively. The N, P and K uptake by succeeding rice and total NPK uptake, rice-grain equivalent yield, production efficiency, net returns and benefit: cost ratio in groundnut–rice cropping system also improved significantly with increase in doses of fertilizers up to 125% RDF applied to groundnut. The crop inoculated with biofertilizers (*Rhizobium*+phosphate-solubilizing bacteria) recorded significantly higher pod (1.74 t/ha) and haulm yields (3.64 t/ha) of groundnut and grain (5.34 t/ha) and straw yields (5.52 t/ha) of succeeding rice over the control. Inoculation of groundnut with biofertilizers significantly increased N, P, K uptake by groundnut and succeeding rice (except N uptake by rice straw) as well as total N, P and K uptake (393.1 kg/ha), rice–grain equivalent yield (9.92 t/ha), net returns (66.8×10^3₹/ha) and benefit: cost ratio (2.01) in groundnut–rice cropping system over no inoculation. This treatment also recorded the maximum production efficiency of the system (38.8 kg/ha/day). Rice crop responded significantly to each higher level of fertilizer up to 125% RDF (direct) in terms of grain and straw yields as well as N, P and K uptake. Application of 125% RDF to rice recorded significantly higher total N, P and K uptake (447.1 kg/ha), rice–grain equivalent yield (10.89 t/ha), production efficiency (42.6 kg/ha/day), net returns (₹78.3×10^3/ha) and benefit: cost ratio (2.17) in groundnut–rice cropping system.

Key words **:** Crop production, Biofertilizers, Direct effect**,** Economics, Fertilizer doses, Groundnut-rice cropping system, Residual effect, System productivity

Rice and rice-based cropping systems are of prime importance for food securitymainly in South and South East Asia. Continuous monocropping of rice has led to decline or stagnation of productivity due to emergence of multiple nutrient deficiency and deterioration of soil physical properties. This problem can be partly overcome by changing fromcontinuous rice production system to growing of rice–legume cropping system. Groundnut is regarded as an important crop to overcome protein energy malnutrition. It fits well in rice-based cropping systems in peninsularIndia (Gowda *et al.*, 2001) and is gaining popularity as post-rainy or summer season crop in rice–fallows in Konkan region of Maharashtra particularly in coarse-textured soils and in regions where irrigation water is limited to grow only one crop of rice.

The unbalanced and continuous use of high analysis inorganic fertilizers in the intensive cropping systems is leading to decline in crop factor productivity, imbalance of nutrients in soil and adversely affect soil physico-chemi-

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cal properties. Nutrient recommendations are based on individual crop needs and do not account for residual effect of applied nutrients. There is a need to adopt system approach of nutrient supply to increase fertilizer-use efficiency and economize the use of costlier mineral fertilizers by accounting the residual effect of the applied fertilizers and preceding crops as well as by adopting integrated use of inorganic and biofertilizers. Use of biofertilizers in crop cultivation is suggested to maintain or improve soil health and also the quality of crop produce (Rugheim and Abdelgani, 2012). Biofertilizers also help reduce adverse effects of excessive and imbalanced use of chemical fertilizers.The present study was undertaken to assess the direct and residual effects and cost effectiveness of applied fertilizers and biofertilizers in groundnut-rice cropping system.

MATERIALS AND METHODS

A two-year field experiment was conducted during the winter (*rabi*) and rainy (*kharif*) seasons of 2010–12 at Agricultural Technical School, Dr B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra) farm, Deodhe (Lanja), District Ratnagiri. The soil was sandy clay loam, acidic (pH 4.9), low in available nitrogen (182.6 kg N/ha), medium in available phosphorus (14.6 kg P/ha) and available potassium status (205.5 kg K/ha). The total rainfall received during 2010–11 and 2011–12 was 4,930.2 and 3,654.0 mm respectively, with corresponding 106 and 100 rainy days.

The experiment, consisting of 4 fertility levels viz. control, 75, 100 and 125% recommended dose of fertilizer (RDF), and 2 biofertilizers levels, viz. control and *Rhizobium* + phosphate solubilizing bacteria (PSB), allotted to main plots (applied to groundnut) and 4 fertility levels control, 75, 100 and 125% RDF allotted to sub-plots (applied to rice), was laid out in split-plot design with 3 replications. The recommended fertilizer dose of 25, 50, 50 kg N, P and K/ha for groundnut and 100, 50, 50 kg N, P and K/ha for rice was applied through urea, single superphosphate and muriate of potash, respectively. The entire quantity of N, P and K to groundnut was drilled manually as per treatment prior to sowing at a depth of 8–10 cm in furrows. Inoculation of groundnut kernels with biofertilizers (*Rhizobium*+PSB) was done before sowing. Groundnut variety 'TKG 19' 'Konkan Tapora' was sown manually in rows at 4–5 cm depth on 14 December 2010 (first year) and 2 December 2011 (second year) using 150 kg/ha seed rate with 30 cm × 15 cm spacing and was harvested on 30 April 2011 (first year) and 18 April 2012 (second year) respectively. Rice hybrid 'Sahyadri 4' was transplanted in the first week of July during both the years at 20 cm × 15 cm spacing. Half dose of N and full doses of P and K were applied at the time of transplanting and remaining N was top-dressed in 2 equal splits (at maximum tillering and panicle initiation stages) as per treatments. All the other recommended package of practices were adopted during the crop growth periods in both the years. Plant samples of both groundnut and rice crops collected during course of investigation were analysed for NPK uptake. The prevailing prices of inputs and outputs were used to work out net returns, benefit: cost ratio, rice-grain equivalent yield and production efficiency of the cropping system.

RESULTS AND DISCUSSION

Effect on groundnut

The successive increase in dose of fertilizers up to 125% RDF significantly increased pod and haulm yields of groundnut (Table 1). Application of 125% RDF resulted in 79.7, 37.7 and 11.0% higher pod yield and 63.3, 23.3 and 10.4% higher haulm yield over the control, 75 and 100% RDF respectively. This may be due to efficient and greater partitioning of metabolites and adequate translocation and accumulation of photosynthates, amino acids, vitamins, etc. to developing reproductive structures under adequate fertilization that might have resulted in increase in growth and yield-attributing characters. Further, the fertilizer application provided better conducive conditions for higher uptake of nutrients (Table 2) and in turn helped the plants to boost their growth leading to development of yield attributes through supply of more photosynthates towards the reproductive sink. Yadav *et al.* (2009) and Singh and Singh (2012) also reported similar results. Doses of fertilizers also had significant effect on N, P and K uptake by pod and haulm of groundnut (Table 2). Successive increase in doses of fertilizers up to 125% RDF significantly enhanced N uptake by 111.0, 48.1 and 13.5% in pod and 85.0, 31.2 and 13.0% in haulm over the control, 75 and 100% RDF respectively. Likewise, P uptake increased by 164.9, 81.5 and 22.5% in pod and 145.8, 55.9 and 27.2% in haulm with the application of 125% RDF over the control, 75 and 100% RDF, respectively. Similarly, each higher dose of fertilizers up to 125% RDF significantly improved K uptake by 121.3, 52.9 and 14.3% in pod and 89.2, 35.3 and 12.8% in haulm over the control, 75 and 100% RDF respectively. The nutrient uptake is a function of yields and nutrient concentrations in the plant. Thus, significant improvement in uptake of N, P and K might be attributed to higher yields (Table 1) and increased concentrations in pod and haulm under 125% RDF. Our findings confirm the results of Kumar *et al*. (2000) and Yadav *et al*. (2009).

Biofertilizers had significant effect on pod and haulm yields of groundnut. Inoculation of groundnut kernels with

Rhizobium+PSB significantly enhanced its pod and haulm yields significantly by 6.1 and 7.1% respectively, over the control (Table 1). Inoculation with biofertilizers might have increased root nodulation and resulted in better root development and more nutrient availability and uptake, resulting in vigorous plant growth and dry-matter production (Sardana *et al*., 2006; Sammauria *et al.*, 2009). Use of biofertilizers also significantly improved N, P and K uptake by pod and haulm of groundnut (Table 2). The crop inoculated with *Rhizobium*+PSB recorded 8.8 and 8.1% higher N uptake, 12.7 and 14.6% higher P uptake and 11.0 and 9.4% higher K uptake over the control (no biofertilizers) in pod and haulm respectively. Increased uptake of N and P may be due to increase in concentration of these nutrients in plant and plant dry-matter; however, increased dry-matter is the sole reason of significant improvement in K uptake in pod and haulm. Pramanik and Singh (2003) and Sammauria *et al.* (2009) also reported such results.

Residual effect on rice

Grain yield of succeeding rice increased significantly in response to residualdose of fertilizers up to 100% RDF and such an increase was 16.9 and 4.8% over no fertilizer (control) and 75% RDF respectively (Table 1). Straw yield increased significantly up to 125% RDF with an increase of 25.4, 10.9 and 4.7% over the control, 75 and 100% RDF respectively (Table 1). This could be ascribed to the increased availability of left-over nutrients applied to previous crop with increasing dose of nutrients. In a cropping sequence, first crop hardly utilized 30–50, 15–20 and 60–80% of N, P and K respectively (Hegde *et al*., 2007) leaving much of the nutrients for use by the succeeding crop. Shivakumar and Ahlawat (2008) and Singh *et al.* (2012) reported similar findings. Application of 125% RDF to groundnut significantly increased N, P and K uptake by succeeding rice crop (Table 2). The increase in N uptake by rice due to 125% RDF applied to groundnut was to the tune of 31.6, 14.1 and 8.7% in grain and 77.6, 29.2 and 14.0% in straw over the control, 75 and 100% RDF respectively. Significantly higher P uptake by rice was recorded with application of 125% RDF to groundnut and such an increase was71.6, 33.7 and 12.4% in grain and 70.3, 37.0 and 26.0% in straw over the control, 75 and 100% RDF respectively. The K uptake by rice grain recorded under 100% RDF applied to groundnut was 36.2 and 13.1%significantly higher over the control and 75% RDF respectively, whereas such an increase with application of 125% RDF to groundnut was 52.4, 27.3 and 9.0% in straw over the control, 75 and 100% RDF respectively. The increased N, P and K uptake by rice was mainly on account of increased yield and nutrient concentrations due

Table 1. Direct and residual effects of doses of fertilizers and biofertilizers on yields, productivity and economics of groundnut–rice cropping system (mean data of 2 years)

Treatment	Groundnut		Rice		Groundnut–rice cropping system			
	Pod yield (t/ha)	Haulm yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	RGEY (t/ha)	Production efficiency (kg/ha/day)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Fertility level (groundnut)								
No fertilizer (control)	1.18	2.59	4.67	4.72	7.77	30.4	39.8	1.62
75% RDF	1.54	3.43	5.21	5.34	9.27	36.2	58.7	1.90
100% RDF	1.91	3.83	5.46	5.65	10.51	41.1	74.1	2.12
125% RDF	2.12	4.23	5.58	5.92	11.17	43.7	82.5	2.24
SEm±	0.03	0.05	0.08	0.08	0.11	0.4	1.4	0.02
CD (P=0.05)	0.09	0.15	0.23	0.22	0.33	1.3	4.2	0.06
Biofertilizer (groundnut)								
Control	1.64	3.40	5.12	5.29	9.44	36.9	60.8	1.93
Rhizobium+PSB	1.74	3.64	5.34	5.52	9.92	38.8	66.8	2.01
SEm±	0.02	0.04	0.06	0.05	0.08	0.3	1.0	0.02
CD (P=0.05)	0.06	0.10	0.16	0.16	0.23	0.9	3.0	0.05
Fertility level (rice)								
No fertilizer (control)			3.90	4.01	8.20	32.1	46.3	1.73
75% RDF			4.98	5.13	9.51	37.2	61.4	1.94
100% RDF			5.68	5.96	10.12	39.6	69.1	2.04
125% RDF			6.36	6.53	10.89	42.6	78.3	2.17
SEm±			0.07	0.07	0.11	0.4	1.4	0.02
CD (P=0.05)			0.19	0.20	0.31	1.2	3.9	0.06

RGEY, Rice grain equivalent yield.

to increased availability of nutrients with each higher dose applied to groundnut. These results are in agreement with the findings of Singh and Ahlawat (2007).

Inoculation of groundnut with *Rhizobium*+PSB left significant residual effect for benefit of grain and straw yields of succeeding rice (Table 1), which was reflected from increase in grain (4.3%) and straw yields (4.3%) over the control. It might be due to beneficial effect of biofertilizers on nodulation and growth of groundnut leading to enhanced N_2 fixation for its own growth and productivity and use of the succeeding crop. Our findings confirm the results of Shivakumar and Ahlawat (2008) and Fauzdar (2011). Uptake of N, P and K uptake by rice grain and straw (except N uptake by straw) improved significantly due to residual effect of biofertilizers (Table 2). Inoculation with *Rhizobium*+PSB showed 8.2% higher N uptake in rice grain over the control (no biofertilizer). It also recorded 8.9 and 8.5% higher P uptake and 5.8 and 8.0% higher K uptake in rice grain and straw respectively, over the control. The significant improvement in N, P and K uptake in grain and straw of rice was mainly owing to increase in yields due to favourableinfluence of *Rhizobium*+PSB inoculation. The results are in agreement with Faujdar (2011).

Direct fertility levels

Rice crop responded significantly to each higher levels of fertilizer up to 125% RDF (Table 1). Application of 125% RDF increased grain yield by 63.1, 27.7 and 12.0% and straw yield by 62.8, 27.3 and 9.6% over the control, 75 and 100% RDF respectively. This might be due to increased availability of N, P and K with 125% RDF. The cumulative beneficial effect of growth and yield-attributing characters was finally reflected in higher grain and straw yields. These results are alike to the findings of Ramesh *et al.* (2008) and Gautam *et al.* (2012).

Successive increase in fertilizer levels up to 125% RDF significantly increased N, P and K uptake by rice grain and straw (Table 2). The increase in N uptake due to 125% RDF was 90.2, 39.5 and 17.7% in grain and 119.3, 45.0 and 15.2% in straw over the control, 75 and 100% RDF respectively. The increase in P uptake due to 125% RDF was to the extent of 112.6, 50.3 and 19.2% in grain; and 103.1, 44.4 and 20.4% in straw over the control, 75 and 100% RDF respectively. Likewise the increase in K uptake due to 125% RDF was to the tune of 114.6, 62.5 and 24.9% in grain and 84.3, 41.9 and 13.4%in straw over the control, 75 and 100% RDF, respectively. Uptake of nutrients is a function of biomass production and nutrient concentration of that biomass which increased with fertilizer application. Hence increase in uptake of nutrients was due to cumulative effect of increase in yield (Table 1) and nutrient concentrations. These results are in close conformity with the findings of Gautam*et al.* (2012).

Table 2. Effect of direct and residual fertilizer levels and biofertilizers on N, P and K uptake by groundnut-rice cropping system (mean data of 2 years)

Treatment	Uptake by groundnut (kg/ha)						Uptake by rice (kg/ha)						Total NPK uptake by system (kg/ha)
	N		P		K		N		P		K		
	Pod	Haulm	Pod	Haulm	Pod	Haulm	Grain	Straw	Grain	Straw	Grain	Straw	
Fertility level (groundnut)													
No fertilizer (control)	28.3	31.4	3.7	5.9	4.7	30.6	55.3	19.2	12.7	3.7	12.7	66.8	275.0
75% RDF	40.3	44.3	5.4	9.3	6.8	42.8	63.8	26.4	16.3	4.6	15.3	80.0	355.2
100% RDF	52.6	51.4	8.0	11.4	9.1	51.3	67.0	29.9	19.4	5.0	17.3	93.4	415.7
125% RDF	59.7	58.1	9.8	14.5	10.4	57.9	72.8	34.1	21.8	6.3	18.4	101.8	465.5
SEm±	0.9	0.9	0.2	0.3	0.2	0.8	1.1	0.8	0.4	0.2	0.4	2.2	4.6
CD (P=0.05)	2.6	2.4	0.5	1.0	0.5	2.2	3.2	2.3	1.2	0.4	1.2	6.3	13.3
Biofertilizer (groundnut)													
Control	43.3	44.5	6.3	9.6	7.3	43.6	62.2	26.6	16.8	4.7	15.5	82.2	362.6
Rhizobium+PSB	47.1	48.1	7.1	11.0	8.1	47.7	67.3	28.2	18.3	5.1	16.4	88.8	393.1
SEm±	0.7	0.6	0.1	0.2	0.1	0.5	0.8	0.6	0.3	0.1	0.3	1.5	3.3
CD (P=0.05)	1.9	1.7	0.3	0.7	0.4	1.5	2.3	NS	0.9	0.3	0.9	4.5	9.4
Fertility level (rice)													
No fertilizer (control)							44.0	16.6	11.1	3.2	10.3	59.3	302.3
75% RDF							60.0	25.1	15.7	4.5	13.6	77.0	358.5
100% RDF							71.1	31.6	19.8	5.4	17.7	96.4	403.5
125% RDF							83.7	36.4	23.6	6.5	22.1	109.3	447.1
SEm±							1.2	0.5	0.4	0.1	0.4	1.5	3.6
CD (P=0.05)							3.4	1.4	1.2	0.4	1.1	4.2	10.0

System productivity and nutrient uptake

Rice–grain equivalent yield and production efficiency of groundnut–rice cropping system was favourably and significantly influenced by doses of fertilizers applied to groundnut (Table 1). The rice-grain equivalent yield was the maximum at 125% RDF, being 43.8, 20.5 and 6.3% higher significantly over the control, 75 and 100% RDF respectively. Maximum production efficiency was obtained at 125% RDF (43.7 kg/ha/day). The magnitude of increase in total NPK uptake by the system due to 125% RDF was 69.3, 31.1 and 12.0% respectively over the control, 75 and 100% RDF (Table 2). Treatment 100% RDF applied to groundnut was also significantly better than the control and 75% RDF in improving rice–grain equivalent yield, production efficiency and total N, P and K uptake. Treatment 75% RDF was also significantly superior to the control.

Inoculation with *Rhizobium*+PSB to groundnut crop significantly improved (5.1%) rice-grain equivalent yield of the system compared to no inoculation. Production efficiency recorded with *Rhizobium*+PSB treatment was also higher than that of without inoculation. There was also significant effect of biofertilizers applied to groundnut crop on total NPK uptake by the system and the magnitude of increase due to *Rhizobium*+PSB treatment was 8.4% over without inoculation.

Successive increase in fertilizer levels up to 125% RDF applied to rice crop significantly improved the rice-grain equivalent yield and registered an increase of 32.8, 14.5 and 7.6% over control, 75 and 100% RDF respectively. Production efficiency was also found maximum with 125% RDF. Total NPK uptake in groundnut–rice cropping system also improved significantly with application of 125% RDF to rice by 47.9, 24.7 and 10.8% over the control, 75 and 100% RDF respectively. Treatment 100% RDF applied to rice was also significantly better than the control and 75% RDF in improving rice-grain equivalent yield, production efficiency and total NPK uptake. Treatment 75% RDF was also significantly superior to the control.

Economics

The net returns and benefit: cost ratio obtained from groundnut–rice cropping system were significantly affected by doses of fertilizers applied to groundnut crop (Table 1). Application of 125% RDF resulted in significantly higher net returns with higher benefit: cost ratio and recorded 42.7, 23.9 and 8.4 $\times 10^3$/ha higher net returns over the control, 75 and 100% RDF respectively. Inoculation with *Rhizobium*+PSB resulted in significantly higher net returns (66.8×10^3₹/ha) with higher benefit: cost ratio and fetched additional net returns of 6.0 x 10^3‘/ha over without inoculation treatment. Application of 125% RDF applied to succeeding rice crop registered significantly higher net returns, being 32.0, 16.9 and 9.2×10^3₹/ha higher than the control, 75 and 100% RDF respectively. Benefit: cost ratio was also found higher in 125% RDF applied to rice compared to lower doses.

It can be concluded that application of 125% RDF (31.25:62.5:62.5 kg N, P and K/ha) and biofertilizers to groundnut and 125% RDF (125:62.5:62.5 kg N, P and K/ha) to rice is recommended for obtaining higher system productivity and net returns.

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