Potassium Unlocks the Potential for Hybrid Rice

By S.K. Pattanayak, S.K. Mukhi, and K. Majumdar

Researchers adjusted the K application rate within a soil test-based fertilizer recommendation for hybrid rice. Adequate K input was responsible for a 6 t/ha grain yield response and lifted the potential for a two crop system yield to near 14 t/ha – a vast improvement over common farm practice, which struggles to achieve one-third of this level of productivity.

Nearly one-third of the rice produced in India comes from within the four East Indian states of West Bengal, Bihar, Orissa, and Assam. As such, East India is of critical importance with regard to food security in India. Rice is by far the dominant cereal in the region. In Orissa, the crop contributes to about 84% of all food grains grown. Orissa itself produces about 25% [6.5 million metric tons (M t) in 2004-05] of the region's rice stocks from a 4.5 M ha area. However, average productivity in Orissa is low at 1,450 kg/ha.

Inadequate and unbalanced nutrient use is one of the major factors responsible for low crop productivity in Orissa. Average fertilizer consumption ($N+P_2O_5+K_2O$) in Orissa's rice crops is also low at 47 kg/ha, much below average NPK removal by rice (160 kg/ha). Soil K status within many districts of the state is medium. However, long-term soil K fertility assessment within India has clearly shown that medium fertility status soils fall quickly to the low category if K application is inadequate. The speed and magnitude of soil K depletion varies according to cropping intensity. The average rate of K application in the state is only 7 kg/ha — about 15% of the total K removed by a single crop of rice. Thus, large negative K balances extend throughout much of the state, which is one of the most important reasons for low rice productivity.

Hybrid rice varieties were introduced to the region to augment the rice production scenario. However, an inadequate nutrient management strategy failed to produce the desired result. The cultivation of hybrids using nutrient rates applicable to 'high yielding' varieties (HYV) has failed to achieve expectations for higher yields. Hybrid varieties have higher yield potential, but require much higher quantities of applied nutrients compared to HYVs. The present study was initiated to evaluate the effect of soil test-based fertilizer recommendation on hybrid rice yield. Focus was given to the impact of alternative K application rates used within the proposed recommendation.

Field experiments were conducted near Bhubaneswar, Orissa, for two consecutive cropping seasons at a site with an acid Inceptisol soil. Soil samples were randomly collected (0 to 15 cm depth) for analysis and a yield target-based recommendation was developed following Agro Services International (ASI) analytical methods (Portch and Hunter, 2002). The experiment was laid out in a randomized block design with 12 treatments and three replications. The treatments were based on the full soil test-based fertilizer recommendation of 290 kg N, 170 kg P_2O_5, 180 kg K_2O, 1 kg B, 7 kg Zn, and 4 kg Cu. Seven treatments comprised of increasing K application rates are reported in this paper. These treatments included: T_1, zero fertilizer (control); T_2, ASI recommendation without K; T_3, ASI with 25% of the recommended K rate; T_4, ASI with 50% K; T_5, ASI with 75% K; T_6, ASI with 100% K; T_7, 150% of NPK plus recommended rates of B, Cu, and Zn.

Uniform cultural practices and plant protection measures were used within all treatments. A blanket dose of 5 t/ha of farmyard manure and 1,800 kg/ha of lime was applied to all treatments, except the zero fertilizer control. Lime was applied two days before transplanting. The basal fertilizer application included 25% of the N and K, 50% of the P, and 100% of the B, Cu, and Zn. A first topdressing occurred 21 days after transplanting and included 50% of the N, P, and K. The remaining N and K were applied at the boot leaf stage. Grain, straw, and chaff samples were analyzed for nutrient concentration and uptake at maturity following standard procedures, as were the post-harvest soil physiochemical properties and nutrient contents for each respective treatment.

The cumulative two season grain, straw, and chaff yield of hybrid rice varied between 4.9 to13.9 t/ha, 6.7 to14.6 t/ha, and 0.48 to 1 t/ha, respectively (**Table 1**). Maximum yields were observed under the full ASI recommendation. The complete exclusion of K from the recommended dose resulted in a 42% loss in grain yield and the highest chaff production. A gradual increase in K rate increased grain yield, narrowed the grain:straw ratio, and steadily improved the harvest index. The harvest index of well-managed modern high-yielding rice varieties should be near 0.5 (Khush, 1995). Application of macronutrients at 150% of the recommended rate of N, P_2O_5, and K_2O produced no extra advantage as yields dropped 35% while quantities of straw increased (**Table 1**).

Macro- and secondary nutrient uptake increased appreciably under higher rates of K application (**Table 2**). Trends in

Table 1. Effect of K rate on hybrid rice yield (two consecutive seasons).

Treatments	Grain, t/ha	Straw, t/ha	Chaff, t/ha	Grain: Straw	Harvest Index
T_1 (Control)	4.9	6.7	0.50	1:1.37	0.40
T_2 (- K)	8.0	11.5	1.00	1:1.44	0.39
T_3 (25% K)	9.3	12.0	0.90	1:1.29	0.42
T_4 (50% K)	10.7	12.3	0.80	1:1.15	0.45
T_5 (75% K)	11.2	12.9	0.70	1:1.15	0.45
T_6 (100% K)	13.9	14.0	0.48	1:1.01	0.49
T_7 (150% NPK)	9.0	14.6	0.79	1:1.62	0.37
CD[1] (0.05)	0.5	0.6	0.08	-	-

[1]Denotes critical difference.

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; B = boron; Cu = copper; Zn = zinc; C = carbon.

Table 2. Effect of K rate on nutrient uptake and recovery by hybrid rice.

Treatments	Nutrient uptake, kg/ha					Nutrient recovery efficiency, %			
	N	P	K	S	Ca	N	P	S	Ca
T_1 (Control)	83	15	148	12	28	-	-	-	-
T_2 (- K)	175	27	215	21	56	29	17	6	7
T_3 (25% K)	185	32	283	22	56	36	22	7	7
T_4 (50% K)	206	34	299	23	56	43	27	8	7
T_5 (75% K)	221	37	331	25	59	49	32	10	8
T_6 (100% K)	236	40	359	27	63	54	36	12	9
T_7 (150% NPK)	224	37	355	27	60	33	22	8	8
CD[1] (0.05)	3	2	22	4	2	-	-	-	-

[1]Denotes critical difference.

uptake indicate that hybrid rice removes much larger quantities of soil K compared to N. Apparent recovery of N, P, S, and Ca increased considerably as K application increased up to levels recommended by the soil test. Nutrient recovery declined under the treatment providing NPK at 150% of the soil test-based recommendation.

Post harvest soil properties showed a general decline in available P and K as well as organic C and an increase in soil pH (due to added lime) compared to the initial status (**Table 3**). Available P and K status declined to comparable levels across treatments with the exception of the 150% NPK treatment (T_7), which had higher soil test P and K levels – more similar to the initial values. Nutrient uptake within T_7 failed to increase significantly beyond that under the 100% NPK treatment (T_6) and the additional yet unbalanced nutrient supply within T_7 led to higher residual fertility. The general change in organic C is attributed to local field management which was conducive to enhanced C oxidization as the soil was subjected to several physical disturbances through ploughing and weeding. Also, instead of flooding or maintaining standing water, the crop was subjected to alternate wetting and drying conditions.

Table 3. Effect of K rate on post harvest soil properties and available nutrient status.

Treatments	pH	EC, dS/m	Organic C, g/kg	Available nutrients, kg/ha		
				N	P_2O_5	K_2O
Initial status	5.0	0.14	7.5	74	17	84
T_1 (Control)	4.8	0.10	5.6	36	7	23
T_2 (- K)	6.8	0.26	5.7	41	9	32
T_3 (25% K)	6.2	0.20	4.7	44	11	31
T_4 (50% K)	6.2	0.19	4.5	53	9	29
T_5 (75% K)	6.0	0.18	4.6	48	10	27
T_6 (100% K)	5.8	0.17	5.2	36	8	23
T_7 (150% NPK)	6.3	0.35	5.9	35	14	79
CD[1] (0.05)	0.3	0.01	0.21	NS	1.8	3.4

[1]Denotes critical difference.

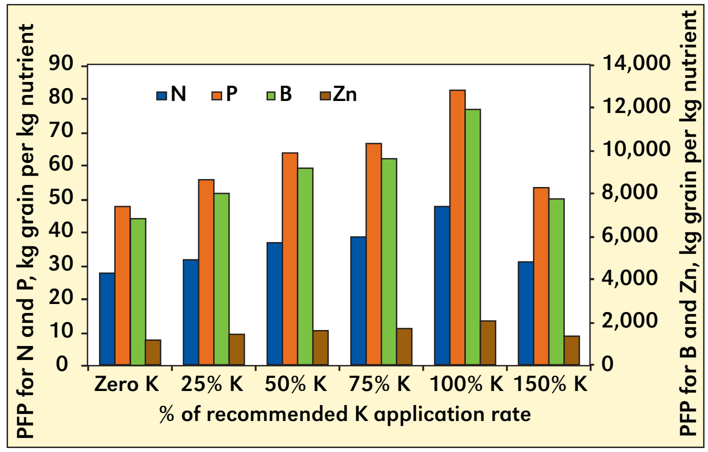

Figure 1. Effect of K rate on partial factor productivity.

Declining partial factor productivity (PFP), measured by grain output divided by the quantity of a single input factor applied (e.g., N), is a major concern in Indian agriculture. Various causes for such declines have been put forward. However, this experiment clearly shows that balanced fertilization, achieved through step-wise increases in the K fertilization schedule, produced steady improvements in PFP for N, P, B, and Zn (**Figure 1**).

Dr. Pattanayak (left) and Dr. Majumdar are shown visiting the hybrid rice trial site in Orissa.

Summary

It is essential to recognize that no nutrient works in isolation and no reason to emphasize a single factor or nutrient in high production systems. In such systems, site-specific nutrient management (SSNM) recommendations are required to fully consider crop requirement and soil nutrient supply. The principles of SSNM are to deliver amounts and ratios of nutrients based on indigenous soil nutrient supply rates, crop requirements, and a yield target, without any biased emphasis on any one particular nutrient. That, along with sound management practices and decisions, will ensure increased efficiency of nutrient use and profitability in high production systems. The magnitude of crop demand for nutrients evidenced in this study suggests a need to revise the K recommendation of hybrid rice varieties in order to match their high yield potential. BC

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