Fertiliser Use in Indian Agriculture — An Eventful Half Century

By H.L.S. Tandon and K.N. Tiwari

Starting with very small amounts of fertilisers in the 1950s, the past half century has been quite eventful for India and the next half century will not be any less. Future fertiliser use will be driven by the varied demands of its population on a nearly stable cultivated area which is in urgent need of soil fertility recapitalization.

The impact of fertiliser inputs on India's food grain-driven agriculture remains of vital interest. At least 50% or more of recent increases in agricultural production are credited to fertilisers (Randhawa and Tandon, 1982). Thus, the food needs of half the population increase are being met because fertilisers are being used, or that one out of every two chapatties, or rice servings, are fertiliser-born. India today is the world's third largest producer and user of fertilisers, with an average annual consumption of 20.3 million metric tons (M t) $N+P_2O_5+K_2O$. Some recent developments in the fertiliser sector are summarised in **Table 1**.

However, nutrient removal by crops far exceeds nutrient additions through fertilisers. For the past 40 years, a gap (removals less additions) of 8 to 10 M t $N+P_2O_5+K_2O$/year has been documented (Tandon, 2004). This situation is akin to mining the soils of their nutrient capital. By adding up some recent state-level data on nutrient use, an illustrative balance sheet of NPK in Indian agriculture has been summarized in **Table 2**.

Fertilisers are meant to correct nutrient deficiencies and improve soil fertility so that higher crop productivity can be obtained and sustained as well. At the all-India level, soil deficiencies of N, P, K, S, Zn, and B are now of widespread importance. Nitrogen deficiency is common in the vast Indian plains. Potassium fertility of soils is not only neglected, but also under severe stress with the ongoing scenario where K removals vastly exceed K input.

Table 2. An illustrative balance sheet of NPK in Indian agriculture (2001).

	Gross balance sheet, '000 t			Net[1] balance sheet, '000 t		
	Additions	Removal	Balance	Additions	Removal	Balance
N	10,923	9,613	1,310	5,461	7,690	-2,229
P_2O_5	4,188	3,702	486	1,466	2,961	-1,496
K_2O	1,454	11,657	-10,202	1,018	6,994	-5,976
Total	16,565	24,971	-8,406	7,945	17,645	-9,701

[1]Accounting for nutrient use efficiency.
Source: Tandon, 2004.

Sulphur deficiencies are now estimated to occur in close to 250 districts and about 40% of soil samples have been found to be S deficient. Based on several years of data and 250,000 soil samples, 49% of soils were found to be deficient in Zn, 12% in Fe, and less than 5% for Cu and Mn. Boron deficiencies now need to be taken seriously in several areas with 33% out of 36,800 soil samples analysed having been found to be B deficient (Singh, 2001).

Large yield gaps are observed not only between on-station and on-farm trials, but also at the farm level. For example, average cereal productivity in the states of Bihar and Uttar Pradesh (UP) is far below that in Punjab (Tiwari et al., 2006). This yield gap is large and to a considerable extent, this can be attributed to differences in fertiliser use levels (**Table 3**).

Thousands of on-station and on-farm trials have been conducted to study the response of crops to fertilisers. Some results from on-farm trials with rice and wheat are summarized in **Table 4** (Leelawati et al., 1986, Randhawa and Tandon, 1982, Takkar et al., 1989). An overall response rate of 9 to 10 kg grain/kg $N+P_2O_5+K_2O$ applied is still valid for rough

Table 1. A summary of developments in fertiliser consumption in India.

	1960-61	1970-71	1980-81	1990-91	2001-02	2004-05	2005-06
Consumption, '000 t							
N	212	1,479	3,678	7,997	11,310	11,714	12,723
P_2O_5	53	514	1,214	3,221	4,382	4,624	5,204
K_2O	29	236	624	1,328	1,667	2,061	2,413
Total	294	2,256	5,516	12,546	17,360	18,399	20,340
Consumption, kg/ha[1]							
N	1.4	9	21	43	59	62	67
P_2O_5	0.4	3.3	7	17	23	24	27
K_2O	0.2	1.4	4	7	9	11	13
Total	2	14	32	68	90	97	107
P_2O_5: K_2O (N=1.0)	0.37: 0.16	0.37: 0.16	0.33: 0.17	0.40: 0.17	0.39: 0.14	0.39: 0.18	0.41: 0.18
Highest state-wise consumption, kg $N + P_2O_5 + K_2O$/ha	6.6 Kerala	0.2 Punjab	117.9 Punjab	161.9 Punjab	173.4 Punjab	195.7 Punjab	212.7 Punjab
Fertiliser sales points	–	81,460	109,964	232,505	282,776	288,756	284,753

Source: The Fertiliser Association of India (FAI), 2006. [1]Consumption, kg/ha numbers are rounded.

Abbreviations and notes for this article: N = nitrogen, P = phosphorus, K = potassium, S = sulphur, Z = zinc, B = boron, Fe = iron, Cu = copper, Mn = manganese.

Table 3. Comparison between fertiliser use levels and cereal productivity in selected Indian states.

State	Cereal yield, kg/ha	Average application, kg/ha			
		N	P_2O_5	K_2O	Total
Punjab	3,953	146	42	5	193
Uttar Pradesh	2,393	92	30	6	128
Bihar	1,684	79	6	3	88

Source: Tiwari et al., 2006.

Table 4. Results of on-farm trials on balanced fertilisation and food grain yields.

Crop	Trials	Nutrients added, kg/ha			Yield increase, kg/ha
		N	P_2O_5	K_2O	
Wheat	10,133	120	0	0	890
	10,133	120	60	0	590 (over N)
	10,133	120	60	60	290 (over NP)
	2,358	[1]25 kg $ZnSO_4 \cdot 7H_2O$			360 (over NPK)
Rice (Kharif)	5,955	120	0	0	1,236
	3,231	120	60	0	636 (over N)
	3,231	120	60	60	366 (over NP)
	4,856	[1]25 kg $ZnSO_4 \cdot 7H_2O$			248 (over NPK)
Rice (Rabi)	4,179	120	0	0	1,116
	1,979	120	60	0	624 (over N)
	1,979	120	60	60	252 (over NP)
	1,891	[1]25 kg $ZnSO_4 \cdot 7H_2O$			252 (over NPK)

[1]Zinc was added along with optimum rate of NPK.
Source: Leelawati et al., 1986; Randhawa and Tandon, 1982; and Takkar et al., 1989.

rice and wheat provided no other major nutrient deficiency exists. A recent analysis in agriculturally advanced Punjab estimates the response ratio to be 17 kg grain/kg $N+P_2O_5+K_2O$ in contrast to an all-India estimate of 8 kg grain/kg (Aulakh and Bahl, 2001). The higher productivity in Punjab is also due to widespread use of high yielding cultivars and better management practices than in many parts of India.

The Indian experience demonstrates that balanced fertilization is a dynamic rather than a static concept enshrined in a fixed NPK consumption ratio. As yield goals shift up, the "nutrient basket" demanded by the crops not only grows bigger, but also becomes more varied and complex. It is obsolete to maintain the view that top productivity can only be sustained with application of balanced ratios of $N+P_2O_5+K_2O$. The law of the minimum cannot be escaped, thus the absence of secondary nutrients, or a mug full of a micronutrient, can withhold the performance of bagfuls of NPK.

Results of on-farm demonstrations conducted by the Indian Council of Agricultural Research (Singh, 1991) revealed an average increase in productivity due to S application to be 650 kg/ha (+24% over NPK) in cereals, 570 kg/ha (+32% over NPK) in oilseeds, and 357 kg/ha (+20% over NPK) in pulses. Results of 2,391 on-farm trials with Zn application (on top of "optimum" NPK) with wheat show increased grain production of 200 to 500 kg/ha in 35% of cases and 500 to 1,000 kg/ha in 16% of cases. Similarly, based on 2,154 on-farm trials with rice, Zn application increased paddy (rough rice) yield by 200 to 500 kg/ha in 39% of cases, and by more than 1,000 kg/ha in 11% of cases (**Table 4**).

Another development of considerable interest in directing the course of balanced and efficient nutrient management refers to site-specific nutrient management (SSNM). SSNM is a systematic agronomic approach which considers field-scale variability in soil fertility and crop responses to applied nutrients. In recognition of the potential applicability of SSNM, the Project Directorate for Cropping Systems Research (PDCSR-ICAR) has established collaborative SSNM research with the International Plant Nutrition Institute (IPNI) on nutrient management in cropping systems. Replicated field trials were conducted at 10 locations with the rice–wheat system and at 6 locations with the rice–rice system (**Table 5**). In the SSNM experiments, 4 to 8 nutrients were applied in a pre-planned manner to evaluate responses to each of these at one or more levels (except N). Both crops received N, P, and K. Only kharif rice also received S and micronutrients implying that the rabi crop, whether rice or wheat, benefited from the residual effect of these nutrients (Tiwari et al., 2006).

Rice-wheat data averaged over 2 years show that annual

Table 5. Experimental locations and the nutrients required to optimise yield in the SSNM plots in rice-wheat and rice-rice systems.

Location	State	Rice	Wheat	Rice	Rice
Sabour	Bihar	NPK S	NPK		
Palampur	Himachal Pradesh	NPK S B Zn	NPK		
R. S Pura	Jammu & Kashmir	NPK S Mn Zn Cu	NPK		
Ranchi	Jharkhand	NPK S B Zn	NPK		
Ludhiana	Punjab	NPK S B Mn Zn Cu	NPK		
Faizabad	Uttar Pradesh	NPK S B Mn Zn	NPK		
Kanpur	Uttar Pradesh	NPK S Zn	NPK		
Modipuram	Uttar Pradesh	NPK S B Mn Zn	NPK		
Varanasi	Uttar Pradesh	NPK S B Mn Zn Cu	NPK		
Pantnagar	Uttaranchal	NPK S B	NPK		
Maruteru	Andhra Pradesh			NPK B	NPK
Jorhat	Assam			NPK S B Mn Zn Cu	NPK
Navsari	Gujarat			NPK S Fe Mn Zn	NPK
Karjat	Maharashtra			NPK B Fe Zn	NPK
Coimbatore	Tamil Nadu			NPK Fe	NPK
Thanjavur	Tamil Nadu			NPK S Mn	NPK

Source: Tiwari et al., 2006.

grain yields of 15 to 17 t/ha were achievable. Average annual grain productivity of the system was 13.3 t/ha of which 60% was from rice and 40% from wheat. None of the SSNM locations had annual grain productivity less than 10 t/ha. Averaged over locations, SSNM caused a 3.4 t/ha annual advantage or 34% more yield than common farmers' practices (FP). SSNM increased the expenditure on fertilisers by Rs.4,170/ha (US$104) compared to FP but generated additional produce valued at Rs.20,530 (US$513) – returning an extra net income per unit extra expenditure, or benefit-to-cost (BCR) ratio of 4.9. A frequency distribution of economic returns for the rice-wheat system (84 location x nutrient x rate combinations) found BCRs under 2 in 13% of cases, 2 to 5 in 17% of cases, 5 to 10 in 24% of cases, and above 10 in 46% of cases. The majority of cases with very high BCRs reflect very high grain yields achieved through high rates of response per unit applied nutrients.

Similarly, two years of rice-rice data revealed grain yields of 15 to 18 t/ha. Average annual grain productivity was 13.3 t/ha – the contribution of Kharif and Rabi rice being almost equal. The annual grain productivity under SSNM was more than 10 t/ha at all locations except one. Averaged over locations, SSNM brought a 2.5 t/ha advantage, or a 23% increase over FP.

SSNM also increased fertiliser expenditure by Rs.4,540/ha (US$114) over the FP but generated additional produce valued at Rs.11,900/ha (US$298) – a BCR of 2.6. The application of several nutrients was profitable at most sites.

Soil testing for fertiliser use started receiving attention in the mid 1950s. Close to 550 soil testing laboratories have been set up during the past 50 years to provide site- and crop-specific fertiliser recommendations. Most of these are owned and operated by government departments, but for various reasons their ground-level impact on facilitating balanced nutrient application is small. The national soil testing system needs to be readily energized and made more farmer-friendly, under the SSNM approach.

The nutrient needs of Indian agriculture are so large and expanding such that no single input, be it fertiliser or organic material, can meet them alone. Integrated nutrient management (INM) is receiving increasing attention, and rightly so. However, most INM packages will continue to be fertiliser-driven. This is because of inadequate amounts of organic sources of nutrients and their competing usage. Available estimates indicate that organic materials available as nutrient sources can meet about 25% of the total nutrients needs in India. The rest must come from soil reserves and inorganic fertilisers. BC-INDIA

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IPNI Scholar Award Announced

Miss K. Vanitha of Tamil Nadu Agricultural University (TNAU), Coimbatore, India, was one of only five recipients of the 2007 Scholar Award sponsored by IPNI. The awards of US$2500 (twenty-five hundred dollars) each are conferred to deserving graduate students in sciences relevant to plant nutrition and management of crop nutrients. Funding for the awards is provided through support of IPNI member companies.


K. Vanitha

Miss Vanitha is a M.Sc. student in Crop Physiology at TNAU, with a thesis title of "Drip Fertigation and Its Nutrio-Physiological Impact in Aerobic Rice (*Oryza sativa* L.)." Rice production and water conservation are two major factors impacting food production in India. Aerobic rice is a new concept to further decrease the water requirements in rice production, which will have major consequences for both soil and plant nutrient dynamics.

A native of Bommidi in Tamil Nadu, Miss Vanitha completed her B.Sc. degree in 2006. Her career goals are to pursue a Ph.D. in abiotic stress management of crops.

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