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Effect of nutrient management on rice (*Oryza sativa*) in rainfed lowland of southeast Madhya Pradesh

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ABSTRACT

In a 3-year field trial, efficiency of different fertilizers in rainfed lowlands was evaluated at the Zonal Agricultural Research Station, Jagdalpur (M.P.). Application of N fertilizer and manures significantly increased the yield and N, P, K uptake by rice (*Oryza sativa* L.) over control and PK only. The higher grain and straw yields of rice were obtained in the treatment receiving ½ FYM + NP (2.58 and 4.90 t/ha), followed by NPK + FYM (2.49 and 5.71 t/ha), CR–N (35) PK (2.14 and 4.31 t/ha) and CR–NPK+Zn (2.13 and 4.68 t/ha). Agronomic efficiency was also higher in ½ FYM + NP treatment, followed by CR-N (3S) and CR-NPK + Zn. Nutrient X water interaction helped buffer the adverse effect of moisture deficit for sustaining rice yield during 1997. The application of manure alone or in combination with chemical fertilizers sustained/improved the soil-fertility status of the soil.

Key words **:** Rice, Rainfed, Lowland, Nutrient management

Rainfed lowland rice encounters an environment more complex and unpredictable than most crops. It is grown in bunded fields without water control, and therefore experiences hydrological conditions fluctuating from complete submergence of the crop to drought, with major consequences for root growth, nutrient availability and weed competition (Garrity *et al.*, 1986). Nearly 97% of the total rice area in Bastar plateau zone of M.P. is rainfed, out of which 60% area is under rainfed lowland, with an average productivity of 1.12 t/ha (Anonymous, 1996). Poor nutrient and average rain-water management are among the major constraints for low productivity and production of rice in this region. Use of chemical fertilizers is very low and imbalanced. Nitrogen-use efficiency (NUE) ranged from 30 to 40% (Prasad and De Datta, 1979). Application of Zn has been

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found to improve rice productivity due to its synergistic effect with applied N (Khanda *et al.*, 1997). Slow-release N fertilizers are known to increase the NUE (Singh and Singh, 1994). The traditional rice varieties that predominate in these areas can tolerate nutrient and water stresses to some degree, but they generally have low potential (Mackill, 1986).

Integrated use of farmyard manure with inorganic fertilizers has been found effective in increasing the productivity as well as sustaining soil fertility (Pandey *et al.*, 1995; Tripathi and Chaubey, 1996). Our objective was to evaluate the effect of integrated use of applied and indigenous nutrients to buffer water limitations and to study the efficiency of nutrient use in achieving stable yields of traditional varieties in this fluctuating and unpredictable environment.

MATERIALS AND METHODS

Field experiments on wet-season transplanted rainfed rice were conducted in the lowland areas of Vertic Ustochrept at the Zonal Agricultural Research Station, Jagdalpur (M.P.) in collaboration with International Rice Research Institute, Philippines during 1995 to 1997. The soil at the site was clayey in texture, having 28.4, 30.0 and 41.6% sand, silt and clay respectively. The soil had a bulk density of 1.25 g/cc, moisture content (v/v) at field capacity 39.8%, pH 6.1, 6%; total N 0.09, organic C 0.71%, available N 238 kg/ha available Bray's P 9.5 kg/ha available K 185 kg/ha, and coefficient of electric conductivity (CEC), 23.9 meq 100/g. Nine treatments comprised no NPK (control), P_2O_5 50 kg/ja and K_2O kg/ha (basal), FYM @ 10 t/ha, NPK @ 80 N + 50 P_2O_5 + 50 K_2O 30 kg/ha (all basal), CR–NPK + $ZnSO_4$ @ 20 kg/ha (NPK as per CR-NPK treatment and $ZnSO_4$ basal), ½ FYM + NP (FYM @ 5.0 t/ha, and 40 kg N in three splits of 15+15+10 kg and 15 kg P_2O_5/ha), and CR-N (3S) and PK (as per CR-NPK treatment but nitrogen applied in three splits as per NPK treatments. The trials were laid out in randomized block design with three replications in plot size of 6.2 × 4.0 m each. The controlled release nitrogen was applied through neemcake–coat prepared locally, containing 31.4% nitrogen. FYM contained 0.8%, 0.77 and 1.01% N, P_2O_5 and K_2O respectively.

Seedlings of 'Kalimoonch' at 25 days were transplanted on 31 July, 10 August and 14 August during 1995, 1996 and 1997 respectively, at 20 × 15 cm hill spacing using 2-3 seedlings/hill. Five hills from each plot were randomly selected at plant-initiation (PI) stage to get constant dry weight. Five tagged plants were used to record plant height, and data on yield and yield attributes were recorded. The standard laboratory methods were used to analyse plant and soil samples.

Agronomic efficiency (AE) was calculated by multiplying the uptake efficiency with physiological efficiency (PE), where AE=kg yield/kg N applied; RE=kg increase in N uptake/kg increase in applied N; and PE=kg increase in yield/kg increase in N uptake.

The total rainfall received during the crop period (June to November) was 1035, 1074 and 790 mm in 1995, 1996 and 1997 respectively. The depth of ponded water

Table 1. Yield, harvest index and agronomic efficiency of rice ('Kalimoonch') as influenced by nutrient management practices

Treatment	Yield (t/ha) Grain			Straw			Harvest index			Agronomic efficiency (kg grain/kg N applied)		
	1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997
Control	1.77	1.36	0.86	3.57	2.23	2.10	0.30	0.38	0.28	-	-	-
PK	1.14	141	0.72	2.41	2.33	2.00	0.32	0.37	0.27	-	-	-
FYM	1.79	2.15	1.94	3.43	3.87	3.42	0.35	0.36	0.37	8.1	9.2	15.3
NPK	2.20	2.17	1.76	4.16	4.72	4.36	0.34	0.31	0.29	13.2	9.5	15.5
NPK + FYM	2.72	2.71	2.04	5.98	5.56	5.71	0.31	0.33	0.26	9.9	8.1	8.3
CR - N + PK (B)	1.70	1.85	1.62	3.91	3.26	4.00	0.30	0.36	0.29	7.0	5.4	11.3
CR + NPK + Zn	2.04	2.21	2.13	4.92	4.79	4.33	0.29	0.32	0.33	4.2	10.0	17.7
1/2 FYM + NP	2.97	2.62	2.14	4.98	4.84	4.89	0.37	0.35	0.30	22.9	15.2	17.8
CR - N (3S) + PK	2.22	2.21	2.01	4.40	3.86	4.67	0.33	0.36	0.30	13.4	10.0	16.2
Mean	2.06	2.08	1.69	4.20	3.94	3.94	0.33	0.35	0.30	12.2	9.6	14.2
SE	0.34	0.13	0.22	0.58	0.33	0.43	0.025	0.011	0.03	4.85	1.54	2.43
LSD (P = 0.05)	1.02	0.39	0.68	1.75	0.98	1.30	NS	0.03	NS	NS	4.59	NS

and water-table was recorded to observe water fluctuation. The mean monthly maximum and minimum temperatures ranged from 27.7 to 34.5, 29.3 to 33.1 and 29.0 to 34.7, and from 16.4 to 24.9, 15.0 to 24.9 and 18.2 to 24.5°C in the respective years.

RESULTS AND DISCUSSION

Depth of ponded water/water-table

The amount of rainfall and its distribution during 1995 and 1996 was substantial and favourable for crop growth and development. There was no ponded water from 23 August to 2 September, and from 8 September to harvest in 1995. Thus the rice crop suffered from a mild water deficit, despite well-distributed rains throughout the growing season. During 1996 and 1997 the ponded water receded after first week of November and second week of October respectively. The water-table was observed below 20 cm depth from soil surface in the second week of October in 1995 and first week of November during 1996 and 1997, and thereafter steep change in ground water-table depth was observed. In spite of unfavorable environment during 1997, the locally adapted traditional variety experienced only mild water shortage during reproductive stage, whereas the improved rice varieties of the same duration in the nearby fields encountered severe water stress.

Yield

The overall mean yields of the

Table 2. Nitrogen, phosphorus and potassium content (%) and their uptake by rice (cv 'Kalimoonch') as influenced by nutrient-management practices

Treatment	Grain			Straw			Uptake (kg/ha)		
	1995	1996	1997	1995	1996	1997	Grain	Straw	Total
				Nitrogen					
Control	0.99	0.94	0.80	0.40	0.46	0.48	12.3	11.5	23.9
PK	0.94	0.92	0.77	0.38	0.38	0.42	9.7	8.7	18.5
FYM	0.97	0.98	0.93	0.40	0.42	0.45	18.9	15.0	33.9
NPK	1.00	0.92	0.84	0.41	0.45	0.49	18.9	19.9	38.8
NPK + FYM	0.98	1.00	0.91	0.41	0.43	0.47	24.1	24.9	49.0
CR - N + PK (B)	0.89	0.91	0.80	0.46	0.46	0.46	15.0	17.3	32.2
CR - NPK + Zn	0.99	0.91	0.88	0.38	0.41	0.43	19.7	18.8	38.5
½ FYM + NP	0.99	0.97	0.85	0.36	0.39	0.42	24.4	19.0	43.4
CR - N (3S) + PK	0.97	0.92	0.80	0.47	0.42	0.45	19.2	19.3	38.5
Mean	0.97	0.94	0.84	0.41	0.42	0.45	18.0	17.2	35.2
SE	0.029	0.022	0.027	0.017	0.018	0.025	1.39	1.68	2.76
LSD	NS	NS	0.087	0.052	0.054	NS	4.15	5.01	8.23
				Phosphorus					
Control	0.22	0.23	0.30	0.05	0.06	0.05	3.20	1.43	4.43
PK	0.26	0.27	0.30	0.07	0.07	0.10	2.96	1.79	4.75
FYM	0.26	0.26	0.35	0.08	0.07	0.14	5.62	3.36	8.98
NPK	0.26	0.26	0.31	0.08	0.07	0.10	5.58	3.70	9.28
NPK + FYM	0.29	0.28	0.32	0.10	0.09	0.13	7.30	5.99	13.29
CR - N + PK (B)	0.26	0.25	0.28	0.06	0.06	0.11	4.48	2.96	7.44
CR - NPK + Zn	0.27	0.28	0.28	0.08	0.08	0.09	5.87	3.91	9.79
½ FYM + NP	0.28	0.28	0.29	0.09	0.08	0.10	7.33	4.51	11.84
CR + N (3S) + PK	0.28	0.28	0.31	0.09	0.08	0.09	6.16	3.79	9.96
Mean	0.26	0.26	0.30	0.08	0.07	0.10	5.39	3.49	8.88
SE	0.007	0.005	0.007	0.005	0.005	0.08	0.35	0.51	0.81
LSD	0.021	0.015	0.021	0.016	0.015	0.023	1.04	1.52	2.42
				Potassium					
Control	0.18	0.17	0.18	1.76	1.74	2.55	2.3	51.6	53.6
PK	0.16	0.14	0.13	1.67	1.58	2.09	1.6	39.5	41.0
FYM	0.15	0.13	0.15	1.87	1.81	2.17	2.7	68.5	71.3
NPK	0.17	0.15	0.15	1.85	1.77	1.95	3.2	81.9	85.2
NPK + FYM	0.18	0.15	0.17	2.16	2.27	2.11	4.1	125.0	129.2
CR - N + PK (B)	0.14	0.13	0.16	1.76	1.71	2.12	2.5	70.2	72.7
CR -NPK + Zn	0.17	0.16	0.12	1.73	1.68	2.07	3.2	85.3	88.5
½ FYM + NP	0.18	0.17	0.13	1.83	1.81	2.12	4.2	94.6	98.8
CR +N (3S) + PK	0.18	0.16	0.16	1.74	1.64	2.05	3.6	79.0	82.6
Mean	0.17	0.15	0.15	1.82	1.78	2.14	3.1	77.3	80.3
SE	0.002	0.009	0.007	0.042	0.067	0.088	0.27	7.34	7.54
LSD (0.05)	0.03	0.027	0.020	0.13	0.200	0.26	0.80	21.90	22.50

treatments were 2.06, 2.08 and 1.69 t/ha grain and 4.20, 3.94 and 3.94 t/ha straw in 1995, 1996 and 1997 respectively (Table 1). In 1995 the significantly higher grain yield (2.97 t/ha) compared with control (1.77 t/ha) was recorded in ½ FYM+NP treatment, which in turn was on a par with NPK +FYM, CR-N (3S) PK and NPK. This may be attributed to the less nutritional demand of traditional varieties (Verma, 1992; unpublished data) and the experimental field may have native and residual nutrients of the preceding year, where legume crop was taken and was thus sufficient to meet the nutritional demand of the traditional variety. The lower yields in PK treatment might be due to lower N content as well as uptake (Table 2). During 1996 the grain yield ranged from 1.36 to 2.71 t/ha, and significantly higher yield (2.71) t/ha) was recorded in NPK+FYM followed by ½ FYM+NP (2.62 t/ha). Significantly lower grains yields, almost similar but different in magnitude in 1996 and 1997, were recorded in control and PK treatments compared with all other treatments. It may be due to adequte levels of P and K in the soil. In 1997 all the treatments, except control and PK, produced grain yields almost at par.

Application of nutrients through manures and fertilizers played a vital role in buffering the adverse effect of moisture deficit. Further, the deeper root system in traditional variety might have explored water from the lower depths. Thus nutrientx water interaction played the critical role in sustaining the yield of rice, in spite of the moisture deficit that the crop experienced during its reproductive phase. Wade and Ladha (1995) also reported similer sesults.

The lower yields recorded in the treatments receiving controlled release-N as basal may be attributed to heavy volatilization losses of ammonia due to wetting and drying cycles in the soil that occurred during the cropping period and thus upsetting the balance between crop N demand and the N supply (Buresh and De Datta, 1991; George *et al.*, 1992). However, the treatment receiving controlled release-N as basal along with Zn did not show much decrease in yield. It seems that Zn application improved the productivity due to its synergistic effect with applied N (Khanda *et al.*, 1997). The significantly higher straw yields were recorded in NPK+Zn treatments. Straw yields followed more or less similar trend as the grain yield. The higher yield with integrated use of organic + inorganic fertilizers might be attributed to the fact that FYM in association of inorganic fertilizer increased the availability of major and minor nutrients by improving physical and chemical environments, of the soil as reported by Chettri *et al.* (1998) Pandey *et al.* (1995) and Tripathi and Chaubey (1996).

The harvest index was almost similar, ranging from 0.30 to 0.35 in different years. Among the treatments, harvest index, although at par, varied from 0.30 to 0.36 and was found higher in FYM and ½ FYM + NP treatments. Higher harvest index in FYM treatment was mainly due to lower straw yield, whereas in ½ FYM +NP treatment it was due to higher grain yield.

Agronomic efficiency on pooled basis showed that ½ FYM+NP treatment gave higher value (18.6 kg grain/kg N applied), followed by CR-N (3S) PK and CR-NPK

Table 3. Final soil status (N, P, organic carbon and pH) as influenced by nutrient-management practices

Treatment	Available nutrients (kg/ha) Nitrogen			Phosphourus			Organic carbon(%)			pH (1:2:5) H_2O		
	1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997
Control	229	228	228	2.54	2.73	2.94	0.74	0.73	0.72	6.3	6.3	6.2
PK	233	231	131	4.47	4.59	4.72	0.66	0.66	0.66	6.3	6.3	6.2
FYM	243	245	248	4.86	5.18	5.34	0.72	0.74	0.74	6.5	6.5	6.6
NPK	240	242	239	4.70	5.06	5.18	0.70	0.70	0.71	6.2	6.2	6.1
NPK + FYM	256	258	255	7.10	7.60	7.92	0.73	0.74	0.75	6.4	6.5	6.6
CR - N + PK (B)	235	238	140	4.54	5.00	5.17	0.68	0.69	0.69	6.0	6.1	6.0
CR - NPK + Zn	240	242	244	4.89	5.16	5.27	0.64	0.64	0.66	6.1	6.0	6.0
½ FYM + NP	250	247	251	4.97	5.44	5.63	0.65	0.67	0.70	6.2	6.3	6.3
CR-N (3S) + PK	239	240	241	5.22	5.46	5.65	0.67	0.70	0.70	6.3	6.2	6.2
Mean	241	241	242	4.81	5.13	5.31	0.69	0.69	0.70	6.3	6.3	6.3
SE	1.12	0.66	1.11	0.40	0.32	0.25	0.03	0.02	0.02	0.010	0.08	0.07
LSD (P = 0.05)	3.37	1.97	3.34	1.20	0.95	0.76	NS	0.06	0.05	NS	0.24	0.22

+Zn. However, the treatments CR-NPK (B) and NPK + FYM resulted in lower values of agronomic efficiency. The treatment NPK+FYM received double nitrogen than the rest of the treatments, and a large portion of this N might have dissipated through (Table 2) and accumulated (Table 3) in soil, leading to lower agronomic efficiency in the treatment.

Nutrient content and its uptake

The trend in nitrogen content of grain and straw varied in different years (Table 2). In 1995 and 1996 the N content in straw showed significant variation among the treatments, but not in 1997. The variation in N content of grain among treatments was just the reverse of the N content of straw. Higher accumulation of N in straw and lower in grains was observed during 1997. It may be attributed to poor source-sink relationship, having resulted due to water deficit during reproductive stage of the rice crop. Nitrogen uptake in grain, straw and total on pooled basis was influenced significantly by treatments; the highest values of N uptake were observed in NPK+FYM treatment. However, N and PK treatments recorded lower uptake of nitrogen, most probably due to variation in grain and straw yields in the respective treatments.

Phosphorus content and its uptake by grain and straw were influenced significantly by various nutrient management treatments in different years (Table 2). The significantly higher P content and its uptake in grain and straw was recorded in NPK + FYM treatment, followed by ½ FYM+NO, CR-NPK+Zn and CR-N (3S) PK treatments, Phosphorus content in grain and straw was found higher in most of the treatments receiving manure and fertilizer during 1997 than during 1995 and 1996 (favourable years for rice growth).

Potassium content and its uptake in grain and straw more or less followed the similar trend as nitrogen (Table 2). Potassium content and its uptake by straw in 1997 were higher in most treatments compared with the preceding years, but its content in grain during 1997 did not follow any difinite trend. However, K uptake by grain was at par in all the treatments except control and PK treatment, which did not differ from each other. Potassium increases the plant tolerance to drought by closing stomatal openings and increasing the water-use efficiency of crop. Higher accumulation of potassium in rice plant helped in increasing the crop tolerance to drought and thus the rice yields were not affected adversely (Table 1) during 1997, when rice crop experienced water scarcity during its reproductive stage.

Improvement in uptake of N, P and K in rice due to application of FYM or controlled release N, either alone or in combination was probably due to improvement in soil conditions, which enouraged the proliferation of roots and improved synchrony between supply and plant demand, which in turn drew more nutrients from larger area and greater depth, as reported by Minhas and Minhas and Sood (1996), and Mishra and Sharma (1997).

Nutrient status of soil

Continuous rice monoculture with different nutrient-management practices influenced the physico-chemical properties of the soil (Table 3). Results indicated that soil pH and organic carbon (%) were not influenced significantly after the first year of experimentation. However, available N and P status did change due to application of manures and fertilizers. Farmyard manure used either alone or in combination with chemical fertilizers improved/sustained the soil pH, organic carbon (%) and the available N and P of the soil. Beillaki *et al.* (1998) also reported significant improvement in soil available N, P and organic carbon with the use of FYM either alone or in combination.

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