Rebalancing Nutrient Application in Late-Sown Potato

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Common practice for cropping systems in the Gangetic Plain places a heavy reliance on soil nutrient reserves. Nutrient balances for most crops indicate significant depletion, especially for K. Potato provides one such example of a system in need of revitalization.

The majority (80%) of potato production occurs within the most fertile alluvial soil zones spreading from Punjab in the northwest to West Bengal in the northeast. These soils are developed on the alluvium of the Ganges and Yamuna rivers. However, soil fertility in the region has declined due to continuous intensive cropping with inadequate and unbalanced use of nutrients.

The 440,000 ha of potato planted in Uttar Pradesh currently accounts for 33% of India's total potato area and 44% of its total production at 10.2 M t. It is a relatively high-yielding zone within India, with an average productivity of 23 t/ha…one-third higher than the national average. This is below the region's yield potential under balanced fertilization.

At current levels of productivity in Uttar Pradesh, annual N, P_2O_5, and K_2O removal by harvested potato tubers amounts to 60,000, 14,000, and 87,000 t, respectively. This represents 2.5% of the total N, 1.8% of P_2O_5, and 60% of K_2O consumed by all crops in the state. A desired 50% increase in productivity would increase potato's share of nutrient use to 3.8%, 2.7%, and 90%. Total K removal by major crops is much higher at 17 M t K_2O. Thus, farmers of Uttar Pradesh depend heavily on soil K reserves for all crops. Since total K additions through external sources only amount to 142,000 t, the state has a large negative K balance of 15.6 M t K_2O.

It is not surprising that symptoms of K deficiency and other nutrients are easily observed and generally spreading throughout potato fields within the state and country. Average per hectare fertilizer use for potato in Uttar Pradesh is comprised of 91 kg N, 29 kg P_2O_5, and 6 kg K_2O…a use ratio of 15:5:1. The current state department of agriculture fertilizer recommendation of 150-75-75 kg/ha is less commonly adopted, but is also proving to be suboptimal to sustain optimum productivity, produce quality, and farmer profit.

Table 1. Outline of treatments applied to potato, Kanpur.

Treatment	Ratio	N	P_2O_5	K_2O
		kg/ha		
T_1	2:1:2	150	75	150
T_2	2:1.25:2	150	94	150
T_3	2:1.50:2	150	112	150
T_4	2:0:2	150	0	150
T_5	2:1.25:1.5	150	94	112
T_6	2:1.25:1	150	94	75
T_7	2:1.25:0	150	94	0
T_8 (SR)	2:1:1	150	75	75

Potato plants shown at left have clear symptoms of K deficiency.

This field experiment was initiated to compare the effectiveness of selected macronutrient application ratios. The study was located at the Fertilizer Research Station in Pura, Kanpur, during the 2004/05 *rabi* winter season (October to March). The site had a sandy loam soil, pH 8.2, and 0.35% organic carbon. Available N (alkaline permanganate method), P (Olsen), and K (ammonium acetate extractable) were all considered low at 175, 8.5, and 110 kg/ha, respectively. Urea, DAP, and KCl were used as fertilizers supplying eight treatment combinations (**Table 1**). Varying ratios of NPK were formulated and tested based on the need to improve the state recommendation for P and K. Along with treatments omitting P and K, the state recommendation (SR, T_8) was compared against those supplying 25 or 50% more P and 50 or 100% more K. Basal applications of

Tuber yields and net returns were highest with balanced NPK application. Rates of 150-112-150 kg N-P_2O_5-K_2O produced 34% more than the state recommendation.

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Zn = zinc; DAP = diammonium phosphate; KCl = potassium chloride; M t = million metric tons.

Table 2. Effect of treatment on fresh tuber yields and net returns.

Treatment	Yield, t/ha	Response over SR, %	Net return over SR, Rs/ha	Benefit-to-cost ratio
T_1	30.1	3.2	2,700	5
T_2	33.4	14.6	14,010	16
T_3	39.0	33.5	33,050	38
T_4	23.7	-18.9	-18,630	–
T_5	33.5	14.7	14,470	25
T_6	31.2	7.0	-6,870	23
T_7	23.4	-20.0	-20,220	–
T_8 (SR)	29.2	–	–	–
C.D.[1] 5%	3.4			

[1]C.D. = critical difference
US$1 = Rs. 46.58

S and Zn were provided to all treatments at 40 kg S/ha and 25 kg $ZnSO_4$/ha. Planting of "Kufri Anand" cv. commenced in early December and was grown using all recommended cultural and pest management practices including weed control. Irrigation was provided as needed to avoid moisture stress. Potato tubers were harvested at full maturity in mid-March, 2005. Highest tuber yield of 39.0 t/ha was recorded under T_3 providing 150-112-150 kg N-P_2O_5-K_2O/ha—a ratio of 2:1.5:2 (**Table 2**). SR (T_8) of 150-75-75 produced 29.2 t/ha, 34% less yield. Treatments omitting P (T_4) and K (T_7) provided the lowest yields of 23.7 and 23.4 t/ha, which mirror the state average.

Net returns followed yield responses, with T_3 being most profitable at Rs.33,050/ha (US$700) over the SR, followed by T_5 at Rs.14,470/ha (US$310), and T_2 at Rs.14,020/ha (US$300) over the SR. Omission of P and K proved least economical as net returns from these plots were Rs.18,625 (US$400) and Rs.20,220/ha (US$405) below the SR, respectively. Benefit-to-cost analysis also determined T_3 to be superior at 38—signaling this to be the most economic yield, or most pertinent goal for farmers.

Discussions on improved fertilizer P and K input strategies also extend to issues surrounding nutrient use efficiency. Typically, N use efficiency is of most critical concern due to input costs and the higher risks of environmental loss associated with greater N mobility. Measuring use efficiency of P and K is less critical since that which is not removed by the initial crop more consistently adds to residual soil pools and is largely available to subsequent crops.

Table 3. Effect of K and P on nutrient uptake in potato.

K_2O rate, kg/ha	Nutrient uptake, kg/ha		
	N	P	K
0	128.9	11.8	133.3
75	185.0	19.0	211.1
112	202.3	20.8	251.5
150	194.9	20.7	258.7
150[1]	259.8	28.0	333.0

Based on N and P_2O_5 rates of 150 and 94 kg/ha.
[1]Treatment used N and P_2O_5 rates of 150 and 112 kg/ha.

Table 4. Effect of K and P on N use efficiency[1] in potato.

		P_2O_5, kg/ha			
		0	75	94	112
K_2O, kg/ha	0			156	
	75			208	
	112			223	
	150	158	201	223	260

[1]Expressed as partial factor productivity (PFP) = grain yield per kg N fertilizer.
Nitrogen supplied at 150 kg/ha across treatments.

The lack of nutrient balance between fertilizer N, P, and K leads to poor N use efficiency in potato production. Uptake of N, P, and K by potato was stimulated with increasing rates of fertilizer P and K (**Table 3**). Narrowing the NPK application ratio from 2:1.25:2 (T_2) to 2:1.5:2 (T_3) produced a 33, 35, and 29% increase in N, P, and K uptake, respectively.

Partial factor productivity (PFP) measurements, provided in **Table 4**, describe the crop response in terms of treatment effectiveness in converting fertilizer N into yield. A steady increase in N use efficiency is achieved as P and K rates increase. However, the PFP_N response reaches a plateau, with no advantage observed at the highest K rate (150 kg K_2O/ha), when P application was limited to 94 kg P_2O_5/ha. A large upward shift in PFP_N was achieved when this P limitation was removed by increasing the P rate to 112 kg P_2O_5/ha.

Cooperators in the potato fertilization study with harvest results.

Higher-yielding potato can be obtained, and nutrient use efficiency substantially augmented, by balanced fertilization—achieved here by keeping the recommended N rate constant and increasing the P and K rates by 50% and 100%, respectively. The current state recommendation not only promotes suboptimal yields and returns to farmers in Uttar Pradesh, but also under-utilizes farm investment in fertilizer inputs, especially N. BC

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