Indian Journal of Agronomy **54**(1): 63–68 (March 2009)

Efficacy of potato (*Solanum tuberosum*) cultivars under varying levels of nitrogen and growth duration in eastern Indo-Gangetic plains

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Received: July 2008

ABSTRACT

A field study was conducted during winter seasons of 2004-05 and 2005-06 at Patna with three potato (*Solanum tuberosum* L.) cultivars namely 'Kufri Giriraj', 'Kufri Pukhraj' and 'Kufri Jyoti', four nitrogen levels (0, 80, 160 and 240 kg/ha) and two growth durations (75 and 100 days) to work out the optimum level of N, efficiency and eco-friendliness. 'Kufri Pukhraj' gave the highest yield (28.7 t/ha) and N uptake (105.8 kg N/ha) and was most efficient in utilizing N from soil and applied N (uptake efficiency 0.54 kg/kg N). The increase in growth durations improved the tuber yield at higher N levels (160 and 240 kg N/ha). The highest increase in agronomic and uptake efficiencies with increasing growth duration was recorded at 160 kg N/ha (42 for agronomic and 0.1 kg/kg N for uptake efficiency). Yield at economic optimum N was normally higher in longer growth durations with higher nitrogen requirement (9.7 and 7.6 t/ha at 81 and 37 kg/ha, higher N for 'Kufri Giriraj' and 'Kufri Jyoti', respectively), however, for 'Kufri Pukhraj' economic optimum N dose decreased by 22%. Eco-friendliness with respect to nitrogen utilization both in absolute and relative indices was maximum in 'Kufri Pukhraj' followed by 'Kufri Giriraj'. Net return and benefit:cost ratio was higher when longer growth duration was given, however, when crop is to be harvested early 'Kufri Pukhraj' is the best option.

Key words: Biocoenosis, Economic viability, Efficiency, Potatoes, Nitrogen, Yields

Potato (*Solanum tuberosum* L.) is a unique crop and can be harvested early or late depending upon market price and requirement of field for subsequent crop. Besides, being highly exhaustive and responsive to N, due to its high rate of production per unit area and time, it plays important role in solving hunger problem by increasing the productivity and efficiency of the resource in the production system. Therefore, potato can be fitted suitably into different cropping systems to increase the efficiency of time and resources (Sharma *et al*., 2006). Potato cultivars differ in their yield potential, response to nitrogen and bulking rate even if they are of same maturity group. The length of growth duration and efficiency of applied nutrient particularly N will determine the amount to be supplied to the crop and its effect on environment (Trehan, 2003, 2005 and 2006). Eastern Indo-Gangatic plains comprising of parts of eastern Uttar Pradesh, Bihar, West Bengal, Assam and Orissa accounts for about half of the potato area of the country. The recommendation of 180 kg N/ha of this region is based on full maturity of some old cultivars, needs improvement for the efficient cultivation of new early bulking varieties particularly when grown for shorter growth duration to fit into different cropping systems. Two new cultivars *viz.*, 'Kufri Pukhraj' and 'Kufri Giriraj' having similar maturity with that of 'Kufri Jyoti' (about 100 days) is taken in the study to examine how they perform when growth duration is reduced to fit into different cropping systems. Keeping this in view, a field experiment was conducted at Patna to find out optimum nitrogen requirement, agronomic and uptake efficiencies and eco-friendliness of these varieties with respect to N utilization from applied N through fertilizer at two growth durations.

MATERIALS AND METHODS

A field experiment was conducted during the winter of 2004-05 and 2005-06 at Central Potato Research Station, Patna (25° 35'N and 85° 04'E). This place has subtropical climate with hot summer from late March to early June, monsoon season from late June to late September and mild winter in the potato growing period from November to February with annual rainfall around 1,000 mm. The minimum and maximum temperature in potato season during

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2004-05 ranged from 5.8 to 19.4 and 17.6 to 31.2 with mean values 12.3 and 25.1°C, respectively. During 2005-06, the minimum and maximum temperature ranged from 4.0 to 20.6 and 18.9 to 35.1 with mean values of 11.0 and 26.5°C, respectively. There was about 43.8 mm rainfall during January and February 2005 with some cloudy days and there was no rain during the crop season of 2005-06.

The soil of the experimental field was clay loam in texture with organic carbon 0.41%, pH 6.59, available N, P and K was 206.6, 30.51 and 323 kg/ha, respectively. Treatments included all possible combinations of three varieties with similar maturity (100 days) *viz.*, 'Kufri Jyoti', 'Kufri Giriraj' and 'Kufri Pukhraj', four nitrogen levels (0, 80, 160 and 240 kg/ha) and two growth durations (75 and 100 days) in three replications with factorial RBD. Thus, there were 24 treatments in plot size of 4.8 x 4.0 m each with plant spacing of 60 x 20 cm. Uniform size of well sprouted seed tubers of 30-40 g were planted in the first week of November during both the years. Half of N through urea was applied as a side-band along with a uniform dose of 44 kg P/ha through single super phosphate and 125 kg K/ha through muriate of potash at planting while the other half dose of N through urea was applied at 30 days after planting during earthing-up. All recommended package of practices including plant-protection measures were followed except nitrogen levels and harvesting, which was done as per the treatments.

The economic optimum nitrogen for both growth durations was calculated using the method given by Sharma and Sharma (1988) taking nitrogen price (q) at Rs 10.38/kg N and potato price (p) at Rs 2500/t (*i.e.* optimum nitrogen level = $(^{q}/_{p}-b)/2c$, where b and c are co-efficient from quadratic response curve $Y = a + bx + cx^2$). The total variable cost (including cost of seeds, fertilizers, irrigations, agro-chemicals and labour wages), net return, and benefit: cost ratios were worked out at optimum N level for 2 growth durations for all 3 varieties. Nitrogen uptake and agronomic efficiencies were calculated by taking difference from control plots. Eco-friendly indices were calculated as per method given by Govindakrishnan *et al*. (1999). Absolute indices measure the utilization of N by a genotype from the soil source, in other words it gives fertilizer N equivalent (kg N/ha) due to the increase in yield in absence of N of a genotype over the standard variety, *i.e.*, dose of N needed for getting yield in standard variety equal to yield of a genotype without N. Relative indices measure the eco-friendliness of a genotype relative to a standard cultivar. Indirectly, it also shows the combined utilization of N from soil and fertilizer sources. It is a measurement of quantity of less N (%) needed by a genotype to produce yield equal to maximum yield of a standard cultivar.

RESULTS AND DISCUSSION

Yield of different grade tubers

Increasing growth duration increased the yield of medium - large - sized and total tubers yield (Table 1). It revealed that increasing growth duration increased the tuber yield mainly by increasing tuber size. The graded and total tubers yield of 'Kufri Pukhraj' was significantly higher than 'Kufri Giriraj' and 'Kufri Jyoti'. Trehan (2005) reported similar observation from north-western plains. Response to nitrogen decreased with increasing N level, however, it was significant up to 240 kg N/ha. Tuber yield was higher during second year (2005-06) mainly due to production of large-sized tubers. This was possibly due to poor weather conditions during bulking and maturity period in the first year which did not allow to develop large-sized tubers while during second year due to favourable weather conditions, part of the medium-and small-sized tubers developed into larger size resulted in overall yield increase.

Increasing growth duration compensated for lower N level and same or higher yields were obtained at 100 days duration with 80 kg/ha less N than that obtained at 75 days with 160 or 240 kg N/ha (Table 2). This was because at longer growth duration, the applied N was utilized more efficiently. The increase in yield with increasing N level was higher when the growth duration was more. This further indicates that at longer growth duration, N was limiting to yield. The interaction of N level and variety was significant and 'Kufri Pukhraj' yielded more than other varieties at all level of N. When 80 kg N was applied, yield of 'Kufri Pukhraj' increased by 76% whereas, yield increase of 'Kufri Giriraj' and 'Kufri Jyoti' was 69 and 61%, respectively over control. Higher response of 'Kufri Pukhraj' at lower N level has also been reported by Kumar *et al.* (2006) and Trehan (2005). Even though the varieties were having similar maturity (100 days), yield increase as a result of increase in growth duration varied at different N levels in three varieties. This increase was higher in 'Kufri Pukhraj' at 80 kg N/ha *i.e.,* 5.75 t/ha (22%) but at higher N levels per cent increase was more in 'Kufri Giriraj' or 'Kufri Jyoti'. This was because 'Kufri Pukhraj' showed capacity to bulk (rate to increase tuber weight) faster and to reach its' potential in shorter period when N was not limiting. On contrary, the other two varieties were slow bulkers and showed more response to increased growth duration at higher N levels.

Nitrogen uptake

Total N uptake and the N uptake in tubers increased significantly with increase in growth duration, whereas, N uptake in haulms decreased significantly with increasing growth duration from 75 to 100 days (Table 3). Varieties

Table 1. Yield of different grades tubers as influenced by growth durations, varieties and N levels (t/ha)

Treatments	Tuber grades									Total		
	>75 g			25-75 g			<25 g			2004-05	2005-06	Pooled
	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled			
Growth duration (days)												
75	3.32	7.39	5.35	14.69	14.31	14.50	2.54	2.13	2.34	20.55	23.83	22.19
100	5.96	10.71	8.34	16.21	15.26	15.74	2.58	2.23	2.40	24.75	28.20	26.47
SEm±	0.30	0.35	0.23	0.33	0.31	0.21	0.14	0.08	0.08	0.38	0.35	0.28
CD (P=0.05)	0.86	0.99	0.66	0.94	0.89	0.60	NS	NS	NS	1.10	0.99	0.81
Variety												
'Kufri Giriraj'	4.72	9.44	7.08	13.76	14.84	14.30	2.30	1.86	2.08	20.78	26.14	23.46
'Kufri Pukhraj'	5.09	11.39	8.24	18.95	16.72	17.84	3.12	2.14	2.63	27.16	30.25	28.71
'Kufri Jyoti'	4.11	6.31	5.21	13.64	12.80	13.22	2.26	2.53	2.40	20.01	21.65	20.83
SEm±	0.37	0.42	0.28	0.40	0.38	0.26	0.17	0.10	0.10	0.47	0.42	0.35
CD (P=0.05)	NS	1.21	0.81	1.15	1.09	0.73	0.49	0.28	0.27	1.34	1.21	0.99
N Level (kg/ha)												
0	0.96	3.10	2.03	8.86	10.39	9.63	2.37	2.23	2.30	12.19	15.72	13.96
80	3.82	8.89	6.36	15.70	14.31	15.01	2.58	1.95	2.27	22.12	25.15	23.64
160	5.69	11.48	8.59	17.67	16.66	17.17	2.76	2.35	2.55	26.12	30.49	28.31
240	8.08	12.73	10.40	19.58	17.78	18.68	2.53	2.18	2.35	30.19	32.69	31.44
SEm±	0.43	0.49	0.33	0.46	0.44	0.29	0.20	0.11	0.10	0.54	0.49	0.40
CD (P=0.05)	1.22	1.39	0.93	1.33	1.26	0.84	NS	NS	NS	1.55	1.40	1.14

Table 2. Interaction effect of N levels with growth durations and varieties on potato yield (t/ha)*

Treatments	N level (kg/ha)			
	0	80	160	240
Growth duration (days)				
75	13.85	22.14	24.84	27.94
100	14.07	25.12	31.77	34.94
SEm±		0.57		
CD (P=0.05)		1.62		
Variety				
'Kufri Giriraj'	13.23	22.39	27.57	30.67
'Kufri Pukhraj'	16.64	29.21	32.66	36.31
'Kufri Jyoti'	12.00	19.29	24.69	27.34
SEm±		0.69		
CD (P=0.05)		1.98		

*On the basis of pooled data of two years

Table 3. N uptake (kg/ha) in potato haulms and tubers as influenced by growth durations, varieties and N levels

Treatments	Haulms	Tubers	Total uptake
Growth duration (days)			
75	33.07	60.27	93.34
100	25.70	73.74	99.44
SEm±	1.02	1.11	1.66
CD (P=0.05)	2.91	3.16	4.74
Varieties			
'Kufri Giriraj'	27.00	67.09	94.09
'Kufri Pukhraj'	30.60	75.20	105.80
'Kufri Jyoti'	30.55	58.72	89.27
SEm±	1.25	1.36	2.03
CD (P=0.05)	3.56	3.87	5.80
N level (kg/ha)			
0	8.43	30.79	39.22
80	23.76	59.46	83.22
160	37.65	81.13	118.77
240	47.70	96.63	144.33
SEm±	1.44	1.57	2.35
CD (P=0.05)	4.11	4.47	6.70

also differed significantly in N uptake with higher uptake in 'Kufri Pukhraj' both in tubers and haulms. This was mainly due to higher production of dry matter rather than N content. This also indicated the better efficiency of variety 'Kufri Pukhraj' in utilizing soil and applied N. With every increment of 80 kg N/ha, the increase in total N uptake was 44.0, 35.6 and 25.6 kg/ha, respectively. It indicates that increasing dose of N, higher proportion of it was lost to the environment. With increasing growth duration, decrease in haulms N uptake (12%) and increase in tuber N uptake (16%) was the least in 'Kufri Pukhraj' (Table 4). There was a reduction of 8.5 and 9.8 kg N/ha in haulms of 'Kufri Giriraj' and 'Kufri Jyoti', respectively, when growth duration was increased by 25 days, whereas, in 'Kufri Pukhraj' the decrease was only 3.8 kg N/ha. This indicates that the foliar N in 'Kufri Giriraj' and 'Kufri Jyoti' was mobilized towards tubers more than 'Kufri Pukhraj'. It further indicates that if the crop is harvested early, the haulms would be more suitable to act as green manure to succeeding crop due to its higher N content. Interaction of N levels and growth duration was significant

on N uptake and effect of increased growth duration was observed only above 80 kg N/ha, mainly because after 75 days of growth, crop started to suffer N stress in plots where low N doses were applied and possibly little or no applied N was available for uptake.

Agronomic and uptake efficiency

Agronomic efficiency increased with increasing growth duration in all three cultivars and at all N levels due to increase in tuber yield (Table 5). With increase in growth duration from 75 to 100 days, there was a mean increase of 35 kg in tuber yield/kg of N applied. The maximum increase was observed in 'Kufri Pukhraj' which produced about 54 kg more tubers/kg of applied N in its last 25 days of crop growth followed by 'Kufri Jyoti' (30 kg) and 'Kufri Giriraj'(18 kg), it means that 'Kufri Pukhraj' could utilize soil N to convert into yield in a better way than other 2 varieties when growth duration is increased. In general, increasing N level decreased the agronomic efficiency at both growth durations in all cultivars. However, at 160 kg N increasing growth duration increased the efficiency maximum (42 kg tubers/kg applied N). 'Kufri Pukhraj' was most efficient at all N levels, however, the differences in efficiency with other two varieties were wider at longer growth duration and lower N level. This means that when longer growing period is available, this variety was able to utilize even the lower applied N more efficiently as compared to other two varieties. This was also possibly due to efficient utilization of soil N with increased duration (Trehan, 2003).

N uptake efficiency decreased with increasing N level and increased with growth duration (Table 5). 'Kufri Pukhraj' was most efficient followed by 'Kufri Giriraj' and 'Kufri Jyoti' at all N levels and during both growth durations. Increasing growth duration increased uptake efficiency, which was maximum in 'Kufri Pukhraj'. It shows that this variety was able to take N from soil and applied source at N stress level when other varieties could not. The effect of growth duration in increasing uptake efficiency was maximum at 160 kg N/ha. It means at lower N application (*i.e.* at 80 kg/ha), after 75 days, crop was not able to increase uptake as there was not enough N available in the soil. On the other hand, at higher N level (*i.e.* at 240 kg/ha), proportion of N towards loss increased, which is also corroborated from uptake data.

Optimum yield and N requirement

Pooled yield data of two years fitted well in quadratic

Table 4. Interaction effect of growth duration with variety and N level on N uptake (kg/ha)

Treatments	Tubers		Haulms		Total	
	75 days	100 days	75 days	100 days	75 days	100 days
Variety						
'Kufri Giriraj'	59.44	74.73	31.26	22.74	90.71	97.47
'Kufri Pukhraj'	69.67	80.73	32.49	28.70	102.16	109.43
'Kufri Jyoti'	51.68	65.75	35.46	25.65	87.14	91.41
SEm±	1.92		1.76		2.87	
CD (P=0.05	5.48		5.03		8.21	
N Level (kg/ha)						
0	30.73	31.45	10.04	6.82	40.18	38.27
80	56.85	62.06	26.97	20.56	83.82	82.62
160	71.54	90.71	40.55	34.74	112.10	125.45
240	82.54	110.73	54.72	40.68	137.26	151.40
SEm±	2.21		2.03		3.32	
CD (P=0.05)	6.33		5.81		9.48	

Table 5. Agronomic (kg tubers/kg N) and uptake efficiencies (kg/kg N) of different varieties at growth durations and varying N levels (kg/ha)

Treatments	80 N	160 N	240 N	Mean	80 N	160 N	240 N	Mean
Variety								
'Kufri Giriraj'	114.5	89.6	72.7	92.0	0.54	0.47	0.45	0.49
'Kufri Pukhraj'	157.1	100.1	82.0	113.0	0.61	0.56	0.45	0.54
'Kufri Jyoti'	91.1	79.3	63.9	77.0	0.51	0.47	0.42	0.44
Growth duration (days)								
75	103.6	68.7	58.7	77.0	0.55	0.45	0.40	0.47
100	138.2	110.7	87.0	112.0	0.55	0.55	0.47	0.52
Mean	120.9	89.7	72.8		0.55	0.50	0.44	

equation ($Y = a + bx + cx^2$) with R^2 ranging from 0.974 to 0.999 (Fig. 1). The optimum N requirement increased by 81 and 38 kg N/ha to get 9.7 and 7.7 t/ha more yield in 'Kufri Giriraj' and 'Kufri Jyoti', respectively when growth duration increased from 75 to 100 (Table 6). On contrary, 'Kufri Pukhraj' needed 60 kg less N/ha to get 6.8 t/ha more yield with increasing growth duration. If longer growth duration was given, 'Kufri Giriraj' and 'Kufri Jyoti' needed more N to yield optimum level of production, whereas, 'Kufri Pukhraj' could utilize even lower level of applied N more efficiently to give higher yield. Besides, when shorter growth duration is available, it is possible to get better harvest by applying higher level of N with this variety. This is because 'Kufri Pukhraj' was capable of maintaining higher bulking rate (395 and 436 kg/ha/day in 100 and 75 days, respectively) when higher N dose was given. The bulking rate of 'Kufri Giriraj' was 361 and 353 kg/ha/day and for 'Kufri Jyoti' it was 320 and 323 kg/ha/day at 100 and 75 days, respectively.

Economics and eco-friendliness

Net return was positive and benefit:cost ratio was more than one for all 3 varieties for both the growth durations at economic optimum N and yield level. These values were always higher for longer growth duration for all 3 varieties. At both growth durations 'Kufri Pukhraj' gave the best return as well as benefit:cost ratio and also this variety showed minimum decrease (33%) in net return as a result of reduced growth duration from 100 to 75 days. Therefore, if the crop is to be harvested early 'Kufri Pukhraj' is the best option.

'Kufri Pukhraj' and 'Kufri Giriraj' were more eco-friendly when compared with standard variety 'Kufri Jyoti' (Table 6). These varieties needed less N to produce a fixed yield, equivalent to maximum produced by 'Kufri Jyoti' in 75 and 100 days and therefore, proportionately less N would be lost to the environment. At the same time, in absolute terms 'Kufri Jyoti' required 66 and 44 kg N/ha to produce the yield which 'Kufri Pukhraj' produced without any N application in the two growth durations, respectively. Its higher value for 'Kufri Pukhraj' definitely indicates the capacity of this variety to utilize soil N more efficiently. Trehan (2005) also had similar observation regarding the efficiency of this variety to utilize N from various sources.

'Kufri Pukhraj' was the highest yielder and agronomically most efficient. There is possibility of reducing N recommendation by about 30% for efficient cultivars *viz.*,

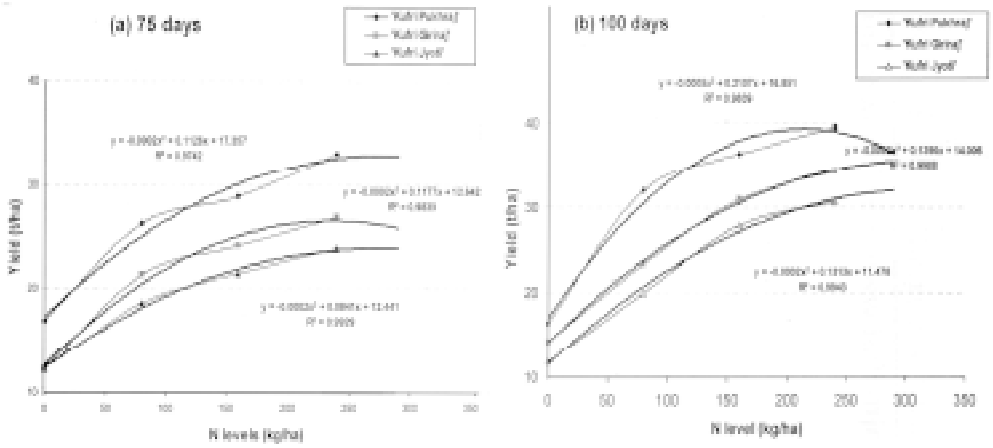

Fig. 1. Response of potato varieties to N levels at two growth durations (a) 75 days and (b) 100 days

Table 6. Economic optimum yield, total variable cost, net return and benefit:cost ratio at optimum N dose and eco-friendliness as influenced by growth durations.

Variety	Growth duration (days)	Economic optimum N dose (kg/ha)	Economic optimum yield (t/ha)	Total variable cost (x 10^3 Rs/ha)	Net return (x 10^3 Rs/ha)	B:C ratio	Eco-friendly indices	
							Relative* (%)	Absolute* (kg/ha)
'Kufri Giriraj'	75	226.7	26.48	47.98	18.22	1.38	49.96	2.40
	100	307.5	36.14	49.93	40.42	1.81	42.35	19.97
'Kufri Pukhraj'	75	270.6	32.68	48.45	33.25	1.69	75.13	66.25
	100	210.6	39.50	48.87	49.88	2.02	70.75	44.07
'Kufri Jyoti'	75	265.9	24.21	48.40	12.12	1.25		
	100	303.0	31.97	49.88	30.04	1.60		

*Taking 'Kufri Jyoti' as standard variety

'Kufri Pukhraj' when with 'Kufri Jyoti' when grown till full maturity. When growth duration is reduced by 25 days, farmers can reduce the nitrogen dose by 12 and 26% in varieties 'Kufri Jyoti' and 'Kufri Giriraj', respectively. At the same time in 'Kufri Pukhraj' applying higher nitrogen may facilitate higher yield in a shorter growth duration.

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