Effect of Balanced Fertilisation on Rice Yield in a Multi-Nutrient Stressed Red and Lateritic Soil

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A 3-year study to assess the efficiency of balanced fertilisation on monsoon rice yield in a typically low yielding red and lateritic soil of West Bengal, India, revealed that a soil test-based recommendation of N, K, and Zn along with 25% higher level of P produced the highest grain yield (6.08 t/ha). Average uptake of nutrients correlated well with the yield of rice. Uptake of nutrients was strongly influenced by application of other nutrients in the fertilisation schedule. The best treatment produced significantly higher net returns over traditional or generally recommended nutrient management practices.

Red and lateritic soils represent 70 million ha of the land area in India (Sehgal, 1998). These soils are usually less productive due to various soil related constraints, including coarse texture, low water holding capacity, acidity, poor availability of N, P, and K, low organic C status, and both excessive and inadequate levels of several secondary and trace elements (Raychaudhury et al., 1963). A large area under this soil group in West Bengal remains in fallow or is mono-cultivated with monsoon (kharif) rice. However, productivity of rice in these soils is low due to multi-nutrient deficiencies and other allied problems. Besides, traditional N-dependent, imbalanced fertilization in these soils further aggravates its productive capacity. This study assesses the possibilities of increasing the yield potential of kharif rice through soil test-based, balanced nutrient use.

The study was conducted during the monsoon season of 2002 to 2004 in a farmer's field in the village of Kendradangal, Birbhum, located in a typical red and lateritic soil belt of West Bengal, India. The soil was sandy clay in texture having a pH of 5.1, 1.3% organic matter, CEC of 14.6 $cmol_+$/kg, and base saturation and acid saturation of 92% and 8%, respectively. Available N, P, K, and Zn content was 38, 15, 197, and 3.5 kg/ha, respectively as per the soil test report by Agro Services International Inc. (ASI), USA. Based on this report, a fertiliser dose of 168 kg N, 112 kg P_2O_5, and 112 kg K_2O/ha was recommended to achieve a targeted rice yield of 6.5 t/ha. Taking this treatment as a base line, 14 treatment combinations were developed with different combinations of N, P_2O_5, K_2O, and Zn. Two more treatments viz. state fertilizer recommendation (SR) and local farmers' fertilization practice (FFP) were also included **(Table 1)**. The experiment was laid out in a randomized block design replicated thrice with the plot size of 5 m x 2.5 m. Rice (var. MTU-7029) was transplanted at a spacing of 20 cm x 10 cm with two seedlings per hill.

Assessment of the data showed that variation in fertiliser application had a significant effect on grain yield of rice during all 3 years **(Table 1)**. The highest average grain yield (6.08 t/ha) was produced from T_9 comprised of 168 kg N, 140 kg P_2O_5, 112 kg K_2O, and 7 kg Zn per hectare. Thus, application of 25% more P than was recommended by soil testing helped to achieve the highest rice yield, which is primarily attributed to the high P-fixing capacity of these soils which tends to reduce the efficiency of the added P fertiliser (Dev and Rattan, 1998). In spite of adding other recommended nutrients in required amounts, the lowest average grain yield (2.86 t/ha) was observed in T_4 where P was omitted – a 49% yield decline owed to P alone. Straw yield and harvest index were also significantly influenced by variations in different nutrient combinations.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; C = carbon; CEC = cation exchange capacity; SR = State recommendation; FFP = farmers' fertilisation practice; STB = soil test-based recommendation; CD = Critical Difference, equivalent to Least Significant Difference.

A soil test-based recommendation of N, K, and Zn, along with 25% higher P level, produced the highest yield of monsoon rice.

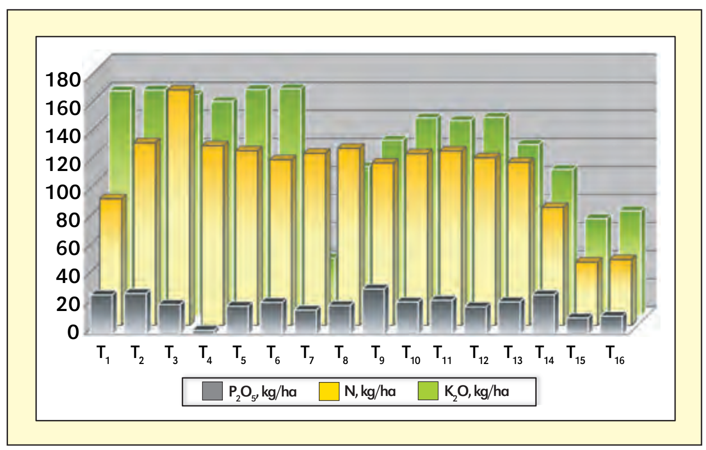

Figure 1. Effects of different treatments on availability of N, P_2O_5, and K_2O in soil after final harvest of kharif rice.

Mean availability of N in the soils after harvest of rice varied significantly under different treatments **(Figure 1)**.

Table 1. Effects of different treatments on grain yield, straw yield, and harvest index of kharif rice.

	Grain yield, t/ha			Straw yield, t/ha			Harvest index, %		
Treatment[1]	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05
$T_1 = N_{126}$-P_{140}-K_{140}-Zn	5.33 bcd	5.06 d*	5.01 d	7.18 d*	6.93 f	6.90 cde	42.61 c*	42.20 a	42.07 a
$T_2 = N_{168}$-P_{140}-K_{140}-Zn	5.33 bcd	5.77 b	5.77 b	7.11 de	7.90 c	7.88 bc	42.85 c	42.21 a	42.36 a
$T_3 = N_{210}$-P_{140}-K_{140}-Zn	5.44 bcd	4.62 f	4.70 e	7.3 c	9.32 a	9.27 a	42.70 c	33.14 b	33.64 b
$T_4 = N_{168}$-P_0-K_{140}-Zn	3.72 f	2.52 j	2.35 j	6.54 g	4.82 m	4.77 g	42.93 c	34.33 b	33.01 b
$T_5 = N_{168}$-P_{84}-K_{140}-Zn	5.67 ab	4.78 ef	4.76 e	7.62 b	6.55 g	6.51 ef	42.66 c	42.19 a	42.24 a
$T_6 = N_{168}$-P_{112}-K_{140}-Zn	5.65 ab	4.98 de	5.00 d	7.32 c	6.82 f	6.78 de	43.56 bc	42.20 a	42.44 a
$T_7 = N_{168}$-P_{140}-K_0-Zn	5.04 d	4.17 g	4.13 fg	6.94 f	5.71 j	5.62 fg	42.07 c	42.21 a	42.36 a
$T_8 = N_{168}$-P_{140}-K_{84}-Zn	5.45 abcd	4.60 f	4.65 e	7.18 d	6.30 h	6.27 f	43.15 bc	42.20 a	42.58 a
$T_9 = N_{168}$-P_{140}-K_{112}-Zn	5.87 a	6.19 a	6.17 a	7.80 a	8.48 b	8.44 ab	42.94 c	42.19 a	42.23 a
$T_{10} = N_{168}$-P_{140}-K_{140}-Zn	5.11 cd	5.69 b	5.76 b	7.06 e	7.79 d	7.75 bcd	41.98 c	42.21 a	42.64 a
$T_{11} = N_{168}$-P_{140}-K_{140}	5.07 d	4.31 g	4.24 f	7.18 d	5.90 i	5.86 fg	41.39 c	42.21 a	41.98 a
$T_{12} = N_{168}$-P_{140}-K_{140}-Zn	5.52 abc	5.42 c	5.39 c	7.28 c	7.43 e	7.39 bcde	43.13 bc	42.18 a	42.18 a
$T_{13} = N_{168}$-P_{112}-K_{112}-Zn STB	5.59 ab	5.82 b	5.79 b	6.88 f	7.97 c	7.91 bc	44.83 bc	42.20 a	42.18 a
$T_{14} = N_{126}$-P_{84}-K_{84}-Zn	5.64 ab	4.18 g	4.11 g	7.14 de	5.73 j	5.69 fg	44.13 bc	42.18 a	41.94 a
$T_{15} = N_{80}$-P_{30}-K_{30} FFP	3.59 f	2.76 i	2.54 i	5.06 i	5.15 l	5.09 fg	49.80 a	34.89 b	33.29 b
$T_{16} = N_{80}$-P_{40}-K_{40} SR	4.32 e	3.02 h	2.98 h	6.04 h	5.51 k	5.44 fg	46.80 ab	35.40 b	35.39 b
CD (P = 0.05)	0.42	0.20	0.12	0.09	0.13	1.09	3.73	3.74	3.89

*Values followed by common letters do not differ significantly.
[1]Subscripted numbers following each nutrient refer to rates (kg/ha) of N-P_2O_5-K_2O.
Note: T_2, T_{10}, and T_{12} differs as plots received S, B, and S&B, respectively, in the previous-planted mustard crop.

In general, treatments with higher doses of N resulted in higher residual N in available form and vice versa. However, uptake of N was influenced by other nutrients which in turn influenced the residual available N levels of the soils. Comparing T_4 and T_5, differing only by the omission of P in T_4, showed that T_4 maintained a higher level of available N – owed to obviously lower N uptake due to poor crop yield in the absence of P. This trend was visible for the entire study, indicating that for improved utilisation of applied N, balanced use of other nutrients, especially P, is necessary.

Lower availability of P in several treatments significantly affected crop production. Residual availability of P was low in most treatments even after application of a comparatively higher dose of P fertiliser **(Figure 1)**. But a wide variation in availability of P was observed among treatments with the same level of P input. Treatments resulting in higher P uptake associated with increased yields (e.g., T_9) showed comparatively lesser amounts of residual P in available form in spite of using higher doses of P fertiliser. Treatments where P was added in high doses – but yield was low due to imbalanced use of other nutrients – also showed low residual availability of P. Thus, imbalanced use of nutrients not only failed to produce good yields, but also could not maintain the unutilised P in available form due to high P-fixation. Considering the critical role played by P in maintaining productivity of red and lateritic soils and also the rapid transformation of this nutrient to insoluble forms through P-fixation (Mandal and Chatterjee, 1972), some measures need to be taken to reduce the quantum of P-fixation in these soils. Use of organic matter and split applications of P fertiliser are known to improve P use efficiency of soils by reducing P-fixing capacity of soils (Dev and Rattan, 1998).

Mean availability of K was low in the soil under study

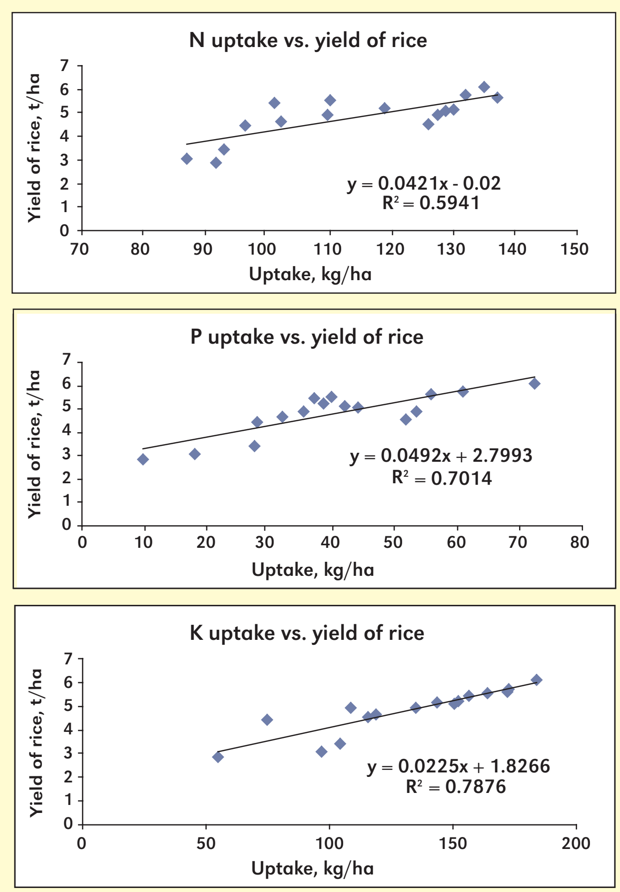

Figure 2. Grain yield and nutrient uptake relations in kharif rice.

Table 2. Economics of cultivation of kharif rice.

Treatment	Cost of cultivation, Rs.	Gross return, Rs.	Net return, Rs.
T_1	19,543	29,850	10,307
T_2	20,005	32,678	12,673
T_3	20,467	29,828	9,361
T_4	16,067	17,528	1,461
T_5	18,430	29,484	11,054
T_6	19,217	30,232	11,015
T_7	18,836	25,904	7,068
T_8	19,537	28,448	8,911
T_9	19,771	35,344	15,573
T_{10}	20,005	32,118	12,113
T_{11}	19,905	26,486	6,581
T_{12}	20,005	31,622	11,617
T_{13} STB	18,983	33,204	14,221
T_{14}	17,737	26,914	9,177
T_{15} FFP	14,925	17,860	2,935
T_{16} SR	15,289	20,596	5,307

Cost of fertiliser: urea at Rs.5; SSP at Rs.4.5; KCl at Rs.5; DAP at Rs.10.
Cost of seeds of paddy at Rs.10/kg.
Labour cost at Rs.60 per labourer per day.
Price of paddy grain at Rs.5/kg; paddy straw at Rs.600/tonne.

(Figure 1). Such restricted availability of K in red and lateritic soils has been reported by Ghosh and Hassan (1976). Use of K fertiliser tended to increase the residual available soil K status. There was a distinct declining trend in the availability of residual K in soil after rice cultivation where no K was included in the fertilization schedule. The submerged condition of rice soils probably aided further reduction of the available K status by causing considerable leaching of K due to poor water retention and low CEC of red and lateritic soils (Panda et al., 1991).

Average nutrient uptake by rice varied from 87 to 137 kg/ha for N, 10 to 72 kg/ha for P_2O_5, and 55 to 184 kg/ha for K_2O under the different treatments. The mean yield of rice for three seasons was significantly correlated with uptake of N, P, and K **(Figure 2)**. Such correlations highlight the importance of soil test-based fertiliser application in kharif rice as was earlier observed by Mukhopadhyay et al. (2008). That nutrient uptake is an interdependent function of other applied nutrients was further highlighted by T_7. Its high dose of P, without any K input, resulted in very low P uptake (data not shown). One important role of K in plant nutrition is to facilitate the uptake of other nutrients, including P. Under the prevailing low K status of red and lateritic soil, exclusion of K in the fertilisation schedule tended to restrict the uptake of P that in turn affected crop yield. On the other hand, T_7 showed comparatively higher uptake of K than T_4 – a P omission treatment. Here very low availability of P probably acted as the major limiting factor, thus affecting yield of rice and uptake of K. These results again emphasize the importance of balanced fertilisation in providing adequate nutrition to the plants. This study showed that removal of nutrients per tonne of rice grain yield varied between 18.6 to 32 kg for N, 3.4 to 11.9 kg for P_2O_5, and 16.8 to 31.6 kg for K_2O (data not shown). The highest average yield of 6.08 t/ha was obtained at a removal of 22.2 kg N, 11.9 kg P_2O_5, and 30.3 kg of K_2O per tonne of grain yield.

Economic calculations **(Table 2)** showed that net return was highest in the T_9 which provided the ASI recommended doses of N, K_2O, and Zn, and 25% more P_2O_5 than the ASI recommendation. Net return in the above treatment was Rs. 12,600/ha higher than the FFP and about Rs. 10,200/ha more than the current nutrient management strategy recommended by the State.

Conclusion

The study revealed that yield target-based balanced use of different nutrients constitutes the key for efficient nutrient management of monsoon rice under red and lateritic soils. Adoption of such balanced fertilisation not only resulted in larger yield levels, but also fetched higher economic benefits and showed excellent sustainability in yields. While applying nutrients in a balanced manner, due care should be exercised to use fertilisers at adequate amounts so that the doses of the nutrients can sustain expected yield levels. In addition, the behaviours and efficiency levels of different fertilisers in a particular soil should also be given due importance. BC INDIA

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