Partial Factor Productivity of Nitrogen in Potato

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Partial factor productivity (PFP) and agronomic efficiency (AE) of N in potato were estimated from published literature in India over the years 1968 to 2000. Results revealed that PFP had an increasing trend during this time, which can be attributed to balanced and efficient use of fertilizers in potato in contrast to other crops and the N-efficient cultivars developed over the years.

Potato has emerged as one of the most important food crops in India. There has been almost a five-fold increase in area and a nearly 16-fold increase in potato production since the independence of India. The increase in production is not only due to an increase in area, but also due to productivity, which has improved from 66 quintals/ha (1 quintal = 100 kg) during 1949-50 to 198 q/ha during 2001-02. This increase has been brought about by both higher levels of inputs and more efficient, high yielding cultivars. However, as input use to grow potato increases, there is generally a decline in its use efficiency. Unless this is countered through better genotypes and best nutrient management, there are likely to be problems of pollution as well as reduced returns for the investment. Thus, there is a need to periodically review the efficiencies of input use in different crops.

Nitrogen is the key nutrient in potato production. A low utilization efficiency with N means the nutrient is prone to leaching, volatilization, etc. To determine the efficiency of applied nutrients, Cassman et al. (1996) introduced the term PFP. The advantage of this index is that it quantifies total economic output from any particular factor/nutrient, relative to its utilization from all resources in the system, including indigenous soil nutrients and nutrients from applied inputs. Thus, the changes in PFP for N over the years can be used to indicate the sustainability of the potato production system.

The data on potato yield under different N levels were obtained from 107 published papers with experiments conducted between 1968 and 2000. Since different research workers have used different N doses, these were classified into six ranges: 20 to 60 kg, 61 to 100 kg, 101 to 140 kg, 141 to 180 kg, 181 to 220 kg, and >220 kg N/ha, besides the zero N (control). Partial factor productivity and agronomic efficiency were calculated as below:

PFP = Yf/Na - expressed in kg yield per kg of N applied
AE = (Yf-Yc)/Na - expressed in kg yield per kg N applied.

Where 'Yf' stands for yield from a N-fertilized plot, 'Yc' stands for yield in control plot, and 'Na' stands for amount of N applied in kg/ha. The PFP was also calculated separately for the last three decades (1971-80, 1981-90, and 1991-2000) and for different cultivars as well.

The overall mean tuber yield showed an increase with an increasing N level up to 220 kg N/ha during 1968-2000 (**Table 1**). Beyond 220 kg N/ha, no increase in the potato tuber yield was observed up to 1980. As for the temporal yield response, during the 1970s the response of potato to applied N was restricted up to 180 kg N/ha (**Table 1**), while during the 1980s the response was up to 220 kg N/ha, and in the 1990s the response to N exceeded 220 kg/ha.

The analysis revealed that as the applied dose of N increased, there was a decrease in PFP (**Table 1**). The overall PFP for the entire period (i.e.1968-2000) was 421 kg tubers/kg N when applied in the range of 20 to 60 kg N/ha, which declined to 130 kg tubers/kg N when applied at doses exceeding 220 kg N/ha. A similar trend was observed during the different decades. This trend reflects the law of diminishing returns – as applied N increases, the response to N decreases. This is also confirmed by AE calculations, which is the response per unit N applied (**Table 2**). The AE shows that the conversion of applied N to yield was higher at lower level of N application (20 to 60 kg/ha).

Perusal of the absolute values for PFP showed it to be higher during the 1990s compared to the 1970s and 1980s at all the levels of N application except at the lowest category (20 to 60 kg N/ha) (**Table 1**). The yield levels also showed an increase with time at any given N level implying that the crop required lesser N during the 1980s and still lesser during the 1990s to maintain the same level of yield as that in the 1970s. This is due to the introduction of high yielding and more N use efficient cultivars like Kufri Badshah and Kufri Bahar during the 1980s and Kufri Anand, Kufri Ashoka and Kufri Sutlej during

Table 1. Potato tuber yield (q/ha) and partial factor productivity (PFP) of N (kg tubers/kg N applied) in potato in India.

		Range of N levels, kg/ha					
Period	Mean	20-60	61-100	101-140	141-180	181-220	>220
1971-1980	PFP	428	277	211	158	134	111
	Tuber yield	221	226	254	265	268	270
	No. of studies	21	19	25	22	1	4
1981-1990	PFP	399	253	206	177	154	114
	Tuber yield	220	237	248	286	308	283
	No. of studies	61	43	38	62	16	20
1991-2000	PFP	409	329	235	188	155	148
	Tuber yield	220	280	294	307	318	350
	No. of studies	19	23	18	31	3	19
1968-2000	PFP	421	282	220	178	156	130
	Tuber yield	229	250	268	291	313	314
	No. of studies	109	88	86	120	21	44

Abbreviations and notes for this article:
N = nitrogen

Table 2. Agronomic efficiency (kg tubers/kg N applied) of N in potato under different N levels.

Range of N levels, kg/ha		Agronomic efficiency
20-60	Mean	135
	No. of studies	78
61-100	Mean	102
	No. of studies	58
101-140	Mean	93
	No. of studies	52
141-180	Mean	75
	No. of studies	78
181-220	Mean	71
	No. of studies	15
>220	Mean	48
	No. of studies	29

the 1990s (Anonymous, 2001).

The varietal composition in the experiments conducted during the different decades showed that during the 1970s early maturing Kufri Chandramukhi and medium maturing Kufri Jyoti cultivars were tested in 67% of the experiments, while during the 1980s and 1990s, these two cultivars were tested in 62% and 42% of the experiments, respectively. These two cultivars had lower yield potential and PFP (**Table 3**) than the other major potato cultivars tested in the experiments which were of medium (Kufri Jawahar and Kufri Bahar) and late (Kufri Badshah and Kufri Sindhuri) maturity, and comparatively higher yield levels and PFP than Kufri Chandramukhi and Kufri Jyoti. The proportion of these high yielding and medium to late maturing potato cultivars in the experiments increased from 23% during the 1980s to 42% during the 1990s. Therefore, PFP has shown an increasing trend with time at similar N levels and is a reflection of the varietal behaviour.

Comparison of the PFP of different cultivars (**Table 3**) showed large differences. However, all the cultivars showed a decreasing trend with increasing N levels. As regards to differences among cultivars, Kufri Ashoka had the highest PFP (486.5) at 20 to 60 kg N/ha while Kufri Jyoti had the lowest PFP (392) at this level. Though the PFP decreased with increase in N level applied, the rate of decrease varied with cultivar.

Under Indian conditions, the economic optimum dose of N is usually in the range of 180 to 220 kg N/ha and at this dose Kufri Badshah had the highest PFP (202). Kufri Sindhuri, Kufri Jawahar, and Kufri Ashoka were also not far behind at this level, while Kufri Chandramukhi and Kufri Jyoti were far behind (142 and 140, respectively). Even at N levels >220 kg/ha, Kufri Badshah, Kufri Sindhuri, Kufri Jawahar, and Kufri Ashoka had higher PFP than Kufri Chandramukhi and Kufri Jyoti at 180 to 220 kg N/ha. Difference in response to N among cultivars has also been reported by Govindakrishnan et al. (1999). They found that Kufri Ashoka required only one-third of the N dose applied to Kufri Chandramukhi to attain the same yield level. Trehan (2004) has also reported that Kufri Jawahar, Kufri Pukhraj, Kufri Sindhuri, Kufri Bahar, and Kufri Sutlej are more N efficient than Kufri Jyoti. Thus, potato breeders have developed higher yielding cultivars over time so as to fully exploit the natural climatic resources, and in turn increasing the cultivar's N use efficiency. Hence, the widespread adoption of these cultivars by farmers would lead to greater N use efficiency.

This study revealed that high yielding potato cultivars released in India from time to time were more N use efficient than earlier varieties. Thus, the goal of realizing more and more of the potential yield would not adversely affect the efficiency of N use. The study also brings out the usefulness of the PFP concept in evaluating the implications of technological developments in any crop. BC

Table 3. Partial factor productivity of N (kg tubers/kg N applied) and yield (q/ha) of some popular potato cultivars.

		Range of N levels, kg/ha					
Cultivar	Mean	20-60	61-100	101-140	141-180	181-220	>220
K. Chandramukhi	PFP	414	261	207	165	142	112
	Tuber yield	217	233	252	268	284	276
	No. of studies	39	32	27	42	9	15
K. Jyoti	PFP	392	257	220	173	140	107
	Tuber yield	215	231	264	291	279	261
	No. of studies	26	15	22	24	4	5
K. Sindhuri	PFP	451	254	230	185	195	135
	Tuber yield	269	233	277	308	390	316
	No. of studies	10	11	12	11	2	4
K. Bahar	PFP	417	374	296	281	197	157
	Tuber yield	231	310	281	301	393	357
	No. of studies	8	7	5	12	1	4
K. Ashoka	PFP	487	303	248	202	199	166
	Tuber yield	212	275	319	329	398	393
	No. of studies	2	3	2	3	1	2
K. Badshah	PFP	444	387	229	207	202	152
	Tuber yield	267	314	275	336	404	356
	No. of studies	5	5	4	9	1	6
K. Jawahar	PFP	428	372	233	176	-	140
	Tuber yield	223	335	294	317	-	350
	No. of studies	3	1	3	3	-	3

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References

Anonymous. 2001. Annual Report 2000-2001, Central Potato Research Institute, Shimla, India.

Cassman, K.G., et al. 1996. Field Crops Res. 47:1-12.

Govindakrishnan, P.M., et al. 1999. Indian. J. Agril. Sci. 69:350-354.

Trehan, S.P. 2004. Annual Report 2003-2004, Central Potato Research Institute, Shimla, India.