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Long-term effect of different manure and fertilizer treatments on grain yield of upland rice

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ABSTRACT

In order to optimize manure and fertilizer application in rice under rainfed upland condition for high and sustainable yield over years and climatic changes, different manure and fertilizer combinations were tested in the research farm of AICRPDA, OUAT, Phulbani, Odisha, India during 1997 to 2008. Highest mean rice yield of 1.50 t ha^{-1} with lowest coefficient of variation was obtained with FYM to supply 30 kg N along with 30kg N+ 40 kg P_2O_5 + 40kg K_2O ha^{-1} in form of chemical fertilizer showing the importance of combined application of organic manure and chemical fertilizers for sustainable yield under rainfed upland situation. This was closely followed by the treatment with FYM to supply 30 kg N along with 20 kg P_2O_5 + 20 kg K_2O ha^{-1} giving 1.47 t ha^{-1}. These two treatments gave almost three times yield over control (4.84 q/ha) and also exhibited higher net income and B:C ratio. Among the monsoon months (June to September), highest monthly rainfall was recorded in August (365.11mm) followed by July (339.02 mm) but the coefficient of variation was lowest in July (52.15) and highest in August (65.51) indicating more rainfall variation over years during August. Negative correlation between crop yields in different treatments and crop seasonal rainfall predicted either excess rainfall over requirement or improper rainfall distribution in the years of high precipitation affecting yield.

Key words: *upland rainfed rice, fertilizer treatments, rainfall, coefficient of variation, correlation*

Rice is the most important food grain crop in Odisha. In spite of its high water requirement, it is grown as a rainfed crop in over 65% areas due to lack of irrigation facility. Even in the hilly districts of North Eastern Ghat Zone like Kandhamal, it is grown in rainfed upland without manure and fertilizer application. 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). However, in most of the locations of India with soils having low organic matter, significant yield advantages with fertilizer-N substitution through FYM were noticed. 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 (Barik *et al.,* 2006).

Due to high topography resulting quick run off and light texture, the soil of the experimental site at Phulbani is so well-drained that water does not stand on the field even after two hours of heavy rainfall. Unlike many other districts, Kandhamal has dense forest cover accounting over 50% of the total geographical area. In such situation, green leaf manuring is a better choice to supply plant nutrients as well as to conserve soil and water. The current investigation therefore was attempted to study the effect of different integrated nutrient management practices on rice grown in red laterite acidic upland soil over years under varied seasonal rainfall in the north-eastern Ghat Zone of Odisha.

MATERIALS AND METHODS

The present investigation was undertaken in the Research Farm of AICRP on Dryland Agriculture, OUAT, Phulbani during wet season from 1997 to 2008 to study the long-term effect of chemical fertilizers and organic manures applied in different combinations on

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rice grain yield and soil properties in red laterite acidic upland soil under varied crop seasonal rainfall. Due to upland situation, a short durational variety ZHU 11-26 maturing within 90 days was used.

At Phulbani, onset of south-west monsoon normally occurs on 10th June which ceases by 6th October. The mean annual rainfall of 1407.34 mm was recorded in 65 rainy days. At least 35 mm mean weekly rainfall with minimum 2 rainy days per week occurred 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. The rainfall during 35th SMW (27th August to 2nd September) was maximum (102.70mm) followed by 31st SMW (30th July to 5th August) with 93.10 mm rainfall. The number of rainy days per week was more than 3.0 during 27th to 33rd SMW and 35th SMW. Sowing was generally completed by the end of June in all the years so that the rice cv. ZHU 11-26 could be harvested by the end of September.

When the experiment started, the soil at the experimental site was sandy-loam in texture with less than 1.5m depth, acidic in reaction with a pH of 5.2, bulk density of 1.63 Mg m^{-3}, electrical conductivity of 0.032 dSm^{-1} and possessed 0.32% organic carbon, 20kg available P_2O_5 ha^{-1} and 220 kg available K_2O ha^{-1}. The field capacity and wilting point were found to be 13.10% and 9.50%, respectively. Soil samples were collected from each treatment of all replications for estimation of different physico-chemical properties using standard analytical procedures (Chopra and Kanwar, 1986).

The experiment was designed in RBD with three replications and nine treatments: T_1- No fertilizer (control); T_2- 100% Recommended fertilizer dose (RD), 60-40-40kg N-P_2O_5-K_2O ha^{-1}; T_3-50% Recommended fertilizer dose (RD), 30-20-20kg N-P_2O_5-K_2O ha^{-1}; T_4- Green *Glyricidia* leaves (GGL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_5- Green *Cassia* leaves (GCL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_6- FYM to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_7- 50% RD + GGL, T_8- 50% RD + GCL; and T_9- 50% RD + FYM. Standard agronomic practices were followed for raising the crop under rainfed situation and standard statistical methods were used for analyzing the data (Gomez and Gomez 1984). Net income was calculated by subtracting cost of cultivation from gross income. B:C ratio was expressed as the ratio of gross income to cost of cultivation. Water productivity (rain water productivity) was expressed as kilograms of rice yield obtained per millimeter of rainwater received.

RESULTS AND DISCUSSION

The rainfall during the crop growing season varied from 586.1 mm in 1998 to 2030.6 mm in 2006 (Table 1). During this period, the average crop seasonal rainfall was 1070.79 mm with standard deviation and coefficient of variation of 455.34 mm and 42.52 %, respectively. When the monsoon months (June to September) were taken into consideration, highest monthly rainfall was recorded in August (365.11mm) followed by July (339.02 mm). The coefficient of variation was lowest in July (52.15 %) and highest in August (65.51 %) showing more rainfall variation over years during August.

Table 1. Rainfall variation during monsoon months from 1997 to 2008

Year	Rainfall (mm)				
	C.S.R.	June	July	August	September
1997	1065.6	250.0	304	640.2	171.0
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
Mean	1070.79	227.38	339.02	365.11	274.6
σ	455.34	130.94	176.80	239.20	150.82
C.V.(%)	42.52	57.59	52.15	65.51	54.92

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

The yield data from 1997 to 2008 revealed that highest mean rice yield of 1.50 t ha^{-1} was with combined application of FYM and inorganic fertilizers 50% of RD + FYM closely followed by the treatment FYM along with 50% P and K giving 1.47 t ha^{-1} (Table 2). These two treatments gave over three times yield as compared to control (0.48 t ha^{-1}) where no manure and fertilizers were applied and over 20% higher yield over recommended fertilizer dose (1.21 t ha^{-1}). The grain yield due to application of green leaves of Cassia (0.73 t ha^{-1}) or Glyricidia (0.76 t ha^{-1}) was almost similar but much lower than that due to FYM. There was significant variation among treatments in different years.

The coefficient of variation for grain yield over years was highest (45.78) in treatment receiving 100% recommended fertilizer dose followed by control (45.53) which shows that cultivation of rice with fertilizer application alone or without any fertilizer / manure application is not sustainable. In contrast, the coefficient of variation for grain yield over years was lowest (23.94) in treatment with FYM to supply 30 kg N along with 30kg N, 40 kg P_2O_5 and 40kg K_2O ha^{-1} in form of chemical fertilizer. The treatments having comparatively lower coefficient of variation were T_7- 50% RD + GGL, 50% RD + GCL, FYM to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1} and 50% Recommended fertilizer dose (RD), 30-20-20kg N-P_2O_5-K_2O ha^{-1} indicating usefulness of combined application of manures and fertilizers or 50% recommended fertilizer dose for high and stable yield over years with much variation in crop seasonal rainfall. When simple correlation and linear regression coefficients were worked out between each treatment and crop seasonal rainfall, negative association was observed in all the cases. This might be due to excess rainfall over requirement or improper rainfall distribution in the years of high precipitation affecting yield. The significance of optimum amount of rainfall along with proper distribution has been documented earlier (Sharma *et al.*, 1979; Ram Suresh *et al.*, 1992; Singandhupe *et al.*, 2000).

Table 2. Rice yield (t ha^{-1}) in different treatments during 1997 to 2008

Year	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	CSR (mm)
1997	0.73	2.31	1.69	1.49	1.46	1.80	2.06	1.95	2.09	1065.60
1998	0.46	1.29	0.80	0.73	0.68	1.61	1.06	1.10	1.24	586.10
1999	0.56	1.53	1.29	0.86	0.68	2.09	1.44	1.51	1.82	611.60
2000	0.91	1.90	1.15	0.98	1.08	2.24	1.03	1.29	2.02	701.00
2001	0.67	1.33	0.92	1.06	1.07	1.75	1.10	1.02	1.44	1537.10
2002	0.58	1.61	0.99	0.70	0.74	1.85	1.06	1.00	1.86	672.90
2003	0.50	0.56	0.74	0.79	0.75	1.44	0.95	0.90	1.17	949.00
2004	0.37	1.01	0.84	0.71	0.61	1.23	1.20	1.08	1.50	756.00
2005	0.32	0.85	0.68	0.56	0.46	1.07	1.04	0.93	1.36	1224.70
2006	0.22	0.62	0.65	0.48	0.53	0.76	0.82	0.80	1.02	2030.60
2007	0.25	0.74	0.68	0.38	0.39	0.79	0.86	0.84	1.18	1580.20
2008	0.20	0.73	0.61	0.36	0.34	1.01	0.91	0.73	1.28	1134.70
Mean	0.48	1.21	0.92	0.76	0.73	1.47	1.12	1.10	1.50	1070.79
σ	2.203	5.539	3.195	3.176	3.263	4.981	3.219	3.448	3.598	-
C.V.(%)	45.53	45.78	34.55	41.63	44.21	33.75	28.56	31.37	23.94	-
Correlation with CSR	-0.47	-0.47	-0.39	-0.29	-0.20	-0.68	-0.32	-0.41	-0.56	-
a	1537.8	1535.2	1577.7	1387.7	1275.2	1991.1	1552.8	1665.3	2130.1	-
b	-96.53	-38.38	-54.82	-41.52	-27.70	-62.37	-42.58	-54.08	-70.46	-

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

T_1- No fertilizer (control); T_2- 100% Recommended fertilizer dose (RD), 60-40-40kg N-P_2O_5-K_2O ha^{-1}; T_3-50% Recommended fertilizer dose (RD), 30-20-20kg N-P_2O_5-K_2O ha^{-1}; T_4- Green Glyricidia leaves (GGL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_5- Green Cassia leaves (GCL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_6- FYM to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_7- 50% RD + GGL, T_8- 50% RD + GCL; and T_9- 50% RD + FYM 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}

As per the data on soil physico-chemical properties, the bulk density declined in all the treatments from the initial value (at the beginning of experiment) of 1.63 Mg m^{-3} (Table 3). Lowest bulk density (1.15 Mg m^{-3}) was recorded in treatment receiving 30 kg N

Table 3. Effect of different chemical fertilizer and organic manure treatments on soil bulk density, pH and N, P, K availability

Treatments	BD ($Mg\ m^{-3}$)	pH	EC $dS\ m^{-1}$	N ($kg\ ha^{-}$)	P_2O_5 ($kg\ ha^{-}$)	K_2O ($kg\ ha^{-}$)
T_1	1.51	5.42	0.027	107.5	23.1	238.8
T_2	1.40	5.20	0.027	202.5	63.4	267.3
T_3	1.39	5.23	0.026	130.0	43.2	243.2
T_4	1.36	5.23	0.020	137.5	47.1	309.8
T_5	1.35	5.31	0.019	132.5	48.9	326.6
T_6	1.15	5.44	0.039	148.7	52.2	290.4
T_7	1.34	5.31	0.024	136.2	42.7	311.4
T_8	1.35	5.20	0.023	150.2	42.7	352.0
T_9	1.15	5.23	0.040	185.0	48.1	300.9

T_1- No fertilizer (control); T_2- 100% Recommended fertilizer dose (RD), 60-40-40kg N-P_2O_5-K_2O ha^{-1}; T_3-50% Recommended fertilizer dose (RD), 30-20-20kg N-P_2O_5-K_2O ha^{-1}; T_4- Green Glyricidia leaves (GGL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_5- Green Cassia leaves (GCL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_6- FYM to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_7- 50% RD + GGL, T_8- 50% RD + GCL; and T_9- 50% RD + FYM 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}

in form of FYM along with 50% P and K as well as in the treatment receiving FYM to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1} along with 50% of recommended fertilizer dose. These two treatments also recorded higher grain yield than other treatments showing the significance of bulk density on crop yield (Lampurlanés and Cantero-Martínez, 2003). The pH in different treatments varied from 5.2 to 5.44 and EC from 0.019 to 0.040 dS/m. All treatments showed higher water holding capacity than control. There was variation in the availability of three major nutrients (N, P_2O_5 and K_2O) in soils of different treatments which in turn had significant bearing on rice yield. Our study corroborates the findings of earlier studies where substitution of 50% fertilizer N by FYM or green manure minimized bulk density and maximized soil water retention and increased soil organic carbon, available N, P, K, S and Zn and consequently increased both quality and quantity of produce (Singh *et al.*,2000; Gupta *et al.*, 2006; Saha *et al.*, 2007).

The economics was calculated based on mean rice yield in different years (Table 4). Highest gross

Table 4. Mean economics of different treatments (1997-2008)

Treatments	Grain Yield ($t\ ha^{-1}$)	Cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B : C ratio	Water productivity ($kg\ mm^{-1}$)
T_1	0.48	6352	4114	-2238	0.65	0.45
T_2	1.21	7400	10285	+2885	1.39	1.13
T_3	0.92	6862	7863	+1001	1.15	0.86
T_4	0.76	6895	6486	-409	0.94	0.71
T_5	0.73	6895	6273	-622	0.91	0.69
T_6	1.47	7842	12546	+4704	1.60	1.38
T_7	1.12	7112	9580	+2468	1.35	1.05
T_8	1.09	7112	9342	+2230	1.31	1.03
T_9	1.50	8142	12776	+4634	1.57	1.40

Grain Price : Rs. 850/q, T_1- No fertilizer (control); T_2- 100% Recommended fertilizer dose (RD), 60-40-40kg N-P_2O_5-K_2O ha^{-1}; T_3- 50% Recommended fertilizer dose (RD), 30-20-20kg N-P_2O_5-K_2O ha^{-1}; T_4- Green Glyricidia leaves (GGL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_5- Green Cassia leaves (GCL) to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_6- FYM to supply 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}; T_7- 50% RD + GGL, T_8- 50% RD + GCL; and T_9- 50% RD + FYM 30kg N ha^{-1} + 20kg P_2O_5 and 20kg K_2O ha^{-1}

income was realized from the treatment receiving 30 kg N through FYM along with 30 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} through chemical fertilizer but highest net income and B:C ratio were observed in treatment receiving 30 kg N through FYM along with 20 kg P_2O_5 and 20 kg K_2O ha^{-1} in form of chemical fertilizer. Water productivity was also higher in above two treatments. In earlier studies, INM practices showed enhanced crop yield resulting higher benefit: cost ratio as compared to application of chemical fertilizer alone (Medhi *et al*., 2002; Jeyabal *et al*., 1999).

The treatment with 100% recommended fertilizer dose resulted in high yields during initial years but it gradually declined as compared to treatments receiving both manures and fertilizers. This investigation exhibited the importance of combined application of organic manure and chemical fertilizers for sustainable rice yield under rainfed upland situation.

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