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Effect of Different Sources of Nutrient on Productivity and Profitability of Rice (*Oryza sativa* L.) - Cowpea (*Vigna unguiculata* L.) Cropping System

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A field experiment was conducted during *Kharif* 2013 and *Rabi* 2013-14 at Agronomy farm of Regional Agricultural Research Station, Karjat of North Konkan Coastal Zone of Maharashtra State to study the effect of different nutrient sources on rice - cowpea cropping system. The treatments for *Kharif* rice comprised of seven nutrient sources viz., recommended dose of NPK fertilizers (RDF) with split application of nitrogen 50 per cent as basal + 25 per cent at active tillering + 25 per cent at flowering and P & K as basal, *Azospirillum* + phosphate solubilising bacteria (PSB) @ 3.5 kg each + 75 per cent RDF, *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + 75 per cent RDF, *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} +75% RDF, *Azospirillum* + Phosphate solubilising bacteria (PSB) @ 3.5 kg each+ *Glyricidia* green leaf manuring @ 3t ha^{-1}+ residue mulch @ 2 t ha^{-1} + 50 per cent RDF, *Azospirillum* + PSB @ 3.5 kg each seed and soil + FYM 5 t ha^{-1} + 50 per cent RDF, use of USG-DAP briquette @ 170 kg ha^{-1} (Optional location specific treatment) laid out in a randomized block design, replicated four times. The succeeding *Rabi* cowpea crop was superimposed on same layout and same set of treatments as per the RDF of cowpea (25:50:00 kg NPK ha^{-1}) with few modification viz., *Rhizobium* was used instead of *Azospirillum*, *Glyricidia* green leaf manuring component was eliminated and fertilizer mixture was used in place of USG-DAP briquette. Application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 75 per cent RDF recorded significantly higher *Kharif* rice grain and straw yields by 9.12 and 12.70 per cent, respectively over recommended dose of NPK. Significantly higher grain and stover yields (9.06 and 9.13 per cent, respectively) of *Rabi* cowpea were recorded by application *Rhizobium* + PSB (@ 3.5 kg each) + residue mulch @ 2 t ha^{-1} + 75 per cent RDF as compared to recommended dose of NPK. Maximum and significantly higher rice grain equivalent yield (REY) of 7.44 t ha^{-1}, total system REY of 12.43 t ha^{-1}, gross returns of the system (Rs. 1,74,064), net returns of the system (Rs. 89,811) and B:C ratio of the system (2.07) were obtained with application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 75 per cent RDF in *Kharif* rice and *Rhizobium* + PSB (@ 3.5 kg each) + residue mulch @ 2 t ha^{-1} + 75 per cent RDF in *Rabi* cowpea.

(***Key words***: *Economics, Green leaf manuring, Mulching, Rhizobium, Rice-cowpea cropping system)*

Rice occupies 37 per cent of the total area under food grains, the largest area (42.3 million ha.) under any single crop in India. Despite, India holding a prominent position at the global level both in area (28.67%) and production (21.11%) the rice productivity of the country is around 2.82 t ha^{-1} which is much less compared to the countries like South Korea (8.3 t ha^{-1}, Egypt (7.9 t ha^{-1}), Japan (6.3 t ha^{-1}), North Korea (6.1 t ha^{-1}) and China (6.0 t ha^{-1}).

Within the country itself, there is a large variation in the productivity among the states, ranging from 1164 kg ha^{-1} in Madhya Pradesh to 3507 kg ha^{-1} in Punjab, while that of transplanted rice in Maharashtra state is 1841 kg ha^{-1}.

India grows a variety of pulse crops under a wide range of agro-climatic conditions and the country is recognized globally as a major player in pulses contributing 25 per cent to the global production (Ali and Kumar, 2005). In spite of being the largest producer in the world, India imports pulses to the tune of 2 million tonnes every year to meet its domestic requirement (Ali and Kumar, 2005). This is due to the fact that pulses are inseparable ingredients of vegetarian diet and one of the cheapest sources of dietary protein in the country. To meet the demand of pulses for a burgeoning population, at least 23.28 million tonnes of pulses are required by 2015 which is expected to touch 29.30 million tonnes by 2020 (Ali and Kumar, 2005). Among pulses, cowpea is

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the most important summer crop next only to mung and it has significant contribution in the pulse economy of the country. It is a short duration crop, the seeds contain over 23 per cent protein, leaves and haulm are rich sources of fodder. Summer cowpea can be fitted very well in different cropping systems with cereal crop in such a way that they will complement their production rather than compete with them. With this background, the present investigation was planned, with objectives to study the effect of different sources of nutrient on productivity and profitability of rice-cowpea cropping system of North Konkan Coastal Zone of Maharashtra State.

MATERIALS AND METHODS

A field experiment was conducted in randomized block design with three replications during *Kharif* 2013 and *Rabi* 2013-14 at Agronomy farm of Regional Agricultural Research Station, Karjat (18.92° N latitude, 73.33° E longitude and 52.00 m altitude, soil type is medium black) of North Konkan Coastal Zone of Maharashtra State with seven different sources of nutrient combination treatments comprising T_1: Recommended dose of NPK fertilizers (RDF) (split application of nitrogen 50% as basal + 25% at active tillering + 25% at flowering and P & K as basal), T_2: *Azospirillum* + Phosphate solubilising bacteria (PSB) @ 3.5 kg each + 75% RDF, T_3: *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + 75 per cent RDF, T_4: *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 75% RDF, T_5: *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 50% RDF, T_6: *Azospirillum* + PSB @ 3.5 kg each seed and soil + FYM 5 t ha^{-1} + 50% RDF, T_7: Use of USG-DAP briquette @ 170 kg ha^{-1} (Optional location specific treatment) for *Kharif* Rice. The succeeding *Rabi* cowpea was superimposed on same layout and same set of treatments as per the RDF of cowpea (25:50:00 kg NPK ha^{-1}) with few modification *viz*., *Rhizobium* was used instead of *Azospirillum*, *Glyricidia* green leaf manuring component was eliminated and fertilizer mixture was used in place of USG-DAP briquette.

RESULTS AND DISCUSSIONS

Growth, yield attributes and yield of *Kharif* rice

Significantly highest plant height (95.8 cm) and dry matter production (9.57 t ha^{-1}) of *Kharif* rice were recorded in the treatment that received *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 75% RDF (T_4) (Table 1) over rest of the treatments. However, the dry matter production at harvest was at par with the treatment *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 50% RDF (T_5). The same treatment T_4 resulted in significantly higher number of effective tillers (9.8 hill^{-1}), number panicles m^{-2} (273.70), length of panicle (25.4 cm), number of spikelets panicle^{-1} (136) and 1000 grain weight (22.76 g) as compared to rest of the treatments except the treatments T_3 and T_5in which number of effective tillers, number of panicles m^{-2}, panicle length and spikelets panicle^{-1} were at par. Significantly the highest grain and straw yields of rice (4.23 and 5.34 t ha^{-1}, respectively) were recorded in the treatment T_4 except treatment T_5 consisting of *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 50% RDF. These results are conformity with the findings of Gaur (2006). Further improvement in the yield of rice owing to combined use of organic manure along with biofertilizers might be because of sufficient release of N by mineralization, which resulted in better crop growth and improvement in various yield components of rice (Babu *et al*., 2001; Chhettri *et al*., 2002). The average grain and straw yields were 9.12 and 12.70 per cent higher, respectively than with nutrients applied as per the RDF (T_1). Integrated application of organic and inorganic sources of nutrient improving the yield of rice was also reported by Mandal *et al*. (2004).

Growth, yield attributes and yield of *Rabi* cowpea

Growth and productivity of cowpea were also influenced by different sources of nutrient management. The treatment T_4 application of *Rhizobium* + PSB @ 3.5 kg each + residue mulch @ 2 t ha^{-1} + 75% RDF recorded significantly highest plant height and dry matter production at harvest as compared to rest of the treatments except application of *Rhizobium* + Phosphate solubilising bacteria (PSB) @ 3.5 kg each + residue mulch @ 2 tha^{-1} + 50% RDF (T_5). Significantly highest number of branches plant^{-1}, number pods plant^{-1}, pod length, number of grain pod^{-1} and weight of pod plant^{-1} were recorded by the treatment T_4 as compared to rest of the treatments except treatment T_5.Similar trend was observed in treatment T_3 except number of grains pod^{-1} and weight of pods plant^{-1} which were at par with treatment T_4. Significantly the highest grain and stover yields of cowpea (1.47 and 2.95 t ha^{-1} respectively) were

Table 1*.Effect of different sources of nutrients on growth, yield attributes and yield of Kharif rice in rice- cowpea cropping sequence*

Treatment	Plant height (cm)	Total dry matter production	No. of effective tillers	No. of panicles per m^2	Panicle length (cm)	No. of Spikelets $Panicle^{-1}$	Test weight (1000 grain wt)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1 Recommended dose of NPK fertilizers (RDF) (split application of Nitrogen 50 per cent as Basal+25 per cent at active tillering + 25 per cent at flowering and P & K as Basal)	94.2	86.14	8.7	244.30	23.3	125.00	22.72	38.80	47.34
T_2 *Azospirillum* + Phosphate solubilising bacteria (PSB) @ 3.5 kg each + 75 per cent RDF	93.7	84.69	8.5	238.70	22.9	123.00	22.73	38.15	46.54
T_3 *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + 75 per cent RDF	94.3	91.47	9.3	259.00	24.4	130.75	22.75	40.66	50.82
T_4 *Azospirillum*+ PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 75% RDF	95.8	95.69	9.8	273.70	25.4	136.00	22.76	42.34	53.35
T_5 *Azospirillum* + Phosphate solubilising bacteria (PSB) @ 3.5 kgeach + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 tha^{-1} + 50% RDF	94.7	94.02	9.6	267.40	25.0	134.25	22.75	41.60	52.42
T_6 *Azospirillum*+ PSB @ 3.5 kg each seed and soil + FYM 5 tha^{-1} + 50% RDF	93.3	88.13	8.6	241.50	23.7	127.00	22.74	39.52	48.61
T_7 Use of USG-DAP briquette @ 170 kg ha^{-1} (Optional location specific treatment) for *Kharif* Rice	93.5	88.42	8.9	248.50	23.8	128.00	22.73	39.65	48.77
SEm $\pm$	0.29	1.17	0.18	5.07	0.3	1.53	0.01	0.52	0.65
CD at 5%	0.89	3.65	0.56	15.79	1.1	4.75	NS	1.63	2.02

Table 2. *Effect of different sources of nutrients on growth, yield attributes and yield of Rabi cowpea in rice- cowpea cropping sequence*

Treatment	Plant height (cm)	Total dry matter production	No. of branches plant^{-1}	No. of pods plant^{-1}	Pod length (cm)	No. of grains pod^{-1}	Pod weight plant^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1 Recommended dose of NPK fertilizers (RDF= 25:50:00 kg NPK ha^{-1})	52.6	36.64	4.4	5.8	11.2	11.7	8.8	9.60	27.04
T_2 *Rhizobium* + Phosphate solubilising bacteria (PSB) @ 3.5 kg each + 75 per cent RDF	52.5	36.02	4.3	5.7	11.0	11.5	8.7	9.43	26.59
T_3 *Rhizobium* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + 75 per cent RDF	53.3	38.39	4.6	6.0	11.7	12.3	9.2	10.05	28.34
T_4 *Rhizobium* + PSB @ 3.5 kg each + residue mulch @ 2 tha^{-1} + 75% RDF	54.2	39.98	4.8	6.3	12.2	12.8	9.6	10.47	29.51
T_5 *Rhizobium* + Phosphate solubilising bacteria (PSB) @ 3.5 kg each + residue mulch @ 2 tha^{-1} + 50% RDF	54.2	39.28	4.7	6.2	12.0	12.6	9.4	10.29	28.99
T_6 *Rhizobium*+ PSB @ 3.5 kg each seed and soil + FYM 5 tha^{-1} + 50% RDF	52.5	37.32	4.5	5.9	11.4	11.9	9.0	9.77	27.54
T_7 Use of Fertilizer mixture as per RDF (Optional location specific treatment) for *Rabi* cowpea	52.7	37.44	4.5	5.9	11.4	12.0	9.0	9.81	27.63
SEm $\pm$	0.60	0.50	0.06	0.08	0.16	0.16	0.12	0.13	0.36
CD at 5 %	NS	1.54	0.18	0.25	0.49	0.50	0.38	0.41	1.14

Table 3. *Effect of different sources of nutrients on rice equivalent yield (REY), system productivity (Total REY) and economics of rice-cowpea cropping sequence*

Treatment	REY (t ha^{-1})	Total REY (t ha^{-1})	Gross returns of system (Rs. ha^{-1})	Cost of cultivation of system (Rs. ha^{-1})	Net returns of system (Rs. ha^{-1})	B:C ratio	Productivity* of the system (kg ha^{-1} day^{-1})	Profitability* G. M. E.** (Rs. ha^{-1} day^{-1})
T_1 As per treatment of *Kharif* rice + As per treatment of *Rabi* cowpea	6.82	11.37	159231	83532	75699	1.91	31.16	436
T_2 As per treatment of *Kharif* rice + As per treatment of *Rabi* cowpea	6.70	11.18	156546	81733	74813	1.92	30.64	429
T_3 As per treatment of *Kharif* rice + As per treatment of *Rabi* cowpea	7.14	11.93	167069	82813	84256	2.02	32.69	458
T_4 As per treatment of *Kharif* rice + As per treatment of *Rabi* cowpea	7.44	12.43	174064	84253	89811	2.07	34.06	477
T_5 As per treatment of *Kharif* rice + As per treatment of *Rabi* cowpea	7.31	12.22	171036	81893	89143	2.09	33.47	469
T_6 As per treatment of *Kharif* rice + As per treatment of *Rabi* cowpea	6.94	11.59	162247	94425	67822	1.72	31.75	445
T_7 As per treatment of *Kharif* rice + As per treatment of *Rabi* cowpea	6.97	11.63	162783	81655	81128	1.99	31.86	446
SEm $\pm$	0.93	1.54	2158		2158	0.03		
CD at 5%	2.88	4.80	6713		6713	0.08		

*Based on 365 days of the year, **G.M.E. = Gross monetary efficiency

recorded by the treatment T_4 as compared to rest of the treatments except treatment T_5. The respective average grain and stover yield obtained by the treatmentT_4 was 9.06 and 9.13 per cent higher than the nutrients applied as per the RDF (T_1). The increase in biological yield due to application of phosphorus from 0 to 33 kg P ha^{-1} to cowpea was due to the response to the applied super phosphate, similar findings also observed by Vikrant *et al*. (2005). The present results are in consonance with those of Ahlawat *et al*. (1979); Patel (1979); Kumar and Pillai (1979); Pattanayak *et al.* (2001) and Akinriude and Okeleye (2005)

Rice equivalent yield (REY) and system productivity

Maximum and significantly higher rice grain equivalent yield (REY) 7.44 t ha^{-1} was obtained from *Rabi* cowpea crop (Table 3) when supplied nutrients through *Rhizobium*+ PSB @ 3.5 kg each + residue mulch @ 2 t ha^{-1} + 75% RDF(T_4) over rest of the treatments except nutrients supplied with *Rhizobium* + PSB @ 3.5 kg each + residue mulch @ 2 t ha^{-1} + 50% RDF (T_5). Total rice grain equivalent yield (Total REY) of rice-cowpea system was maximum and significantly higher (12.43 t ha^{-1}) when *Kharif* rice was applied with *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 75% RDF and *Rabi* cowpea was applied with *Rhizobium*+ PSB @ 3.5 kg each + residue mulch @ 2 t ha^{-1} + 75% RDF as compared to rest of the treatments except treatment T_5 (Table 3). Total REY of treatment T_4 was 9.31 per cent higher than the recommended dose of NPK to *Kharif* rice and *Rabi* cowpea crops in Rice-cowpea cropping sequence. Organic manure alone or along with biofertilizers enhanced the yield potential of crops which ultimately increased the rice equivalent yield of the system reported by Debjani *et al*. (2009). Maximum productivity (34.06 kg ha^{-1} day^{-1}) was observed due to treatment (T_4) followed by treatment T_5 (33.47 kg ha^{-1} day^{-1}) and T_3 (32.69 kg ha^{-1} day^{-1})

Economics and system profitability

In the cropping system, the significantly higher gross income (Rs. 1,74,064 ha^{-1}) was obtained when *Kharif* rice was applied with *Azospirillum* + PSB @ 3.5 kg each + *Glyricidia* green leaf manuring @ 3 t ha^{-1} + residue mulch @ 2 t ha^{-1} + 75% RDF and *Rabi* cowpea was applied with *Rhizobium*+ PSB @ 3.5 kg each + residue mulch @ 2 t ha^{-1} + 75% RDF (Table 3) over rest of the treatments except treatment T_5. Net income (Rs. 89,811ha^{-1}) and benefit : cost ratio (2.09) recorded by the treatment T_4 also significantly higher over rest of the treatments except treatment T_5 and T_3 which were at par. Maximum profitability (Gross Monetary Efficiency) of Rs. 469 ha^{-1} day^{-1} was observed due to treatment T_4 followed by treatment T_5 (Rs. 458 ha^{-1} day^{-1}) and treatment T_3 (Rs. 458 ha^{-1} day^{-1}).

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