Phosphate Fertiliser Management of Hybrid Rice

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Appropriate P application rates were suggested for rice through a soil test-based approach wherein application of the full recommendation was responsible for a 5.2 t/ha grain yield response which raised the potential of a two crop system to 13.9 t/ha. The soil test-based approach improved harvest index, increased the recovery efficiency of N and K, and the corresponding economic benefits from hybrid rice cultivation.

Proper P nutrition is critical for producing maximum rice yields, which contributes about 84% of the total food grains grown in the state of Orissa. It promotes vigorous, early plant growth and development with strong root systems and profuse tillering, in addition to flowering, fruiting, and many other biochemical processes in the plant. However, its deficiency in rice is often referred to as a "hidden hunger" because its symptoms are hard to observe unless deficient plants are directly compared to sufficient plants (Dunn and Stevens, 2007).

The soils of Orissa are largely acidic (70%) in nature and low to medium in available P status. The red and lateritic soils have particularly low soil P status (Bray-1 P, 6 to 27 kg/ha), although their total P_2O_5 content, is considered adequate (0.08 to 0.35%). The extent of P fixation is up to 92% under well aerated acid soil conditions and up to 70% under reduced/submerged condition (Pattanayak and Misra, 1989). Recovery of applied P seldom exceeds 25% in the year of application (Misra and Pattanayak, 1997) and its proper management under acid soil conditions is very critical for improving production. The average N + P_2O_5 + K_2O consumption of Orissa is about 50 kg/ha, of which P_2O_5 contributes about 12 kg/ha. Such low application of nutrients, coupled with high P-fixing soils, is a major contributing factor for low crop productivity in the state.

High yielding rice varieties, including hybrids, have been introduced in Orissa to increase food grain productivity. The nutrient requirement of hybrid rice is high, but most often fertiliser is recommended without evaluating soil nutrient status or the yield potential of hybrid rice. The result is inadequate and unbalanced fertilisation leading to poor yields that are much lower than expected achievable yield. Nutrient mining or accumulation and increased potential for environmental pollution are other impacts of such fertilisation practice. The present study was undertaken to evaluate the effect of a soil test-based fertiliser recommendation and graded doses of P on hybrid rice yield, nutrient uptake and recovery, and post harvest soil properties.

The field experiment was conducted at the Central Farm of Orissa University of Agriculture and Technology (Agro Ecological Region-12) for two consecutive seasons, namely the winter and summer rice seasons of 2005-06. The soil at the site was an Inceptisol with sandy texture and an acidic pH (pH 5.0). The surface (0 to 15 cm) soil was analyzed according to the Agro Services International (ASI) analytical method (Portch and Hunter, 2002). The hybrid rice crop (cv. Sreeram) received 12 treatments, each replicated three times in a randomised block design. The ASI recommended dose of fertiliser for rice (for two seasons) was 290 kg N, 170 kg P_2O_5, 180 kg K_2O, 1 kg B, 7 kg Zn, and 4 kg Cu/ha. This paper considers seven treatments including a control, five treatments with P application rates from 0 to 100% of the ASI recommendation in increments of 25%, and a dose having 1.5 times the ASI recommended rates for N, P_2O_5, and K_2O (**Table 1**).

A blanket dose of 5 t FYM/ha and 1,800 kg $CaCO_3$/ha was applied to all treatment except the control. Basal application to 20 day-old transplants included 25% of total N and K rates, 50% of the total P, and all of the B, Zn, and Cu. The crop was topdressed at 21 days after transplanting with 50% of the total N, P, and K rates. The remaining 25% N and K was applied at the boot leaf stage.

Uniform cultural and irrigation practices were followed for all treatments. The crop was harvested 120 days after sowing and grain, straw, and chaff yields (sun-dried) were recorded. Two border rows were left in each treatment plot for analysis of plant nutrient concentration and uptake. Grain, straw, and chaff samples were analysed for nutrient concentration and uptake at maturity following standard procedures.

Under the selected range of treatments, cumulative yield of grain, straw, and chaff ranged between 4.9 to 13.9 t/ha, 6.7 to 14.6 t/ha, 0.48 to 0.95 t/ha, respectively (**Table 1**). Excluding P entirely from the fertiliser schedule resulted in 38% less yield. Straw yields followed a similar trend to that observed for grain. Chaff production was lowest under the ASI recommendation and it increased steadily to 0.95 t/ha under complete omission of P. Harvest index (HI = grain yield/total biomass)

Table 1. Influence of incremental doses of P on yields, harvest index, and biomass ratios of hybrid rice, Orissa University of Agriculture.

	Yield, t/ha			Harvest	Grain:	Grain:
	Grain	Straw	Chaff	index	straw ratio	chaff ratio
Control	4.9	6.7	0.5	0.4	1.37	10
ASI-P	8.7	12.8	0.95	0.38	1.47	9
ASI+25% P	9.7	13.2	0.9	0.4	1.39	11
ASI+50% P	11.7	13.4	0.82	0.45	1.15	14
ASI+75% P	12.9	14.0	0.68	0.48	1.09	19
ASI+100% P	13.9	14.0	0.48	0.5	1.01	29
150% NPK	9.0	14.6	0.79	0.37	1.62	11
C.D.† (p=0.05)	0.47	0.64	0.06	–	–	–

†Denotes the critical difference

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; B = boron; Zn = zinc; Cu = copper; FYM = farmyard manure; CD = critical difference.

Table 2. Influence of incremental dose of P with full dose of N, K, and other nutrients on nutrient uptake and apparent recovery by hybrid rice, Orissa University of Agriculture.

	Nutrient uptake, kg/ha					Recovery efficiency, %		
Treatment	N	P	K	S	Ca	N	P	K
Absolute control	83.0	15.0	148.0	12.0	28.0	-	-	-
ASI-P	191.0	20.7	248.0	15.0	36.0	37	-	67
ASI + 25 % P	207.0	28.2	293.0	17.0	46.0	43	70	97
ASI + 50 % P	212.0	33.8	307.0	21.0	53.0	45	50	106
ASI + 75 % P	224.0	36.7	346.0	30.0	59.0	48	39	132
ASI + 100 % P	236.0	40.0	359.0	27.0	63.0	53	38	141
150 % NPK	224.0	37.0	355.0	27.0	60.0	32	22	92
CD (P = 0.05)	3.5	1.8	20.0	31.0	3.2	-	-	-

was again highest under the ASI recommendation, and HI decreased steadily to a minimum due to gradual withdrawal of P application (**Table 1**). The narrowest grain: straw ratio was recorded with the ASI recommended P dose and this ratio widened as P rate decreased. The grain: chaff ratio varied from an undesirable 9:1 under P omission to a desirable 29:1 under the ASI recommendation. Application of macronutrients at 150% of the ASI recommended rates produced more straw and chaff, and less grain than the 100% recommendation, which lead to a wider grain: straw ratio, a narrow grain: chaff ratio, lowest harvest index, and showed no added advantage.

Data on nutrient uptake and apparent nutrient recovery are presented in **Table 2**. Nutrient uptake by rice could be arranged as follows: K > N > P. Higher P application rates increased uptake of all nutrients – a relationship which held true up to and including the P rate provided under the ASI recommendation. Maximum nutrient removal occurred under the ASI recommendation. By comparison, nutrient uptake under the 1.5 ASI treatment appeared to plateau or decrease slightly.

Without P application, the apparent recoveries for N and K amounted to 37% and 67%, respectively. Increasing P application in 25% increments increased N and K recoveries considerably to a maximum of 53% for N and 141% for K at the ASI P recommendation. Incremental rates of P caused a steady decline in P recovery. Phosphorus recovery ranged between 70% under the lowest application rate to 38% and 22% under the ASI and 1.5 ASI recommendations, respectively.

Table 3. Economics of hybrid rice cultivation, Orissa University of Agriculture.

Treatments	Production cost, Rs./ha	Income, Rs./ha	Benefit, Rs./ha	Income per Rs. investment
Absolute control	35,302	46,553	11,251	1 : 1.32
ASI-P	62,066	83,323	21,257	1 : 1.34
ASI + 25 % P	63,001	90,143	27,142	1 : 1.43
ASI + 50 % P	63,936	109,208	45,272	1 : 1.71
ASI + 75 % P	64,871	119,828	54,957	1 : 1.85
ASI + 100 % P	65,806	128,303	62,497	1 : 1.95
150 % NPK	67,676	87,228	19,552	1 : 1.29

*Costs assumed for this example: hybrid fine rice, Rs.8,500/tonne; N, Rs. 11/kg; P_2O_5, Rs.22/kg; K_2O, Rs.8/kg; borax, Rs. 90/kg; zinc sulphate, Rs. 55/kg; and copper sulphate, Rs.160/kg.

Partial factor productivity (PFP) of nutrients in this experiment was estimated by dividing grain output by the quantity of a single nutrient. The results showed that PFP of N, K, Zn, B, and Cu steadily improved with incremental P rates up to the recommended level. Any further increase in P rates decreased grain output per unit of nutrient (**Figure 1**). Declining PFP in crop production is a major concern in India and the current experiment showed that balanced and adequate nutrition can reverse the situation.

The cumulative two-season production cost of hybrid rice (**Table 3**) varied between Rs.35,302/ha to Rs.67,676/ha. Highest income (Rs.128,303) and profit (Rs.62,497) per ha was obtained in the full recommended dose of nutrient application. The return per rupee invested varied from 1.29 to 1.95 and highest return was in the ASI + 100% P dose. There was no extra economic advantage of application of 150% of the recommended rates of nutrients.

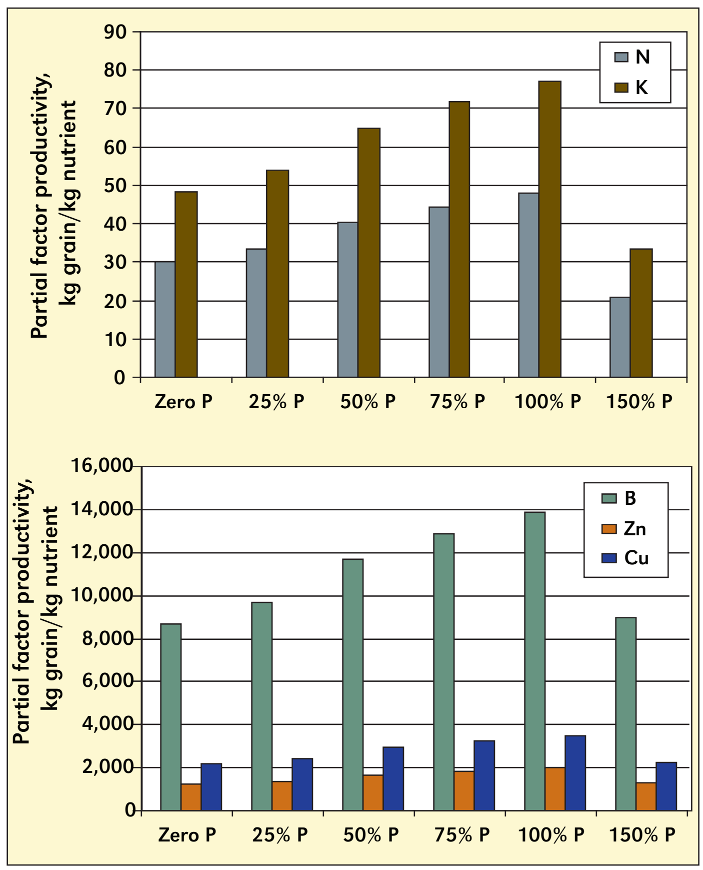

Figure 1. Effect of P rate on partial factor productivity for N and K (top) and for B, Zn, and Cu (bottom), Orissa University of Agriculture.

Summary

Productivity of rice in India, particularly in the eastern part, has stagnated over the past few years. The ever-increasing population in the country demands that rice productivity is also improved. Hybrid rice, with improved yield potentials as compared to the existing varieties, will play an important role

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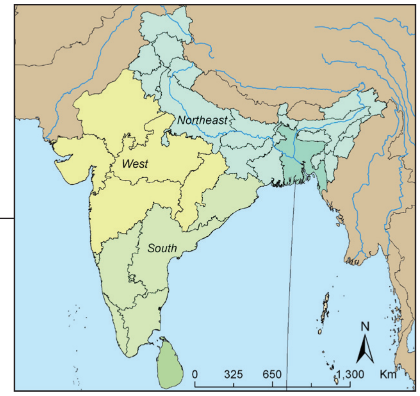

Northeast Zone	Project Number	Title
	EZ INDIA-40	Balanced Fertiliser Use in Major Crops of Jharkhand
	EZ INDIA-41	Maximising Productivity, Farmer Profit, and Nutrient Use Efficiency in Rice-Based Cropping Systems in the Terai Agro-Ecological Region of West Bengal
	EZ INDIA-42	Site-Specific Potassium Management for Sustainable Production in Selected Rice Domains of West Bengal
	EZ INDIA-43	Importance of Soil Test Based Nutrient Application through Farmers' Participatory Approach in Red and Lateritic Soils of West Bengal
	EZ INDIA-45	Spatial Variability in Soil Physico-Chemical Properties and Nutrient Status in an Intensively Cultivated Village of West Bengal
	EZ INDIA-46	Site-Specific Nutrient Management in Wheat in East India
	NWZ INDIA-59	Balanced Fertilisation for Quality Fruit (Mango) Production in Uttar Pradesh
	NWZ INDIA-63	Site Specific Nutrient Management for High Yield and High Profits in the Southwestern Plain Zone of Uttar Pradesh
	NWZ INDIA-69	Maximising Crop Yield through Site-Specific Nutrient Management in Uttar Pradesh
	NWZ INDIA-73	Evaluating Production Systems for Attaining Maximum Productivity and Profits in Uttar Pradesh

West Zone	Project Number	Title
	NWZ INDIA-64	Site-Specific Nutrient Management for Maximum Economic Yield and Quality of Sugarcane in Maharashtra
	NWZ INDIA-70	Site-Specific Nutrient Management in Mosambi Sweet Orange
	NWZ INDIA-71	Balanced Fertilization for Maximisation of Crop Yields in Gujarat
	NWZ INDIA-72	Appraisal of Multi-Nutrient Deficiencies and Their Redressal through Site-Specific Nutrient Management

South Zone	Project Number	Title
	SZ INDIA-47	Investigations on Balanced Fertilization for Breaking Maize Yield Barriers in Tamil Nadu
	SZ INDIA-48	Balanced Fertilisation for the Maize-Redgram Cropping Sequence in Alfisols of Karnataka
	SZ INDIA-49	Site-Specific Nutrient Management for Maximisation of Crop Productivity in Southern Karnataka
	SZ INDIA-50	Site-Specific Nutrient Management for Maximum Economic Yield and Quality of Transgenic Cotton in Northern Karnataka

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in maintaining food security. However, we need to keep in mind that the full potential of hybrid rice can only be harnessed with appropriate management, particularly nutrient management. One of the major reasons for falling partial factor productivity in the country is inadequate and imbalanced nutrient application. This experiment clearly showed that soil test-based nutrient application, with focus on adequate application of all limiting nutrients following the concept of site-specific nutrient management, will help to break existing yield barriers. This will also ensure higher nutrient use efficiency and better economics of production, which are prerequisites of a sustainable production system. BC-INDIA

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