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# Precising nitrogen requirement of table potato (*Solanum tuberosum*) cultivars for different growth periods

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## ABSTRACT

A field experiment was conducted for 3 consecutive seasons (2004–2007) at Modipuram to optimize the growth period-specific N requirements of table potato cultivars 'Kufri Pukhraj' and 'Kufri Anand' in sandy loam soils. Growth, yield and economic parameters of both the genotypes were evaluated for their response to 4 N levels (0, 90, 180 and 270 kg/ha) and 2 growth periods (75 and 110 days). The crop-growth traits and tuber number were not influenced due to harvest stages; however, tuber yield was 31.3% higher with extended duration (110 days). N application had favourable effect on growth parameters, but showed quadratic response to marketable and total tuber number/ha. Likewise, it showed steady increase in marketable and total tuber yields. Agronomic N-use efficiency (118.6–66.0 kg tubers/kg N applied) decreased linearly with increase in N levels. 'Kufri Anand' recorded better growth than 'Kufri Pukhraj', but tuber number and yield as well as economic variables were statistically similar in both the cultivars. Net income and benefit : cost (B: C) ratio indicated that both the cultivars should be fertilized with 270 kg N/ha when harvested at 110 days, but 180 kg N/ha is sufficient when harvested at 75 days.

***Key words:*** Growth period, Nitrogen-use efficiency, Potato, Tuber yield, N uptake,



Nitrate contamination of ground-water is a major environmental concern associated with potato (*Solanum tubersorum* L.) production, and considerable efforts have been made to reduce N losses through improved fertilizer management practices (Zebarth and Rosen, 2007). One approach to reduce N losses is to increase the efficiency of N utilization by précising the N rate as per growth period given to the potato crop by the growers depending upon the cultivar used (Zebarth *et al.*, 2008). The pattern of land use in the past 2 decades clearly indicates that the net area sown as well as average land holdings are shrinking consistently due to high pressure of industrialization, urbanization and population. Though a majority of table potatoes are being harvested at full maturity, potato growers are favouring short-duration crop to adjust late-sown wheat crop in quick succession to achieve better farm profits. However, presently no separate recommendation of nutrient management exists for short and long-duration potato crops, where the growing period differs markedly by 30–35 days. Among the major nutrients, the role of nitrogen is well documented vis-à-vis tuber development, yield and quality (Ojala *et al*., 1990). Its inadequate fertilization leads to poor crop growth and yield, whereas its excessive application leads to delayed tuberization, poor quality, excessive nitrate leaching and occasionally reduction in tuber yield (Harris, 1992). Since potato cultivars differ in their growth behaviour and yield potential (Love *et al*., 2005), it is pertinent to evaluate each genotype for its attributes. Therefore, the present investigation was taken up to determine the N requirement specific for the growth period of popular varieties 'Kufri Pukhraj' and 'Kufri Anand' for better productivity, net income and efficient N utilization under short or prolonged crop duration.

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## MATERIALS AND METHODS

A field experiment was conducted for 3 consecutive seasons during 2004–2007 at Modipuram Campus of Central Potato Research Institute, ($29^0$ '4 'N, $77^{0'}$ 46 'E, 237 m above mean sea level) in split-split-plot design with 3 replications, where N dose (0, 90, 180 and 270 kg/ha) were assigned to sub-subplots, and cultivars ('Kufri Pukhraj' and 'Kufri Anand') to sub-plots, whereas growth period (75 and 110 days) was kept in main plots. The soil was deep, well drained and sandy loam (Typic Ustochrept). Chemical analysis of the soil (top 15 cm) showed neutral pH (6.83), low organic carbon (0.28%) and $KMNO_4$ extractable N (152.4 kg/ha), high Olsen's (0.5 M $NaHCO_3$-extractable) P (83.3 kg/ha) and medium exchangeable K (156.8 kg/ha). Treatment-wise half the N, and full amounts of P (34.9 kg/ha) and K (103.7 kg/ha) were applied at the

time of planting; whereas the remaining half N was top dressed at 25 days after planting, while hilling. The source of N was calcium ammonium nitrate at planting and urea at hilling, P and K were given through single superphosphate and muriate of potash respectively. The experimental crop was planted on 27, 19 and 30 October during 2004, 2005 and 2006, respectively. Well-sprouted seed tubers (50-60 g seed weight, 40-45 mm seed size) were planted at a spacing of 60 × 20 cm in plots of 7.2 × 3 m, and the crop was raised under assured irrigation using furrow method. Dehaulming was done manually at 75 and 110 days after planting (DAP) as per the treatments and harvesting was done immediately at first harvest date but 2 weeks later at second date of harvest after skin setting.

The plant stand was monitored up to 30 days, whereas observations on growth parameters such as plant height, stem number and compound leaf number were recorded from five randomly selected potato plants from each plot at 50 DAP. Leaf-area index (LAI) was recorded with the help of Ceptometer (AccuPAR model LP-80) at 50 DAP. Total and marketable-grade (> 25 g) tuber yield and number were recorded at harvest from the whole produce of the plot. Further, biomass yield was calculated by adding the weight of fresh vines at the time of dehaulming to the tuber yield. Five tubers were chopped into fine pieces and 50 g sample was taken to determine the dry matter, tuber-N content and tuber-N uptake. Total returns were calculated by taking the price of the potato tubers as Rs 5,000/t for produce of the first harvest (75 days) and Rs 3,000/t for the produce of the second harvest at full maturity.



## RESULTS AND DISCUSSION

### *Plant emergence and growth*

Plant emergence was recorded till 30 days in both the cultivars and final plant stand was more than 98 % in all the treatments, indicating that it did not interfere in the evaluation of growth parameters and variety-specific response to different N levels (Table 1). The crop-growth traits such as stem number, plant height, number of compound leaves and LAI were not significantly affected due to different growth periods, because the observations on these parameters were taken before the harvest of the first date. The above mentioned growth parameters responded positively to N fertilization; however, the increase in stem number was statistically non-significant. The plant height increased with the increase in N dose up to 180 kg N/ha, whereas significant increase in number of leaves/plant was restricted only to 90 kg N/ha. Higher N dose positively affected the plant-growth parameters. Kumar *et al*. (2007b) reported similar results for Chipsona cultivars under similar conditions. 'Kufri Anand' showed significantly better growth characteristics than 'Kufri Pukhraj' (Table 1). The interaction effects were not significant indicating that both the cultivars responded alike to increased doses of N.

### *Tuber number and yield*

The total and marketable grade of tubers were not influenced by different growth periods, but the response to N application was quadratic for marketable-grade tuber number ($R^2$=0.997) and total tuber number/ha ($R^2$ = 0.998). Marketable tuber number/ha increased with increase in N dose up to 180 kg N, but significant increase in number of total tubers was only up to 90 kg N/ha (Table 1). However, Morena *et al*. (1994) and Belanger *et al*. (2002) reported both positive and negative effects of N application on tuber number/plant. Marketable and total tuber number was statistically at par for both the cultivars.

Marketable and total tuber yields were significantly higher when potato crop was harvested at full maturity (110 days) than early harvest (75 days). However, fresh biomass yield (FBY) did not differ significantly due to different growth periods, but haulm dry weight (HDW) was significantly lower when the crop duration was 110 days than 75 days. The reason is that senescence had already taken place especially in the plots receiving low level of nitrogen where dehaulming was done at 110 days. The main effect of N application led to quadratic response for marketable tuber yield ($R^2$=0.99), total tuber yield ($R^2$=0.99), FBY ($R^2$=0.99) and HDW ($R^2$=0.99). Significant response in these variables was also recorded up to 270 kg N/ha (Table 1). The increase in total tuber yield due to higher N application was owing to higher crop growth and tuber weight/plant. Higher crop-growth rate with higher N application could have led to greater synthesis and translocation of photosynthates to the tubers by the foliage. Belanger *et al*. (2000) also reported increase in potato tuber and fresh biomass yield by N fertilization.

Interaction between growth period × nitrogen rate was also found significant both for marketable and total tuber yield. Significant response of N was observed only up to 180 kg N/ha with early harvest (75 days), and up to 270 kg N/ha when potato crop was harvested at full maturity (110 days) for both the variables (Fig. 1). Economic optimum dose of N for total tuber yield was 263 kg/ha for 75 days growth period and 273 kg/ha for 110 days crop duration. Total tuber yield and the response expected at this dose (EOD) were 33.66 t/ha and 56.8 kg tuber/kg N for 75 days crop, and 44.58 t/ ha and 85.7 kg tuber/kg N for 110 days crop duration, respectively.

Cultivar 'Kufri Pukhraj' yielded at par with 'Kufri Anand' but the later variety showed significantly higher FBY and HDW than the former (Table 1). It shows that both the cultivars behaved similarly for marketable and

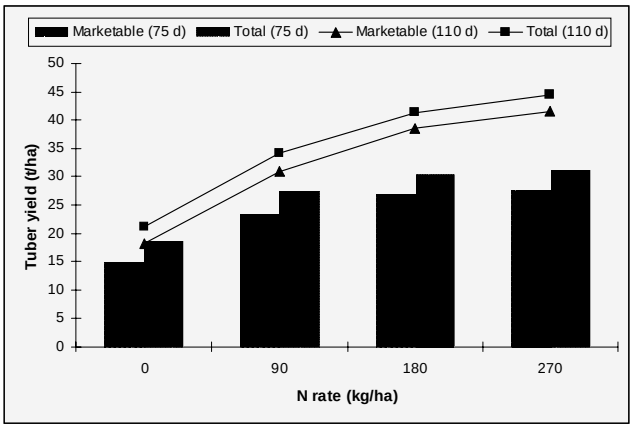


**Fig. 1.** Interaction between growth period and N rate for marketable and total tuber yield (pooled data of 3 years)

total tuber yield during all the years of study. In contrast to these findings, Kumar *et al.* (2007a) reported significant difference in total tuber yield of cvs 'Kufri Chipsona 1' and 'Kufri Chipsona 2' under Meerut conditions.

### *Nitrogen uptake and use efficiency*

The tuber N content was not significant at both the harvest dates, but the N uptake by the tubers increased significantly when the crop was harvested at full maturity (73.1 kg/ha) in comparison with that at 75 days growth period (57.5 kg/ha). This was due to the fact that when the crop was harvested at 110 days it gave more tuber yield than that when it was harvested at 75 days. The tuber-N content and uptake increased significantly by increasing the N rate from 0 to 270 kg N/ha (Table 2), because higher N rate resulted in higher tuber yield. Both these values were significantly higher in 'Kufri Pukhraj' than in 'Kufri Anand'.

Agronomic-use efficiency ($AE_N$) was higher when the crop was harvested at full maturity (113.6 kg tubers/kg N) compared with that at 75 DAP (68.4 kg tubers/kg N). $AE_N$ decreased linearly with increase in N level (Table 2) and was maximum (118.6 kg tubers/kg N) at 90 kg N /ha, which decreased to lowest (66.0 kg tubers/kg N) at highest N dose of 270 kg/ha. It decreased linearly with every incremental dose of N, confirming the findings of Love *et al*., (2005). With respect to cultivars, 'Kufri Pukhraj' had significantly higher $AE_N$ than 'Kufri Anand'. Kumar *et al.* (2006) also reported higher N efficiency of potato 'Kufri Pukhraj' under Bihar conditions.

### *Economics*

Analysis of variance showed significant effect of growth period and N rates for net income and benefit : cost (B: C) ratio. Net income and B: C ratio were higher to a level of significance when the crop was harvested earlier at 75 DAP than at 110 DAP (Table 2), due to its premium price in early season. The response of N rate was quadratic for net income ($R^2$=0.99) and B : C ratio ($R^2$= 0.99), and the net income continued to increase till the highest N dose tested in the study (270 kg/ha). The B:C ratio increased significantly till 180 kg N /ha, and thereafter further addition of N resulted in non-significant increase of B: C ratio (Table 2). Higher economic returns



**Table 1.** Effect of growth period, cultivar and nitrogen rate on growth, tuber number and yield (t/ha) of potato crop (pooled data of 3 years)

| Treatment | Emergence (%) | Stems no./plant | Plant height (cm) | Compound leaves no./plant | Leaf area index | Tuber no.(× $10^3$/ha) Marketable (> 25 g) | Tuber no.(× $10^3$/ha) Total | Tuber yield Marketable (> 25 g) | Tuber yield Total | Fresh biomass yield | Haulm dry weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Growth period* (*days after planting DAP*) | | | | | | | | | | | |
| 75 DAP [a] | 99.0 | 4.39 | 37.5 | 58.3 | 1.77 | 427.4 | 703.9 | 23.15 | 26.85 | 43.66 | 1.57 |
| 110 DAP | 98.9 | 4.14 | 36.9 | 55.6 | 1.48 | 457.1 | 646.9 | 32.35 | 35.26 | 42.34 | 0.96 |
| SEm± | 0.13 | 0.06 | 0.28 | 1.10 | 0.09 | 6.50 | 14.1 | 0.52 | 0.42 | 0.63 | 0.07 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | 3.12 | 2.52 | NS | 0.41 |
| *Cultivars* | | | | | | | | | | | |
| 'Kufri Pukhraj' | 98.8 | 4.10 | 31.6 | 53.2 | 1.38 | 439.0 | 674.5 | 27.67 | 31.18 | 40.63 | 0.99 |
| 'Kufri Anand' | 99.1 | 4.43 | 42.9 | 60.8 | 1.87 | 445.5 | 676.3 | 27.83 | 30.92 | 45.37 | 1.54 |
| SEm± | 0.10 | 0.07 | 0.78 | 1.52 | 0.09 | 6.57 | 10.8 | 0.38 | 0.43 | 0.74 | 0.04 |
| CD (P=0.05) | NS | 0.30 | 3.06 | 5.98 | 0.38 | NS | NS | NS | NS | 2.92 | 0.14 |
| *N rate (kg/ha)* | | | | | | | | | | | |
| 0 | 99.3 | 4.08 | 27.6 | 47.8 | 1.19 | 348.4 | 593.5 | 16.53 | 19.95 | 24.90 | 0.59 |
| 90 | 98.8 | 4.27 | 37.5 | 57.4 | 1.64 | 455.8 | 689.4 | 27.17 | 30.62 | 41.10 | 1.09 |
| 180 | 99.0 | 4.33 | 41.2 | 60.5 | 1.72 | 488.6 | 718.0 | 32.75 | 35.86 | 50.40 | 1.52 |
| 270 | 98.8 | 4.39 | 42.6 | 62.4 | 1.96 | 475.9 | 700.6 | 34.54 | 37.78 | 55.70 | 1.88 |
| SEm± | 0.11 | 0.14 | 0.74 | 1.70 | 0.14 | 8.56 | 11.2 | 0.55 | 0.48 | 0.76 | 0.06 |
| CD (P=0.05) | NS | NS | 2.16 | 4.96 | 0.43 | 25.0 | 32.6 | 1.61 | 1.40 | 2.23 | 0.20 |

**Table 2.** Effect of growth period, cultivar and nitrogen rate on tuber N content, uptake, agronomic NUE and economics of potato (pooled data of 3 years)

| Treatment | Tuber N content (%) | Tuber N uptake (kg/ha) | Agronomic NUE (kg tubers/kg N) | Cost of cultivation (x $10^3$ Rs/ha) | Net income (x $10^3$ Rs/ha) | B : C ratio |
|---|---|---|---|---|---|---|
| *Growth period (days)* | | | | | | |
| 75 DAP [a] | 1.26 | 57.5 | 68.4 | 57.43 | 76.82 | 2.32 |
| 110 DAP | 1.22 | 73.1 | 113.6 | 62.43 | 43.36 | 1.68 |
| SEm± | 0.01 | 0.95 | | | 1.75 | 0.03 |
| CD (P=0.05) | NS | 5.71 | | | 10.55 | 0.18 |
| *Cultivars* | | | | | | |
| 'Kufri Pukhraj' | 1.30 | 68.9 | 96.4 | 59.93 | 61.16 | 2.02 |
| 'Kufri Anand' | 1.18 | 62.0 | 85.7 | 59.93 | 59.03 | 1.98 |
| SEm± | 0.03 | 0.65 | | | 2.14 | 0.04 |
| CD (P=0.05) | 0.11 | 2.52 | | | NS | NS |
| *Nitrogen rate (kg/ ha)* | | | | | | |
| 0 | 1.02 | 34.6 | | 57.50 | 21.08 | 1.38 |
| 90 | 1.18 | 61.4 | 118.6 | 59.12 | 59.99 | 2.03 |
| 180 | 1.29 | 78.6 | 88.3 | 60.74 | 77.15 | 2.28 |
| 270 | 1.44 | 92.5 | 66.0 | 62.36 | 82.15 | 2.33 |
| SEm± | 0.03 | 1.05 | | | 1.71 | 0.03 |
| CD (P=0.05) | 0.09 | 3.06 | | | 5.00 | 0.08 |



and B: C ratio were obtained at higher N doses because increased marketable and total tuber yield realized at higher N application. This study also demonstrated that the profitability of cultivation was similar for both the cultivars. These results are in partial agreement with the findings of Love *et al*. (2005), who reported that net returns were relatively low without N, increased to a highest level at some intermediate N rate, and then decreased again at the highest N rates. Across the growth period and N rate both the cultivars showed similar net income and B : C ratio.

It was concluded that cultivation of 'Kufri Pukhraj' and 'Kufri Anand' is equally profitable for the potato growers and should be supplied with 180 kg N/ha when harvested at early date (75 DAP) to raise wheat crop in the cropping system. But, for harvesting at full maturity (110 DAP) these cultivars should be fertilized with 270 kg N/ha.

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