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Performance of rice and blackgram with different nutrient management practices in rainfed upland

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ABSTRACT

An experiment was conducted at Phulbani, Odisha to examine the performance of three cropping systems (sole rice, sole blackgram and rice + blackgram) with nine different manure and fertilizer treatments under rainfed upland condition. Different nutrient treatments include Control (Farmers' practice- no nutrient); 100% recommended N through inorganic fertilizer; 50% recommended N through inorganic fertilizer; 25kg N through FYM; 15kg N through FYM + 10kg N through inorganic fertilizer; 15kg N through FYM + 20kg N through inorganic fertilizer; 15kg N through green leaf + 10kg N through inorganic fertilizer; 15kg N through green leaf + 10kg N through inorganic fertilizer; and 15kg N through FYM + 10kg N through green leaf. Based on the data on mean rice grain equivalent yield (REY) over 12 years from 1998 to 2009, cultivation of sole blackgram was found to be more remunerative (2.43 t ha^{-1} REY) than sole rice (1.42 t ha^{-1}) or rice + blackgram (5:2) (1.28 t ha^{-1}). Considering the three cropping systems together, application of FYM to supply 15 kg N along with chemical fertilizer (urea) to supply 20 kg nitrogen + 40 kg P_2O_5 +40 kg K_2O was found to be the most effective (2.23 t ha^{-1} REY) followed by the same dose of FYM with 10 kg N through fertilizer + 40 kg P_2O_5 +40 kg K_2O (2.19 t ha^{-1}REY). The best treatment registered 37% higher REY over the recommended fertilizer dose.

Key words: *upland rainfed rice, black gram, sole crop, intercrop, nutrient treatments*

In spite of very high water requirement, rice is grown as a rainfed crop in over 65% of the cultivated areas of Odisha. Even in hilly districts of North Eastern Ghat Zone like Kandhamal, it is grown as a main crop under rainfed upland situation although such type of lands could be profitably diverted for different kharif pulses like pigeonpea, cowpea, green gram, black gram, etc. and oilseeds like groundnut, niger, sunflower, sesame, etc. The farmers of Kandhamal grow rice without manure and fertilizer application, thus realizing poor yield gradually over years. Rice, being a part of social and cultural life, can't be substituted to any significant extent and thus, rice-based intercropping systems particularly with pulses may be taken up as a choice.

The effect of long term use of chemical fertilizers and organic manures on crop yield and soil properties have been reported under different rice-based cropping systems with several fertilizer treatments. In soils with high organic matter or in high clay soils, nitrogen substitution by organic sources may not be possible without decreasing system productivity (Hegde, 1998). The importance of combined application of organic manure and chemical fertilizers for sustainable yield under rainfed upland situation has earlier been established from a 12 years' study at this centre (Mishra *et al.*, 2011). Integrated nutrient management practices help to increase efficiency of applied and native nutrients, improve soil health, economize fertilizer use and decrease nutrient losses resulting in high and sustainable agricultural production (Panda, 2005).

The soil of the experimental site was in high topography and of light texture resulting heavy run off and seepage, and rapid moisture scarcity even in short dry spells of rainy season. Although this site is unsuitable for rice cultivation, farmers of Kandhamal cultivate rice in such type of land over large acreage. In contrast, very few farmers of the district grow blackgram which seems quite ideal for rainfed uplands. Rice + Pigeonpea intercropping (5:2) system was studied earlier at this

station with different nutrient management practices (Behera *et al.*, 2009). Keeping this in view, the current investigation was carried out to study relative profitability of rice and blackgram as sole and intercrop as well as to highlight the impact of different management practices for these three systems in red laterite acidic upland soil over years under varied crop seasonal rainfall in the N-E Ghat Zone of Odisha.

MATERIALS AND METHODS

The present study was undertaken in the Research Farm of AICRP on Dryland Agriculture, OUAT, Phulbani during wet seasons from 1998 to 2009 to investigate the long-term effect of chemical fertilizers and organic manures (applied in different combinations) on rice equivalent crop yield and rain water productivity of sole rice, sole blackgram and rice + blackgram intercrop in red laterite acidic upland soil under varied crop seasonal rainfall. The experiment was designed in split plot with three replications. There were nine nutrient treatments such as control (no nutrient); 100% Recommended (60kg ha^{-1}) N through inorganic fertilizer (60kg N+ 40 kg P_2O_5 +40 kg K_2O for rice and 20kg N+ 40 kg P_2O_5 +40 kg K_2O for black gram); 50% Recommended (30kg ha^{-1}) N through inorganic fertilizer; 25kg N through FYM.; 15kg N through FYM + 10kg N through inorganic fertilizer; 15kg N through FYM + 20kg N through inorganic fertilizer; 15kg N through green leaf + 10kg N through inorganic fertilizer; 15kg N through green leaf + 20kg N through inorganic Fertilizer and 15kg N through FYM + 10kg N through green leaf.

The soil of research farm was sandy-loam in texture with less than 1.5m depth, acidic in reaction with a pH of 5.2 and possessed 0.32% organic carbon, 20kg P_2O_5 ha^{-1} and 220 kg K_2O ha^{-1} (Table 1). Due to upland situation, a short durational variety ZHU 11-26 maturing within 90 days was chosen in this experiment. Black gram variety 'Ujala' was used both in sole and rice-based intercrop.

At Phulbani, onset of south-west monsoon normally occurs on 10th June which ceases on 6th October (Table 2). The mean annual rainfall is 1407.34 mm in 65 rainy days. At least 35 mm mean weekly rainfall with minimum 2 rainy days per week occurs between 24th standard meteorological week (SMW) to 39th SMW which falls between 11th June to 30th September and this period was therefore considered as crop growing season in this experiment. Sowing was generally completed by the end of June in all the years so that the rice cv. ZHU 11-26 could be harvested within September. Proper agronomic practices were followed for raising the crop under rainfed situation and standard statistical methods were used for analyzing the data (Gomez and Gomez, 1981).

Table 1. Initial soil properties at the experimental site

Physical properties		Chemical properties	
Attribute	Value	Attribute	Value
Sand (%)	71.60	pH	5.2
Silt (%)	14.00	EC (dSm^{-1})	0.032
Clay (%)	14.40	Organic carbon(%)	0.32
Textural Class	Sandy-loam	Total N	165 kg ha^{-1}
Soil depth (m)	< 1.5m	Available P_2O_5	20 kg ha^{-1}
Bulk density (gcm^{-3})	1.63	Available K_2O	220kg ha^{-1}
Field Capacity (%)	13.10		
Wilting point (%)	9.50		

RESULTS AND DISCUSSION

The rainfall during crop growing season (sowing to harvest) varied from 586.1 mm in 1998 to 2030.6 mm in 2006 (Table 3). During this period, the average crop seasonal rainfall was 1094.90 mm with standard deviation and coefficient of variation of 462.6mm and 42 %, respectively. When the monsoon months (June

Table 2. Normal weekly rainfall during crop growing season

SMW	Period	Rainfall (mm)	Rainy days
24	11-17 Jun	60.10	2.45
25	18-24 Jun	51.10	2.70
26	25 Jun-1 Jul	64.00	2.80
27	2-8 Jul	83.60	3.15
28	9-15 Jul	62.00	3.18
29	16-22 Jul	74.50	3.80
30	23-29 Jul	83.10	3.35
31	30Jul-5Aug	93.10	3.65
32	6- 12Aug	85.80	3.45
33	13-19 Aug	88.30	3.28
34	20-26 Aug	61.40	2.85
35	27 Aug-2 Sep	102.70	3.43
36	3-9 Sep	55.90	2.90
37	10-16 Sep	78.20	2.93
38	17-23 Sep	44.20	2.25
39	24-30 Sep	35.70	2.05

to September) were taken into consideration, highest monthly rainfall was recorded in July (387.20 mm) followed by August (338.5 mm) (Fig. 1). The coefficient of variation during crop growing season was 42% which was lower than each of monsoon months showing more rainfall variation in a particular month than the total of crop season taken together.

Based on the yield data over 12 years from 1998 to 2009, sole black gram exhibited highest rice equivalent yield(REY) of 2.43 t ha^{-1} followed by sole rice (1.42 t ha^{-1}) while rice + black gram inter crop exhibited the lowest REY (1.28 t ha^{-1}) (Table 4). There was significant variation among three main crop treatments in all the years. Sole black gram recorded 71.5% higher REY than sole rice and sole rice exhibited 10.6% higher REY than rice + black gram inter crop. Higher REY in sole black gram is attributed mostly to high market price (over three times than rice).

Significant variation among nine nutrient treatments was also recorded in most of the years. The treatment with 15kg N through FYM + 20kg N through inorganic fertilizer exhibited higher mean REY of 22.32 q/ha closely followed by 15kg N through FYM + 10kg N through inorganic fertilizer (2.19 t ha^{-1}). The best treatment had 137% higher REY over control (0.94 t ha^{-1}). The crop × nutrient interaction was not significant in many years. The application of FYM, vermicompost or green manure can reduce the NPK rate by 1/3 without reducing rice and wheat yields (Singh *et al.*, 2003). Similar result was also found by Barik *et al.,* 2006 who observed that application of 50% recommended fertilizer in combination with vermicompost at 10 t ha^{-1} significantly improved the growth and yield attributes of rice compared with the application of 100% recommended fertilizer. Gupta *et al.,* 2006 also observed that substitution of 50% N by green leaf manuring with sunnhemp (*Crotalaria juncea*) attained the highest system productivity of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system.

Table 3. Rainfall variation during monsoon months from 1998 to 2009

Year	Rainfall (mm)				
	C.S.R.	June	July	August	September
1998	586.1	84.0	225.6	191.5	227.0
1999	611.6	206.0	367.8	134.2	269.4
2000	701.0	144.0	279.0	273.0	126.0
2001	1537.1	504.9	797.6	300.1	124.7
2002	672.9	149.0	129.0	329.0	134.9
2003	949.0	117.0	237.0	358.1	350.1
2004	756.0	188.0	364.0	242.0	229.0
2005	1224.7	94.0	500.3	139.8	572.4
2006	2030.6	297.7	412.5	987.2	176.0
2007	1580.2	424.0	188.4	363.8	465.4
2008	1134.7	270.0	263.0	422.4	449.3
2009	1354.6	124.6	881.6	321.4	220.2
Mean	1094.9	216.9	387.2	338.5	278.7
Σ	462.6	133.9	235.3	223.0	148.4
C.V.(%)	42	62	61	66	53

C.S.R.= Crop seasonal rainfall (mm); σ = Standard Deviation; C.V.= Coefficient of variation(%)

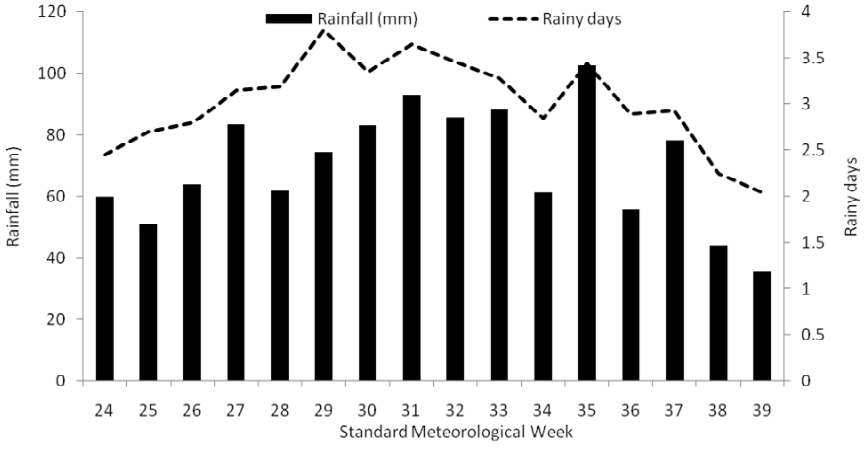

Fig. 1. Normal weekly rainfall during crop growing season

Table 4. Effect of different treatments on rice equivalent grain yield (q ha^{-1}) during 1998-2009

Treatments	Rice equivalent grain yield (t ha^{-1})													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	CV (%)
Main treatments														
C_1- Rice	0.97	1.29	2.57	1.98	1.14	0.87	1.39	0.90	1.88	1.25	1.32	1.40	1.42	35.27
C_2- Blackgram	2.66	6.15	3.35	1.51	1.77	1.40	2.82	1.65	3.05	2.44	1.14	1.13	2.43	57.72
C_3-Rice + Blackgram	1.75	1.75	1.76	0.77	1.43	1.26	1.39	1.12	1.71	0.89	0.74	0.76	1.28	32.34
CD (P=0.05)	0.99	1.13	0.64	0.74	0.48	0.58	0.16	0.26	0.09	0.08	0.08	0.04	-	
Sub-treatments														
Control (no nutrient)	1.21	2.27	1.65	0.50	0.81	0.69	0.89	0.61	1.06	0.77	0.37	0.41	0.94	59.03
100% Recommended (60kg/ha) N through inorganic fertilizer (60kg N+ 40 kg P_2O_5 +40 kg K_2O for rice and 20kg N+40kg P_2O_5+40kg K_2O for black gram)	1.72	2.54	2.64	1.73	1.70	1.07	1.83	1.12	1.75	1.40	0.98	1.00	1.62	33.89
50% Recommended (30kg/ha) N through inorganic fertilizer	1.69	3.09	2.27	1.15	1.35	1.10	1.48	0.92	1.65	1.27	0.91	0.94	1.49	43.08
25kg N through FYM	1.97	3.10	2.29	1.10	1.39	1.28	2.26	1.59	2.78	1.86	1.41	1.43	1.87	33.38
15kg N through FYM + 10kg N through inorganic fertilizer	2.06	3.81	3.25	1.80	1.57	1.26	2.35	1.47	2.93	1.97	1.38	1.40	2.19	39.09
15kg N through FYM + 20kg N through inorganic fertilizer	1.94	3.61	3.25	2.14	1.80	1.53	2.50	1.81	2.81	1.91	1.67	1.74	2.23	30.10
15kg N through green leaf + 10kg N through inorganic fertilizer	1.99	3.13	2.47	1.77	1.42	1.20	1.98	1.18	2.25	1.41	0.85	0.91	1.71	39.78
15kg N through green leaf + 20kg N through inorganic Fertilizer	1.94	3.16	3.01	1.72	1.72	1.42	2.01	1.31	2.06	1.55	0.95	0.97	1.82	38.21
15kg N through FYM + 10kg N through green leaf	1.62	2.93	2.24	1.16	1.32	1.07	1.51	1.01	2.63	1.61	1.09	1.09	1.61	40.46
CD (P=0.05)	NS	0.69	0.35	0.47	0.32	NS	0.51	0.47	0.26	0.19	0.10	0.10	-	
CD (P= 0.05) for interaction	NS	NS	NS	NS	NS	NS	0.88	0.82	0.47	0.33	0.18	0.06	-	

Among cropping systems, sole black gram recorded highest C.V. while among nutrient treatments control (no nutrient) exhibited highest C.V. with respect to REY. The rain water productivity was found to be in accordance to rice equivalent yield. Sole black gram exhibited highest mean rain water productivity of 2.22 kg ha^{-1}-mm while it was lowest in rice + black gram inter crop (Table 5). Among nutrient treatments, 15kg N through FYM + 20kg N through inorganic fertilizer recorded highest REY of 2.04 kg ha^{-1}-mm closely followed by 15kg N through FYM + 10kg N through inorganic fertilizer (2.0 kg ha^{-1}-mm). In earlier studies, INM practices have also been found to decrease dependence on chemical fertilizers, increase of crop yield and higher benefit: cost ratio as compared to application of chemical fertilizer alone (Medhi *et al.,* 2002; Jeyabal *et al.*, 1999). The coefficient of variation (C.V.) for rain water productivity was also highest in sole black gram among cropping systems and in control among nutrient treatments.

The data on REY and rain water productivity gives clear picture on justification for adopting suitable cropping system and nutrient management in rainfed upland ecosystem. The result shows that black gram cultivation is more profitable than sole rice or rice + black gram inter-crop based on rice equivalent yield and more eco-friendly, based on rain water productivity particularly in rainfed uplands of N-E ghat zone of Odisha.

The effect of different nutrient treatments on the soil physico-chemical properties indicated that the water holding capacity increased in all the nutrient treatments over control (Table 6). Highest water holding capacity of 29.8% was recorded in the treatment with 15 kg N through FYM + 20 kg N through urea. The pH marginally decreased in completely chemical treatment but remained same or marginally increased when organic manure was added along with fertilizers. Singh *et al.,* 2002 also observed that the soil bulk density and pH were reduced under nutrient management practices compared to control. The electrical conductivity of 100% chemical (RDF) was the highest (0.051 dS m^{-1}) while it was lowest in the control (0.032 dS m^{-1}) clearly indicating influence of added nutrients on increasing electrical conductivity. The organic matter content

Table 5. Effect of different cropping systems and nutrient treatments on rain water productivity (kg/ha-mm)

Treatments	Rain water productivity (kg ha^{-1}-mm)													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	CV (%)
Main treatments														
C_1- Rice	1.67	2.11	3.67	1.29	1.71	0.93	1.85	0.74	0.93	0.79	1.17	1.04	1.30	54.88
C_2- Blackgram	4.54	10.07	4.79	0.98	2.63	1.48	3.73	1.35	1.50	1.55	1.01	0.84	2.22	92.78
C_3-Rice +BG	3.00	2.88	2.52	0.50	2.13	1.33	1.85	0.92	0.85	0.57	0.66	0.57	1.17	64.14
Sub-treatments														
Control (no nutrient)	2.08	3.72	2.36	0.33	1.21	0.73	1.19	0.50	0.52	0.49	0.33	0.30	0.86	92.73
100% RDN	2.94	4.15	3.77	1.13	2.54	1.13	2.42	0.92	0.87	0.89	0.87	0.74	1.49	66.57
50% Recommended (30kg ha^{-1}) N through inorganic fertilizer	2.90	5.06	3.25	0.75	2.02	1.16	1.96	0.76	0.82	0.81	0.81	0.70	1.36	78.40
25kg N through FYM	3.37	5.08	3.27	0.72	2.07	1.36	2.99	1.31	1.37	1.18	1.25	1.06	1.71	62.86
15kg N through FYM + 10kg N through inorganic fertilizer	3.52	6.23	4.64	1.17	2.35	1.33	3.11	1.20	1.45	1.25	1.22	1.04	2.00	70.67
15kg N through FYM + 20kg N through inorganic fertilizer	3.33	5.91	4.64	1.40	2.68	1.62	3.31	1.48	1.39	1.21	1.48	1.29	2.04	62.04
15kg N through green leaf + 10kg N through inorganic fertilizer	3.40	5.12	3.53	1.15	2.11	1.27	2.63	0.97	1.11	0.89	0.76	0.67	1.57	72.01
15kg N through green leaf + 20kg N through inorganic Fertilizer	3.33	5.18	4.30	1.12	2.56	1.50	2.66	1.07	1.02	0.98	0.84	0.72	1.66	71.07
15kg N through FYM + 10kg N through green leaf	2.77	4.80	3.21	0.76	1.97	1.13	2.01	0.83	1.30	1.02	0.97	0.81	1.47	69.13

RDN - recommended dose (60 kg ha^{-1}) of N

Table 6. Effect of different nutrient treatments on Physico-chemical properties of soil

Nutrient treatments	B.D. ($g\ cc^{-1}$)	WHC (%)	pH	EC ($ds\ m^{-1}$)	O.C. ($g\ kg^{-1}$)	Available nutrients ($kg\ ha^{-1}$)		
						N	P_2O_5	K_2O
Control	1.45	24.9	5.1	0.032	3.2	120	13.7	121
100% RDF	1.40	27.5	4.9	0.051	3.8	170	22.9	257
50% RDF	1.38	27.3	5.0	0.045	3.5	150	19.2	247
25kg N (FYM) + 40 kg P_2O_5 +40 kg K_2O	1.10	28.2	5.2	0.035	4.7	140	16.5	254
15kg N (FYM)+ 10kg N (urea) + 40 kg P_2O_5 +40 kg K_2O	1.21	27.9	5.1	0.043	4.5	145	19.1	278
15kg N (FYM)+ 20kg N (urea) + 40 kg P_2O_5 +40 kg K_2O	1.18	29.8	5.2	0.041	4.4	165	20.2	254
15kg N (green leaf)+ 10kg N (urea) + 40 kg P_2O_5 +40 kg K_2O	1.30	27.6	5.2	0.042	4.6	135	19.2	182
15kg N (green leaf)+ 20kg N (urea) + 40 kg P_2O_5 +40 kg K_2O	1.34	27.5	5.3	0.040	4.5	145	17.2	178
15kg N (FYM)+ 10kg N (green leaf) + 40 kg P_2O_5 +40 kg K_2O	1.20	27.4	5.1	0.038	4.4	130	18.8	169

varied from 3.2 g kg^{-1} in control to 4.7 g kg^{-1} in treatment with 25kg N through FYM. There was spectacular hike in the content of N, P_2O_5 and K_2O in all the nutrient treatments over control. Organic matter addition is very crucial for soil health and crop production. Saha et al (2007) from a 7-year-long field trial had also found that application of cow dung at the rate of 5 t ha^{-1} (oven-dry basis) once a year at the time of Boro transplanting supplemented 50% of the fertilizer nutrients other than nitrogen in the subsequent crop of the cropping pattern. The application of cow dung and dhaincha along with chemical fertilizers not only increased organic C, total N, available P, and available S but also increased exchangeable K, available Zn, available iron (Fe), and available manganese (Mn) in soil. Considering the three cropping systems together, application of FYM to supply 15 kg N along with chemical fertilizer (urea) to supply 20 kg nitrogen + 40 kg P_2O_5 +40 kg K_2O was found to be the most effective (2.23 t ha^{-1} REY) followed by the same dose of FYM with 10 kg N through fertilizer + 40 kg P_2O_5 +40 kg K_2O (2.19 t ha^{-1}REY). The best treatment registered 37% higher REY over the recommended fertilizer dose.

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