Phosphorus Needs of Indian Soils and Crops

By K.N. Tiwari

In 2025 the foodgrain requirement for India's 1.4 billion people will be about 300 million tonnes (M t). This production level will require about 30 M t of nitrogen (N), phosphorus (P), and potassium (K), including 8.6 M t of P_2O_5. In addition, another 14 to 15 M t of NPK would be needed for vegetable, plantation, sugar cane, cotton, oilseed, potato, and other crops. Thus, about 40 to 45 M t of NPK, containing 11 to 13 M t of P_2O_5, will be required just to maintain a broad average $N:P_2O_5:K_2O$ ratio of 4:2:1. This paper further explores P needs of Indian soils and crops.

Phosphorus Fertility Status in India

Based on about 9.6 million soil tests, 49.3 percent of districts and Union Territories are low in available P, 48.8 percent are medium, and 1.9 percent are high (Hasan, 1996). In comparison to an earlier compilation by Ghosh and Hasan (1979), this present survey indicates the low P fertility class has increased by 3.0 percent while medium and high categories have decreased by 2.7 and 0.3 percent, respectively. Both surveys highlight the need for P fertilizer application for proper crop growth in nearly 98 percent of India's districts.

Building the P Status in India's Soils

There are many good reasons why soil P fertility should be built up. High soil P status allows greater flexibility in use of all fertilizer nutrients. Complete crop requirements can be met with smaller annual fertilizer applications. In addition, under difficult economic times, farmers can exercise an option of short-term cutbacks in fertilizer application and possibly incur smaller losses in yield potential.

Utilization of fertilizer P by the first crop to which it is added will range from 15 to 30 percent. However, the balance remaining contributes to residual soil P build-up and is not lost except through erosion or runoff. Good management practices are those that ensure soil fertility status can gradually progress from low to medium to high. Building soil P will:

- Ensure more profitable crop yields over more years. High fertility also helps to reduce the risk associated with crop production.
- High fertility results in more residues remaining after harvest to protect the soil against wind or water erosion, while building

organic matter levels, thereby increasing long-term production potential.

- High P (and K) fertility improves N use efficiency in balanced plant nutrient programs.
- High fertility conserves water by reducing amounts required per unit of crop production.
- Soil P (and K) fertility boosts yield potential, even in weather stress years.
- High fertility interacts positively with other production inputs (i.e., tillage practices, variety, planting date, population) to get the most out of the crop

Phosphorus Consumption Trends in India

Phosphorus consumption in India steadily increased up to 1992. However, the combined government action of removing subsidies on P fertilizer while lowering urea prices effectively reduced national P consumption in 1993-94 (**Table 1**). Phosphorus use recovered slowly, but 1992 consumption levels did not return until 1997-98.

Phosphorus consumption in India increased from 3.92 M t during 1997-98 to 4.10 M t during 1998-99. This increase resulted in a NPK use ratio of 8.5:3.1:1, a step backwards from 7.9:2.9:1 recorded in 1997-98. India's movement towards balanced fertilization is often hampered by greater relative increases in N consumption. Nitrogen consumption increased by 3.9 percent in 1998-99. However, the normal growth rate is closer to 5.0 percent per year. Therefore, had consumption of N maintained its normal growth pattern in 1998-99, the imbalance between N and P would have been even greater.

Perspective on the amount of P consumed in India can be provided through a direct comparison with China. China consumes 2.7 times more P, 2.5 times more N and 2.7 times more K despite having 38 percent less arable land and a similar irrigated cropland area as India. Calculated on arable land basis, in 1997 China applied 188 kg N/ha, 60 kg P_2O_5/ha, and 18 kg K_2O/ha, whereas India applied only 61 kg N, 18 kg P_2O_5, and 6 kg K_2O/ha.

Nutrient use can generally be considered low in India, but P and K use in particular is very low. Average NPK application rates are much lower than usually recommended rates. For example, the recommendation for both rice

Table 1. Consumption of P_2O_5 in India during 1961-99.

Year	Consumption Million t	Consumption kg/ha	Share of total, %	$N:P_2O_5$ ratio	$P_2O_5:K_2O$ ratio
1960-61	0.005	0.4	18.0	4.0	1.8
1970-71	0.05	3.3	24.0	2.7	2.3
1980-81	1.21	7.0	22.0	3.0	1.9
1990-91	3.22	17.3	25.7	2.5	2.4
1991-92	3.32	18.2	26.1	2.4	2.4
1992-93	2.84	15.3	23.4	3.0	3.2
1993-94	2.67	14.3	21.6	3.3	2.9
1994-95	2.93	15.6	21.6	3.3	2.6
1995-96	2.90	15.4	20.9	3.4	2.5
1996-97	2.98	16.0	20.8	3.4	2.9
1997-98	3.92	21.0	24.2	2.7	2.9
1998-99	4.10	22.0	24.4	2.7	3.1

and wheat is 120-60-30 kg N-P_2O_5-K_2O/ha.

However, a survey found India's rice received only 87 percent of this P_2O_5 recommendation and 30 percent of the recommended K_2O, while wheat received 65 percent of the recommended P_2O_5 and 17 percent of the recommended K_2O (FAO/IFA/IFDC, 1994). This survey also found a deficiency in N application, as 58 percent of the recommended N rate was applied to rice and only 70 percent to wheat.

This survey compared fertilizer consumption rates for 1992 in China and India and revealed 90 to 100 percent of major crops in China were fertilized with N at rates averaging from 55 to 145 kg/ha. Forty to 90 percent were fertilized with P_2O_5 at rates ranging from 25 to 85 kg/ha. Average K_2O rates varied from 0 to 75 kg/ha. In contrast, India fertilized 47 to 94 percent of the same crops with N, but at much lower rates of 31 to 89 kg/ha.

India applied P and K to a greater percentage of crop area, but much lower rates were used compared to China. Average application rates for P_2O_5 and K_2O ranged from 10 to 50 kg/ha and 2 to 30 kg/ha, respectively. It is clear that fertilizer use in India must be increased to achieve higher yield goals and sustain soil health.

Table 2. A balance sheet of P in Indian agriculture (illustrative of 1998-99).

	000 tonnes P_2O_5		
Items	Gross	Net	Remarks
INPUT			
1. Fertilizers	4,096	-	Actual consumption
1a. Efficiency (20%)	-	819	20% of 4,096
2. Farmyard manure	655	-	50% of total dung
2a. Efficiency (10%)		66	10% of 655
3. Composts (rural and urban)	1,373	-	Total production (FAI, 1998)
3a. Efficiency (10%)		137	10% of 1,373
4. Crop residues	280	-	5% of total uptake
4a. Efficiency		28	10% of 280
Total Input	6,404	1,050	
OUTPUT			
1. Crop uptake	5,800	-	
Net removal	-	5,200	5% returned through residues
2. Grazing	?	?	Estimates not available
3. Erosion	?	?	Reported to be substantial
Total Output	5,800	5,200	
Balance	+604	-4,200	Excluding erosion and grazing

Balance Sheet of Phosphorus

A balance sheet for P in Indian agriculture in 1998-99 is presented in **Table 2.** Using a one-year P use efficiency value of 20 percent, every five units of fertilizer input supplies one unit of plant-available P. The use efficiencies of all other P input sources such as farmyard manure, composts, and crop residues create a net P input far less than the net output resulting from crop removal, animal grazing, and erosion losses.

Phosphorus Removal by Intensive Cropping Systems

Knowledge of nutrient removal under intensive cropping systems is important for development of future P management strategies. Estimates of nutrient uptake for a number of cropping systems in India are provided (**Table 3**).

Table 3. Nutrient uptake in high-intensity and inter-cropped systems in India.

		Nutrient uptake, kg/ha/year			
Cropping system	Yield, t/ha	N	P_2O_5	K_2O	Total
Rice-wheat	8.8	235	92	336	663
Maize-wheat	7.7	220	87	247	554
Pigeonpea-wheat	4.8	219	71	339	629
Rice-rice	6.3	139	88	211	438
Soybean-wheat	7.7	260	85	204	549
Maize-wheat-greengram	8.2	306	62	278	646
Rice-wheat-greengram	11.2	328	69	336	733
Maize-potato-wheat	8.6 + 11.9(t)[1]	268	96	358	722
Rice-wheat-cowpea	9.6 + 3.9(f)	272	153	389	814
Soybean-wheat-potato	3.2 + 6.8(t)	284	41	202	527
Rice-wheat-maize + cowpea	9.3 + 29(f)	305	123	306	734

[1]t and f represent tuber and fodder yield, respectively.
Source: Adopted from Tandon and Sekhon (1988).

Removal of P_2O_5 can reach 150 kg/ha/year (rice-wheat-cowpea fodder), and annual uptake of 75 to 100 kg P_2O_5/ha is quite common under high intensity cropping (i.e., two to three crops/year). Production of 8 to 12 t grain/ha is associated with P uptake of 70 to 120 kg P_2O_5/ha.

Imbalanced Use of Nitrogen Accelerates Depletion of Other Soil Nutrients

Imbalanced application of N (often a result of its relatively low price) neither increases yield nor profit in the long run. But it may result in accelerating deficiency of other nutrients in the soil. Beaton et al. (1993) studied different crop sequences at various locations and found application of N alone increased soil depletion of available P, thus causing fast appearance of P deficiency symptoms (**Table 4**). The same is true for other plant nutrients and is a situation that must be avoided.

Table 4. Depletion of soil by application of N only in intensive cropping.

			kg P_2O_5/ha removed	
Location	Soil	Cropping sequence	Control plot	N-only plot
Barrackpore	Alluvial	Rice-wheat-jute	321	642
Ludhiana	Alluvial	Maize-wheat-cowpea	183	412
New Delhi	Alluvial	P. Millet-wheat-cowpea	160	366
Coimbatore	Black	F. Millet-wheat-cowpea	344	458
Jabalpur	Black	Soybean-wheat-maize	275	366
Hyderabad	Red	Rice-rice	527	847
Bhubaneswar	Laterite	Rice-rice	275	458
Palampur	Hill	Maize-wheat-potato	155	252
Pantnagar	Terai	Rice-wheat-cowpea	893	1,420

Phosphorus Requirement for Meeting India's Food Needs

India's population reached 1 billion in 2000 and is projected to be 1.4 billion by 2025. During 1998-99, India produced 188 M t of cereals and 15.5 M t of pulses. It was estimated that the country will produce 245 M t of food grains during 2001-02 and 285 M t in 2006-07. As food grain production levels increase, fertilizer demand for P (and K) will also increase. The demand for NPK in 2000 and 2005 in India is estimated to be high (**Table 5**).

If India is to bring its current $N:P_2O_5:K_2O$ consumption ratio from 8.9:3.2:1.0 closer to an ideal 2:1.5:1, current P and K consumption must be markedly increased. However, this would still not balance nutrient removal by crops at higher yield targets, and soil P would still be mined.

Table 5. Demand projections of fertilizers (M t) in India by different agencies.

Working group	Year[1]	N	P_2O_5	K_2O
MOA				
	2000	12.8	5.80	2.05
	2005	15.2	7.00	2.40
NIC				
	2000	10.9	4.73	1.94
	2005	12.6	5.61	2.25
PPI				
	2000	13.2	5.88	2.43
	2005	17.8	8.59	4.74

MOA–Sub-working group on fertilizers on 8th Plan projection; NIC-Planning Commission, Government of India; PPIC-India Programme.

Special effort will be needed from the laboratory to the land to balance N and P tonnage and assure crops get the P they need.

Conclusion

Phosphorus deficiency in Indian soils is widespread (98 percent of districts), and crop responses to its application are highly profitable. All indications are that P removal will continue to exceed net P additions, and P deficiency will accentuate further with time. Phosphorus, in fact, must play a much greater role in Indian agriculture than in the past. Profitable cropping with only N is a short-lived phenomenon. Sites initially well supplied with P become deficient with continuous cropping using N alone. Increasing N application without P (and K) application would not be a sound proposition.

Fertilizer rates presently considered as optimum still result in soil nutrient depletion at high productivity levels and, in the process, become sub-optimal rates. There are cases where, in spite of optimum P application, crop yields on low P soils remain lower than yields obtained on high P soils. Also, significant responses to P on high P soils are being recorded from different soil-crop-climatic conditions. Thus, there is urgent need to develop different fertility rating criteria for different soils. The present P fertility limits used in many soil-testing laboratories have outlived their utility. In addition to this, the goal of P research should be to develop methods, products, practices, and programmes which would encourage balanced and efficient use of P in India. **BCI**

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