Soil Test-Based Nutrient Management to Attain Targeted Yields in a Rice-Based Cropping Sequence

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A 2-year experiment was conducted in the alluvial tract of West Bengal to study appropriate P and K management strategies in a jute-kharif (winter) rice-boro (summer) rice sequence under a lowland rice ecosystem. Compared to State recommended rates, the approach based on soil testing did lead to higher crop yields, net returns, and relative agronomic effectiveness.

India's resounding success from its past green revolution has been followed by stagnating or declining agricultural productivity, even with increased total fertiliser use in the country over the years. This declining factor productivity is largely due to imbalanced fertiliser use (Kumar et. al. 2007). Fertiliser application is highly skewed in favour of N, with relatively small use of K and P application, and rare use of secondary and micronutrients.

Current generalised fertiliser recommendations are also sub-optimal and need upward refinement. In rice-based cropping systems, a negative K balance of 31 kg K_2O/ha/year was estimated, and this imbalance is projected to increase further (Trivedi, 2001). Phosphorus removal under this intensive crop rotation amounts to 150 kg P_2O_5/ha/year, which is often higher than the annual nutrient replenishment (Tandon and Sekhon, 1998). Keeping in view the need for more balanced and intensive agriculture in India, P and K application needs to be increased (Sanyal and Chatterjee, 2007). The present study was conducted to optimise P and K management strategies to achieve maximum yields in an important rice-based cropping sequence.

Two years of field experiments were conducted on a jute (var. JRO-524)-*kharif* rice (var. IET-4786)-*boro* rice (var. IET-4094) sequence at Kalyani, West Bengal, India. The experiment was laid out in randomised block design with nine treatments. The treatments included: (i) a control (C), (ii) a soil test-based recommendation of N_x, P_y, and K_z, where x, y, and z represent kg/ha rates for a given targeted yield, (iii) the State recommended doses of N_s, P_s, and K_s (**Table 1**), and (iv) several other treatments having gradual withdrawal of P and K from the full soil test-based treatment. Deficient micronutrients were applied only in the first year of experimentation. Soil samples were collected at the initial stage and were analysed for physiochemical properties as well as for pools of different forms and/or fractions of soil P and K. Soil at the site was an Entisol with clay loam texture, a pH of 8.0, and 0.4% organic C, and a CEC of 12 $cmol_{(+)}$/kg. Available P and K status was 45 kg P_2O_5/ha and 162 kg K_2O/ha.

Water soluble K of the experimental soil was low [0.05 $cmol_{(+)}$/kg], whereas the non-exchangeable K (NEK) [6.02 $cmol_{(+)}$/kg] and the total K [52.2 $cmol_{(+)}$/kg] were much higher (**Table 2**).

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; C = carbon; CEC = cation exchange capacity.

Table 1. Outline of state recommendations and soil test-based recommendations used in this study.

	State recommendations, kg/ha			Soil test-based recommendations, kg/ha				
	Ns	P[1]s	K[1]s	Nx	Py	Kz	S	B
Jute	50	25	50	200	50	100	30	1.5
Kharif rice	60	30	30	168	56	100		
Boro rice	100	50	50	168	56	140		

[1]P_2O_5 and K_2O

From this data, the site was expected to release significant amounts of K from the native pool under plant uptake driven stress. The release pattern of NEK under successive extraction under boiling 1M HNO_3 is presented in **Table 2**, which also corroborated the inference above regarding a substantial reserve of non-exchangeable K in the soil. Constant-rate K (CR-K) of the soils was determined by successive extraction of the soil with boiling 1 M HNO_3 to a stage where release of K from the soil continued at a more or less constant rate. In the Kalyani soil, CR-K was reached after the fourth extraction. By subtracting the amount of CR-K from K released in each step of successive extraction, the amount of relatively easily extractable or available form of nonexchangeable K was computed. This latter form is known as Step-K.

The different fractions of soil P at the experimental site, determined by analytical method of Chang and Jackson (1957), are shown in **Table 3**. The distribution of inorganic P fractions followed the order: Ca-P > Fe-P > reductant soluble P > Al-P > occluded Al-P. A high content of Ca-P is likely a result of a high content of exchangeable Ca (9.10 $cmol_{(+)}$/kg) and the calcareous nature of the soil, and this fraction is relatively

Table 2. Contents of different forms and fractions of K in the initial soil at Kalyani.

Site	Forms of K [$cmol_{(+)}$/kg]: Water soluble K	Exchangeable K	Non-exchangeable K	Mineral K	Total K
Kalyani	0.05	0.08	6.02	46.0	52.2

Site	(NEK - CR-K) in successive extractions [$cmol_{(+)}$/kg]: I	II	III	IV	V	VI	VII	Step-K[1] [$cmol_{(+)}$/kg]	CR-K[2] [$cmol_{(+)}$/kg]
Kalyani	5.04	2.12	0.24	0.05	-	-	-	7.45	0.29

[1]Step-K relatively easily extractable or available form of nonexchangeable K .
[2]CR-K, Constant-rate K, relatively stable form of nonexchangeable K.

Table 3. Content of plant available P and different P fractions in the initial soil at Kalyani.

Site	Available P, kg/ha	Content of different P fractions, mg/kg				
		Al-P	Fe-P	Ca-P	Reductant soluble Fe-P	Occluded Al-P
Kalyani	44.8	6.32	19.2	28.0	15.2	1.60

Table 4. Effect of different treatments on yield (fibre and stick) of jute at Kalyani.

	1st year		2nd year	
	Yield, t/ha		Yield, t/ha	
Treatments	Fibre	Stick	Fibre	Stick
$T_1 (N_x, P_y, K_z)$	2.90	6.00	2.86	6.06
$T_2 (N_s, P_y, K_z)$	2.70	5.40	2.66	5.83
$T_3 (N_s, P_{0.5y}, K_z)$	2.70	5.10	2.40	5.60
$T_4 (N_s, P_{0.25y}, K_z)$	2.74	4.90	2.20	5.30
$T_5 (N_s, P_o, K_z)$	2.58	5.00	2.03	5.03
$T_6 (N_s, P_y, K_{0.5z})$	2.52	4.10	2.36	5.50
$T_7 N_s, P_y, K_{0.25z})$	2.43	4.10	2.30	5.26
$T_8 (N_s, P_y, K_o)$	2.45	4.30	1.96	5.00
$T_9 (N_s, P_s, K_s)$	2.53	4.70	2.40	5.26
$C (N_0, P_0, K_0)$	1.90	3.60	1.63	4.53
S.Em (±)	0.13	0.22	0.08	0.10
C.D. (P=0.05)	0.40	0.68	0.23	0.24

easily available as compared to occluded P.

Application of fertilisers based on soil test (T_1) led to highest fibre yields of jute (**Table 4**). Gradual reduction of applied P and K (i.e., T_3, T_4, T_5 for P; and T_6, T_7, T_8 for K) led to significant declines in fibre yield. These yield declines were generally more prominent under the withdrawal of K fertiliser. Yield responses to increasing K application are reported by Mitra et al. (1999) and Roy and Chouddhury (2000). A similar trend was observed for stick yield of jute.

Grain and straw yield of *kharif* rice was significantly influenced by P and K application. However, responses were not apparent in the first year of experimentation due to significant water stress suffered by this rainfed crop (**Table 5**). Differences between the performance of T_1 and T_9 (the State recommendation) were significant during the second year of experimentation. Gradual reduction in P and K application led to lower grain yields, but yield losses were even more prominent under lower K rates. This response was attributed to low initial plant available K as well as a high K-fixing capacity of this illite-dominated soil. Poor response of *kharif* rice to P application could be attributed to the mobilisation of fixed soil P under submerged lowland conditions, and also the relatively high available P status after the harvest of jute in the second year (data not shown). Rice straw yields followed a pattern which was similar to the corresponding grain yields (**Table 5**).

Grain yield of *boro* rice followed similar trends as those obtained with the *kharif* rice. However, yields were generally higher compared to those obtained in the *kharif* season. *Boro* rice showed a much better response to applied P and K compared to the *kharif* crop due to less control over the growing environment in the rainfed rice season. In the two *boro* season crops, the response to applied P varied between 0.4 to 1.0 t/ha while K application improved yield by 1.1 to 1.5 t/ha compared to the plots without K.

Economics of Crop Production

During the first year, the highest net profit from jute was obtained under T_9, while T_1 returned the highest net profit in the second year (**Table 6**). For *kharif* rice (IET-4786) the first year brought negative net returns due to very low yields and production expenses exceeding gross returns. During the

Table 5. Effect of different treatments on yield (grain and straw) of *kharif* and *boro* rice.

	Kharif rice (var. IET-4786)				*Boro* rice (var. IET-4094)			
	1st Year		2nd Year		1st Year		2nd Year	
	Yield, t/ha		Yield, t/ha		Yield, t/ha		Yield, t/ha	
Treatment	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	1.88	2.71	3.93	4.93	5.45	6.10	5.79	6.18
T_2	1.75	2.57	3.72	4.70	5.32	5.84	5.51	6.09
T_3	1.72	2.49	3.53	4.30	5.12	5.60	5.32	5.78
T_4	1.67	2.49	3.34	4.06	5.17	5.39	5.24	5.57
T_5	1.66	2.41	3.14	3.93	5.08	5.47	4.81	5.24
T_6	1.76	2.61	3.26	4.06	5.06	5.61	4.98	5.42
T_7	1.66	2.37	2.90	3.60	4.75	5.22	4.54	5.24
T_8	1.45	2.39	2.72	3.63	4.34	5.06	4.25	4.79
T_9	1.76	2.37	3.23	3.96	4.79	5.12	4.51	5.07
C	1.04	2.17	2.16	3.09	3.03	3.87	2.98	3.92
S.Em (±)	0.08	0.58	0.09	0.12	0.14	0.22	0.07	0.08
C.D. (P=0.05)	0.24	NS	0.27	0.37	0.42	0.67	0.22	0.26

Table 6. Economics of crop production for different treatments at Kalyani.

	1st year			2nd year		
	Net return, Rs./ha			Net return, Rs./ha		
Treatment	Jute (JRO-524)	*Kharif* rice (IET-4786)	*Boro* rice (IET-4094)	Jute (JRO-524)	*Kharif* rice (IET-4786)	*Boro* rice (IET-4094)
T_1	5,870	-1,870	16,770	14,880	11,890	19,520
T_2	5,560	-1,260	16,520	14,720	11,550	18,550
T_3	7,800	-1,740	15,720	12,800	10,720	17,730
T_4	9,110	-1,760	16,360	11,500	9,690	17,350
T_5	9,010	-1,590	15,910	10,450	8,680	14,900
T_6	4,510	-1,420	15,370	12,540	8,940	15,310
T_7	4,320	-1,900	13,540	12,050	6,60	12,860
T_8	5,140	0	11,250	9,440	5,980	10,990
T_9	13,270	-340	15,150	13,240	9,530	13,400
C	4,970	-3,350	6,210	8,160	3,970	6,080

Price details used in economic analysis: *kharif* and *boro* rice: Rs. 5.50 per kg; Jute: Rs. 8.60 per kg; N: Rs.10.50 per kg; P_2O_5: Rs. 16.22 per kg; K_2O: Rs. 7.43 per kg.

second year the highest net return in *kharif* rice was obtained with T_1. Net return for *boro* rice in both years was highest under T_1.

The Relative Agronomic Effectiveness (RAE), expressed as percent, was calculated for each crop using **Equation 1**. Using the State recommended doses (T_9) as the standard treatment, for all crops, the highest RAE value was obtained with T_1 (**Figure 1**). The gradual reduction of applied P (T_3 to T_5) and K (T_6 to T_8) from the soil test recommendation led to declining RAE. As in grain yield of rice, or fibre yield of the jute, the decline in RAE was more sensitive to the decrease in application rate of K than P.

In general, application of nutrients following soil test-based

Equation 1:

$$\text{RAE} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in state recommendation} - \text{Yield in control}} \times 100$$

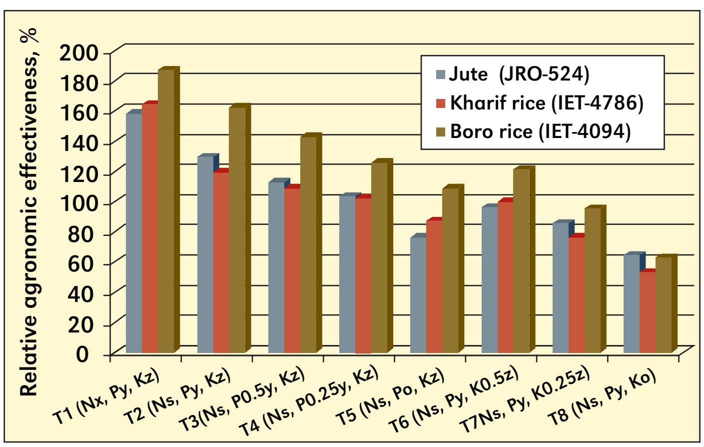

Figure 1. Relative Agronomic Effectiveness (%) of different levels of P and K fertilization in Jute and Rice at Kalyani.

recommendation led to significantly higher yield of each crop under lowland ecosystem than those where nutrients were applied following general recommendations. The experiment showed that soil K is more limiting to crop growth as compared to P in this alluvial soil. This study also shows that a nutrient management strategy based on soil test can improve the productivity of the Jute-Rice-Rice cropping system, one of the important cropping sequences followed in West Bengal. This also provides an opportunity for higher economic return to farmers. BC-INDIA

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