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Research Paper

Effect of tillage and nutrient-management practices on yield, economics and soil health in rice (*Oryza sativa*)–greengram (*Vigna radiata*) cropping system under rainfed condition of Odisha

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2012–13 and 2013–14 at the Instructional farm , Krishi Vigyan Kendra, Angul, Odisha, to study the effect of tillage and nutrient-management practices on yield, economics and soil health in rice (*Oryza sativa* L.)–greengram [*Vigna radiata* (L.) Wilczek] cropping system under rainfed condition. Among the tillage practices, conventional tillage (CT)–zero tillage (ZT) recorded the maximum system productivity (6.71 t/ha), production efficiency (40.6 kg/ha/day), sustainable-yield index (0.87). However, the maximum available nitrogen (218.3 kg/ha), phosphorus (17.3 kg/ha), potassium (242.7 kg/ha), organic carbon (0.47%), agronomic efficiency (12.9 kg grain/kg of nutrient), net returns (₹63.6 × 10^3/ha), benefit: cost ratio (3.3) and economic efficiency (₹385.6/ha/day) were obtained in ZT (rainy season)–ZT (winter season). Application of 75% recommended dose of fertilizer (RDF) + 5 t/ha FYM to *kharif* rice followed by 3 t/ha FYM to *rabi* greengram resulted in significantly higher system productivity, production efficiency and sustainable-yield index. Further, higher available nitrogen, phosphorus, potassium and organic carbon were achieved in 50% RDF + 10 t/ha FYM to *kharif* rice followed by (fb) 50% RDF + 3 t/ha FYM + bioferilizers to *rabi* greengram. Thus, yield could be increased in CT–ZT, whereas better economics and soil health could be obtained in ZT (*kharif*)–ZT (*rabi*) practices. Among the nutrient-management practices, 75% RDF + 5 t/ha FYM to *kharif* rice fb 3 t/ha FYM to *rabi* greengram; 50% RDF + 10 t/ha FYM to *kharif* rice fb 50% RDF + 3 t/ha FYM + bioferilizers to *rabi* greengram recorded better yield and soil health respectively in rainfed condition.

Key words : Cropping system, Economics, Greengram, Nutrient management, Rainfed, Rice, Soil health, Tillage, Yield

Rice is a component of widely varying cropping systems. Rice-based cropping systems form an integral part of agriculture in Odisha. It is the main crop of the mid central table land zone of state with a total coverage of 0.17 million ha in both rainy (*kharif*) and winter (*rabi*) seasons, which is about 43% of the total cultivable area of the zone (Samant, 2015). Intensive agriculture, involving exhaustive, high-yielding varieties of rice and other crops, has led to heavy withdrawal of nutrients from soil, and imbalanced and indiscriminate use of chemical fertilizers has resulted in deterioration of soil health (Porpavai *et al.*, 2011). Tillage is a practice, which changes the physical properties of soil and enables the plants to attain their full potential. Tillage techniques are used to provide a good seedbed, root development, weed control, and manage crop residues, level the surface for help in uniform irrigation and incorporation of fertilizers (Salahin *et al.*, 2011).

Cultivation of winter (*rabi*) urdbean or blackgram and mungbean or greengram in coastal regions of South India is being practiced since long but it could get momentum only after development of powdery mildew-resistant genotypes having high yield potential. Development of these varieties in late eighties has revolutionized urdbean and mungbean cultivation in rice fallow, especially in Andhra Pradesh. This cropping system is highly productive and improves soil health (Singh *et al*., 2009). Besides increasing overall productivity and income, intercropping of legumes with cereals helps in conserving moisture by reducing runoff, improving physical properties of soil and building up of soil fertility. Legumes like greengram being short-duration crop may constitute potential intercrop in

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upland rice under rainfed condition (Lawrence and Gohain, 2011).

Cropping system has an immense effect on physical and chemical soil properties and thereby on crop productivity. Soil fertility often changes in response to land use and cropping systems and land-management practices. Use of green manure especially legumes in a cropping pattern could help restore crop productivity. Soil tillage is among the important factors affecting soil properties and crop yield. Crop production could be increased by adopting appropriate tillage operation and selecting suitable crops in the cropping pattern including leguminous crops, which demands intensive field research. Reducing tillage positively influences several aspects of the soil, whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Losses of soil organic carbon and deterioration in other properties exaggerated where conventional tillage was employed. Thus, currently there is a significant interest and emphasis on the shift from extreme tillage to conservation and no-tillage methods (Alam *et al*., 2014).

Therefore, a study was conducted to find out suitable tillage and nutrient-management practices in rice–greengram cropping system for better yield, economics and soil health under rainfed condition in mid central table land zone of Odisha.

MATERIALS AND METHODS

A rainfed field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2012–13 and 2013–14 at the Instructional farm, Krishi Vigyan Kendra, Angul (20° 49' N, 85° 04' E, 300 m above mean sea-level) in mid central table land zone of Odisha. The soil was clay loam in texture with slightly acidic in reaction (*p*H of 5.8), medium in organic carbon (0.42%), low in nitrogen (198.3 kg/ha), medium in phosphorus (13.8 kg/ha) and potassium (176 .3 kg/ha) content. The climate of the experimental area was fairly hot and humid monsoon and mild winter. The average rainfall in both the years during the study period was 1,389 mm. The mean maximum and mean minimum temperature registered in both the year was 40.0° C in April and 14.0 °C in December respectively.

The experiment was laid out in a split-plot design with 3 replications. The main plot involved 4 different sequential tillage practices, viz. conventional tillage (CT) in *kharif* followed by CT in *rabi* (CT–CT); CT in *kharif* followed by (fb) zero tillage (ZT) in *rabi* (CT–ZT); ZT in *kharif* followed by CT in *rabi* (ZT–CT); ZT in *kharif* followed by ZT in *rabi* (ZT–ZT), and 6 levels of nutrients management practices, namely control (no fertilizer), no organic manure and no bioferilizers to *kharif* rice and *rabi* greengram; 100% recommended dose of fertilizer (RDF) to *kharif* rice followed by 100% RDF to *rabi* greengram; 75% RDF + 5 t/ha FYM to *kharif* rice followed by 3 t/ha FYM to *rabi* greengram; 50% RDF + 10 t/ha FYM to *kharif* rice followed by 50% RDF + 3 t/ha FYM + bioferilizers to *rabi* greengram; 20 t/ha FYM to *kharif* rice followed by 3 t/ha FYM + biofertilizers to *rabi* greengram; brown manuring to *kharif* rice followed by 3 t/ha FYM to *rabi* greengram. The conventional tillage included ploughing by tractor-drawn 9-tyne cultivator with direct sowing by broadcasting and zero tillage includes sowing by zero-till drill. Brown manuring was done by sowing rice with *dhaincha* and knocking down of *dhaincha* 30 days after sowing with 2, 4-D ethyle easter @ 0.40–0.50 kg/ha followed by incorporation. Application of biofertilizers to greengram was through seed inoculation with *Rhizobium* and phosphate-solubilizing bacteria (PSB) @ 500 g/ha each. Recommended package of practices were followed for raising rice during *kharif a*nd greengram during *rabi* season. During *kharif*, rice was sown in the third week of June and harvested in the first week of October. Similarly, during *rabi,* greengram was sown in the first week of October and harvested in the first week of December. The recommended fertilizer doses for rice ‘Sahabhagidhan’ and greengram ‘OBGG 52’ were 60–30–30 and 20–40–20 kg N-P-K/ha respectively. Final crop yields were recorded and their monetary returns were calculated on the basis of prevailing market prices of the produce. Harvest index is the relationship between economic yield and biological yield (Gardner *et al.,* 1985), and was calculated as:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

For comparison between crops in sequence the yield of *rabi* greengram was converted into rice-equivalent yield by converting the yield into economic value based on prevailing prices as per Yadav and Nevraj (1990). Production efficiency (PE) was expressed as the ratio of system productivity in kg/ha rice yield to total duration of the system in days (Patil *et al.*, 1995). Sustainable-yield index (SYI) was calculated as per Guggari and Kalanghatagi (2004). For computing SYI; average yield, maximum yield and standard deviation (SD) were taken into account.

$$\text{Sustainable yield index (\%)} = \frac{\text{Average yield} - \text{SD}}{\text{Maximum yield}}$$

Variations in organic carbon and available NPK content of the soil at the end of first year and second year were measured using standard soil-analysis methods. The initial soil samples and post-harvest soil samples collected from 0–30 cm depth for NPK status and organic carbon content were analyzed using standard laboratory procedures (Jackson, 1973). Nutrient-use efficiency, in terms of agronomic efficiency (AE), was calculated as per Prasad (2009) and reported as kg grain/kg nutrient (NPK) applied.

$$AE = \frac{Yf - Yc}{Na}$$

where Yf, grain yield (kg/ha) in fertilized plot; Yc, grain yield (kg/ha) in the control plot; Na, nutrient (N + P_2O_5 + K_2O) applied (kg/ha). Since data followed the homogeneity test, pooling was done over 2 years and mean data were presented. The price of inputs and market price of output of both crops were considered to work out the cost of cultivation and gross returns. The net returns/ha were calculated by deducting the cost of cultivation/ha from gross income. Benefit: cost ratio was calculated by dividing the gross returns with cost of cultivation (Manea *et al.*, 2015). Economic efficiency in term of ₹ ha/day was worked out by dividing the net returns of the sequence by total duration of crops in a system in an agriculture year (Narkhede *et al.*, 2015). All data obtained in the cropping sequence for 2 consecutive years of study were statistically analyzed using the F-test, the procedures given by Gomez and Gomez (1984). Critical difference (CD) values at P=0.05 were used to determine the significance of difference between mean.

RESULTS AND DISCUSSION

Grain and straw yields and harvest index

Pooled data (Table 1) revealed that CT (*kharif*)–CT (rabi) and CT–ZT recorded higher grain yield in *kharif* rice and *rabi* greengram respectively. Maximum straw yield of rice was recorded under ZT–CT and stover yield of greengram under ZT–ZT. Harvest index was the maximum for rice and greengram in CT–CT and CT–ZT respectively.

Among the nutrient-management practices, 50% recommended dose of fertilizer (RDF) + 10 t/ha FYM to *kharif* rice followed by (*fb*) 50% RDF + 3 t/ha FYM + bioferilisers to *rabi* greengram resulted in the maximum grain yield in rice and stover yield in greengram, whereas 75% RDF + 5 t/ha FYM to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram gave the maximum grain yield in greengram and straw yield in rice. Combined use of farmyard manure with biofertilizers improved grain yields of rice, besides improvement in soil fertility. All the nutrient-management practices increased the grain yield of rice crops significantly over the control (Kumar, 2014). The highest harvest index for rice and greengram was observed in brown manuring to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram and in control treatment respectively.

System productivity, production efficiency and sustainable-yield index

The pooled system productivity in terms of rice-equivalent yield (REY) was computed (Table 1) and maximum system productivity, production efficiency (kg/ha/day) and sustainable yield index were recorded under CT–ZT, being higher than ZT–ZT. However, the minimum system productivity, production efficiency and sustainable yield index were observed under CT–CT.

Among the nutrient-management practices, 75% RDF + 5 t/ha FYM to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram recorded the higher system productivity, production efficiency and sustainable yield index which were closely followed by 50% RDF + 10 t/ha FYM to *kharif* rice *fb* 50% RDF + 3 t/ha FYM + bioferilizers to *rabi* greengram which might be owing to significant effect of organic nutrient management on soil organic carbon status and sustainable yield index (Yadav *et al.*, 2000; Pradhan *et al.*, 2015). Similarly, Singh *et al.* (2011) reported that sustainability-yield index in rice–wheat–greengram system was most sustainable followed by greengram, wheat and rice crop under integrated use of organic sources of nutrients.

Soil-fertility status

The changes in organic carbon and availability of major nutrients (Table 2) revealed that there was a significant increase in organic carbon, available nitrogen, phosphorus and potassium contents in all treated plots as compared to initial and the control plot values and the maximum increase in organic carbon and available nitrogen, phosphorus and potassium contents in comparison to initial soil status was observed under treatments of 50% RDF + 10 t/ha FYM to *kharif* rice *fb* 50% RDF + 3 t/ha FYM + bioferilizers to *rabi* greengram might be owing to high C : N ratio of FYM, resulting in organic carbon built up in soil and higher available N,P and K might have increased the activity of microorganisms in soil (Suryavanshi *et al.*, 2015). Prasad *et al*. (2011) also reported similar results. Among the tillage practices, ZT–ZT recorded the maximum available nitrogen, phosphorus, potassium 218.3, 17.3, 242.7 kg/ha, respectively, with organic carbon content 0.47% which was followed by ZT–CT and CT–ZT. The treatment CT–CT recorded the minimum available nitrogen, phosphorus, potassium, being 205.6, 14.1, 185.1 kg/ha, respectively, with organic carbon content 0.45%.

Similarly, agronomic efficiency was the highest under treatment ZT–ZT followed by CT–CT. Among the nutrient-management practices, 75% RDF + 5 t/ha FYM to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram recorded the maximum agronomic efficiency. The next order was found in 50% RDF + 10 t/ha FYM to *kharif* rice fb 50% RDF +

Table 1. Effect of tillage and nutrient-management practices on grain yield, straw yield, harvest index, system productivity, production efficiency and sustainable yield index (pooled data of 2 years)

Treatment	Grain yield (t/ha)		Straw/stover yield (t/ha)		Harvest index (%)		System productivity in terms of REY (t/ha)	Production efficiency (kg/ha/day)*	Sustainable-yield index*
	Kharif rice	*Rabi* greengram	*Kharif* rice	*Rabi* greengram	*Kharif* rice	*Rabi* greengram			
Tillage methods									
CT in *kharif fb* CT in *rabi*	3.08	0.85	3.37	2.09	47.9	29.1	5.68	34.40	0.67
CT in *kharif fb* ZT in *rabi*	3.01	1.09	3.60	2.50	45.6	31.4	6.71	40.65	0.87
ZT in *kharif fb* CT in *rabi*	2.91	0.94	3.75	2.21	43.8	30.2	5.97	36.15	0.75
ZT in *kharif fb* ZT in *rabi*	2.82	1.06	3.44	2.61	44.9	29.3	6.46	39.12	0.85
SEm±	0.004	0.004	0.005	0.009	0.005	0.012	0.158	0.95	
CD (P=0.05)	0.014	0.014	0.016	0.030	0.016	0.042	0.546	3.312	
Nutrient-management practices									
No fertilizer, no organic manure and no bioferilizers to *kharif* rice and *rabi* greengram (control)	1.78	0.72	2.09	1.21	45.9	36.5	3.72	22.52	0.57
100% RDF to *kharif* rice *fb* 100% RDF to *rabi* greengram	3.24	1.08	3.80	2.47	46.0	30.5	6.82	41.35	0.86
75% RDF + 5 t/ha FYM to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram	3.31	1.10	4.15	2.76	44.4	28.6	7.04	42.68	0.88
50% RDF + 10 t/ha FYM to *kharif* rice *fb* 50% RDF + 3 t/ha FYM + biofertilizers to *rabi* greengram	3.39	1.09	4.06	3.06	45.5	26.3	6.83	41.37	0.87
20 t/ha FYM to *kharif* rice *fb* 3t/ha FYM + biofertilizers to *rabi* greengram	3.04	1.00	3.68	2.35	45.2	29.9	6.36	38.98	0.80
Brown manuring to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram	2.99	0.90	3.46	2.25	46.4	28.3	6.36	38.57	0.72
SEm±	0.011	0.003	0.010	0.011	0.002	0.036	0.051	0.310	
CD (P=0.05)	0.031	0.009	0.030	0.033	0.005	0.103	0.146	0.887	

CT, conventional tillage; ZT, zero tillage; fb, followed by; RDF, recommended dose of fertilizers
*Calculated on rice equivalent yield (REY) basis

Table 2. Effect of different tillage and nutrient-management practices on soil health and economics (pooled data of 2 years)

Treatment	Available nutrients (kg/ha)			Organic carbon (%)	Agronomic efficiency (kg grain/kg nutrient NPK applied)*	Gross returns (× 10³₹/ha)	Net returns (×10³₹/ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)**
	N	P	K						
Tillage methods									
CT in *kharif fb* CT in *rabi*	205.6	14.1	185.1	0.45	12.68	84.2	50.9	2.52	308.4
CT in *kharif fb* ZT in *rabi*	206.6	14.9	201.3	0.45	12.44	94.8	63.5	3.07	384.7
ZT in *kharif fb* CT in *rabi*	209.8	16.1	222.6	0.46	11.65	86.1	56.2	2.90	340.8
ZT in *kharif fb* ZT in *rabi*	218.3	17.3	242.7	0.47	12.92	91.4	63.6	3.30	385.6
SEm±	0.69	0.09	1.01	0.001	–	0.18	0.19	0.011	1.16
CD (P=0.05)	2.39	0.31	3.50	0.004	–	0.61	0.66	0.036	4.00
Nutrient management practices									
No fertilizer, no organic manureand no bioferilizers to *kharif* rice and *rabi* greengram (Control)	175.1	12.9	160.5	0.39	–	58.7	35.7	2.52	213.8
100% RDF to *kharif* rice *fb* 100% RDF to *rabi* greengram	206.7	15.5	215.9	0.45	15.54	97.5	68.8	3.42	417.2
75% RDF + 5 t/ha FYM to *kharif* rice*fb* 3 t/ha FYM to *rabi* greengram	212.7	16.0	217.8	0.46	16.63	100.4	67.8	3.09	410.9
50% RDF + 10 t/ha FYM to *kharif* rice *fb* 50% RDF + 3 t/ha FYM + biofertilizers to *rabi* greengram	227.6	16.0	234.1	0.49	15.55	101.4	66.8	2.94	404.8
20 t/ha FYM to *kharif* rice *fb* 3 t/haFYM + biofertilizers to *rabi* greengram	220.8	16.4	227.3	0.48	13.58	91.1	53.1	2.41	321.9
Brown manuring to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram	217.6	16.2	221.8	0.47	13.24	85.5	59.5	3.32	360.7
Initial soil status	198.3	13.8	176.3	0.42					
SEm±	5.28	0.08	0.57	0.009	–	0.58	0.29	0.007	1.75
CD (P=0.05)	15.09	0.21	1.62	0.024	–	1.63	0.83	0.021	5.01

CT, conventional tillage; ZT, zero tillage; fb, followed by; RDF, recommended dose of fertilizers
*Calculated on rice equivalent yield (REY) basis; **calculated on net return basis

3t/ha FYM + bioferilizers to *rabi* greengram and 100% RDF to *kharif* rice *fb* 100% RDF to *rabi* greengram, which were equivalent as humic substances help in increasing fertilizer-use efficiency by plant and reducing leaching losses of nutrients by retaining more water (Senapati *et al.*, 2003).

Economics

Economic analysis pooled over 2 years (Table 2) revealed that treatment ZT–ZT recorded the maximum net returns, economic efficiency with benefit: cost ratio (3.3) owing to comparatively lower cost of cultivation which included water, labour and other inputs and drastically reduced the use of machinery than other tillage practices (Shukla *et al.*, 2012). Among the nutrient-management practices, 100% RDF to *kharif* rice *fb* 100% RDF to *rabi* greengram recorded the maximum net returns, economic efficiency with benefit: cost ratio. Maximum gross returns were recorded under 50% RDF + 10 t/ha FYM to *kharif* rice *fb* 50% RDF + 3 t/ha FYM + bioferilizers to *rabi* greengram followed by 75% RDF + 5 t/ha FYM to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram.

It was concluded that yield could be increased under CT–ZT, whereas better economic and soil health could be obtained in ZT–ZT practices in rice–greengram cropping system. Among the nutrient-management practices, 75% RDF + 5 t/ha FYM to *kharif* rice *fb* 3 t/ha FYM to *rabi* greengram; 50% RDF + 10 t/ha FYM to *kharif* rice *fb* 50% RDF + 3 t/ha FYM + bioferilizers to *rabi* greengram recorded better yield and soil health, respectively, in rainfed condition.

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