Indian Journal of Agricultural Sciences **80** (7): 588–91, July 2010

Direct and residual effect of nitrogen in high-yielding/hybrid chilli (*Capsicum annuum*)–radish (*Raphanus sativus*) system

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Received: 3 August 2009; Accepted: 29 April 2010

ABSTRACT

A field experiment was conducted in a sandy loam soil involving 'Arka Lohit', a high-yielding variety and 'ECL', an F_1 hybrid chilli (*Capsicum annuum* L.) during 2002–05 using ^{15}N-enriched (1% N abundance) urea as the tracer to evaluate direct and residual of applied nitrogen in chilli–radish (*Raphanus sativus* L.) system. Response in terms of dry matter production was observed in both the varieties when 100% N dose (120 and 200 kg/ha, respectively) was applied in 3 splits, i e basal + 2 top-dresses. The highest yield 'Arka Lohit' was obtained when the same dose was applied in 2 equal splits as basal + top-dress due to its slower growth habit. 'ECL' hybrid outyielded other treatments when 100% N dose was applied in 3 splits as basal + 2 top-dresses due to its quick yielding habit. Either deferring the time of application by 10 days or reducing the N dose by 20–40% and increasing the splits from 2 to 3 were not beneficial. A significant residual effect of N was exhibited by 'Arka Nishant' radish raised during July-August 2003, in terms of fresh yield, dry matter production and different parameters of N-use efficiency compared with the 'control'. Response of radish decreased as the dose of N input to chilli decreased. Therefore, the yield and N recovery was higher in radish where 'ECL' chilli was raised earlier. The highest overall recovery of residual fertilizer N was observed under 100% N dose applied to chilli crop as 3 splits (basal + 2 top-dresses), followed by the same dose applied in 2 splits (basal + top-dress) and 3 splits (deferred by 3 days) in radish raised after both the chilli varieties. Radish utilized only 0.50 – 2.58% of residual N from fertilizer applied to previous chilli crop, indicating a low recovery which is a common feature in most crops.

Key words: *Capsicum annuum*, Chilli, Direct effect, High-yielding variety, Hybrid, Nitrogen-use efficiency, Radish, *Raphanus sativus*, Residual effect

Nitrogen is a mobile nutrient applied in large quantities to sustain high production of crops and therefore enhancing N–use efficiency is of utmost importance for cost-effectiveness and eco-safety. The strategy of improving N–use efficiency consists of banding, incorporation into the soil, increasing number of splits and manipulating the time of application to suit the crop needs. Studies conducted on 'Arka Vikas' tomato showed that a saving of 25% of N input was possible without loss in yield by manipulation of number of splits and time of application (Shivananda *et al*, 1996). Therefore an evaluation of the direct and residual effect of applied N to high yielding and hybrid chilli (*Capsicum annuum* L.) varieties, followed by radish crop was studied in a field experiment using ^{15}N-enriched urea as the tracer.

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MATERIALS AND METHODS

Chilli (*Capsicum annuum* L.) crop was raised during 2002–05, on a sandy loam (Typic Haplustalf) having a pH of 5.9, organic carbon of 0.30%, cation exchange capacity of 8.7 cmol (p^+)/kg and available N of 246 kg/ha. The recommended fertilizer dosage was 120: 80: 40 and 200: 150: 150 g N, P and K kg/ha for 'Arka Lohit' and 'ECL'varieties respectively. The spacing adopted was 60 cm×30 cm. The treatments consisted of (i) 'control' (no N); N applied in (ii) 100% recommended N dose in 2 equal splits as basal and top-dress at 30 days after transplanting; (iii) 100% recommended N dose in 3 equal splits applied as basal and 2 top-dresses at 25 and 45 days after transplanting; (iv) 100% recommended N dose in 3 equal splits deferred by 10 days at 10, 35 and 55 days after transplanting; (v) 80% of the recommended N dose applied as in (iv); and (vi) 60% of the recommended N dose applied as in (iv). To assess the efficacy of each split application of N, each of them was applied through ^{15}N-enriched (1% N abundance) urea in separate series in 1.0 m × 1.8 m plots located in the midst of

3 m × 3 m plots. The remainder of the experimental plot received N through unlabelled urea. The fruits were harvested at green stage. The whole plant was sampled for assessing N use parameters at peak harvest stage and reported for the plot of 1.8 m^2. Total N was estimated by Kjeldahl method and ^{15}N abundance using ratio mass spectrometer (CE Instruments Flash EA-1112 Series Thermoquest). Nitrogen derived from fertilizer (% Ndff) was calculated as:

$$\text{Ndff (\%)} = \frac{\%\ ^{15}\text{N atom excess in the plant sample}}{\%\ ^{15}\text{N atom excess in the fertilizer}} \times 100$$

To evaluate the residual effect of N, 'Arka Nishant' radish (*Raphanus sativus* L.) was raised during same period in the same plots immediately after chilli crop. Recommended fertilizer dose of 120: 50: 50 kg N, P and K kg/ha was applied to radish crop and the spacing adopted was 30 cm×10 cm. Yield, dry matter production, N content, total N uptake, N derived from fertilizer (%) and residual N utilized were determined. The crops were irrigated at weekly interval during dry periods.

RESULTS AND DISCUSSION

The results showed that the response of both the varieties of chilli to applied N in terms of yield and dry matter production was significant compared to 'control' (Table 1) and was in direct proportion to the dosage of N applied. Relatively higher dry matter and fruit yield was obtained at 100% of recommended N dose and as compared to 60 and 80% N doses. Neither increasing the splits from 2 to 3 nor deferring the time of split applications did help when N dosage was reduced. However at 100% N dose, increasing the number of splits from 2 to 3 and manipulation of time of application showed distinct differences in the 2 varieties. In both the varieties, application of 3 splits (basal + 2 top-dresses) gave the highest dry matter. However at 100% N dose, 'Arka Lohit' chilli gave the highest fruit yield when N was applied in 2 equal splits (basal + top-dress) and application of 3 splits either as basal + 2 top dresses or as deferred by 10 days, yielded significantly lower fruit yield. On the other hand, in 'ECL' chilli, the application of 3 splits at 100% N dose as basal + 2 top dresses out-yielded the same N dose applied in 2 equal splits as well as 3 splits at 100% N dose as basal at 2 top-dresses deferred by 10 days. A perusal of N use parameters presented in Table 2 showed that increasing the number of splits from 2 to 3 at 100% dose applied as basal + 2 top-dresses significantly increased N content (1.28 and 1.24% in 'Arka Lohit' and 'ECL' hybrid respectively), its uptake (8.79 and 7.43 g/plot) as well as the overall fertilizer N uptake from all the splits (2.17 and 2.65 g/plot) and fertilizer utilization (30.39% and 22.07%) in both the varieties compared to 100% N dose applied in 2 equal splits or reduced N doses applied in deferred splits. This does not explain the superior performance of 'Arka Lohit' chilli in producing maximum yield at 100% N dose applied in 2 splits. This differential behaviour may be attributed to a relatively slower growth habit of the high yielding 'Arka Lohit' variety that took over 45 days to reach grand growth and start flowering then on. The first harvest was made only at 60 days after transplanting. In comparison, 'ECL' hybrid variety was relatively fast growing and started flowering at 25 days after transplanting. The first harvest of fruits was made a mere 40 days after transplanting. Any attempt to reduce the N dose of deferring the application or increasing the number of splits reduced the fruit yield.

The results of the assessment of residual effect on 'Arka Nishant' radish presented in Table 3 and 4 showed that significant residual effect was exhibited by 'Arka Nishant' radish in the form of higher fresh yield, dry matter and

Table 1 Effect of number of splits, time and level of N application on dry matter and fruit yield of 2 varieties of chilli (g/1.8 m^2)

Treatment (per cent N dose)	'Arka Lohit' chilli			'ECL' chilli		
	Total dry matter	Fruit yield		Total dry matter	Fruit yield	
		Fresh fruit	Dry fruit		Fresh fruit	Dry fruit
Control	377.4	455.6	107.4	289.6	825.9	141.7
100% (basal + top-dress)	835.3	1325.4	320.1	619.6	1689.3	294.7
100% (basal +2 top-dresses)	863.9	1003.0	248.9	677.7	1995.4	348.9
100% (3 splits deferred)*	800.6	1126.7	251.9	563.5	1731.4	296.8
80% (3 splits deferred)*	707.19	1055.7	248.0	477.1	1378.0	235.5
60% (3 splits deferred)*	680.62	1020.5	243.7	450.4	1221.8	215.6
SEm (±)	6.684	14.18	4.60	4.58	17.35	2.46
CD (*P*=0.05)	21.05	44.67	14.50	14.44	54.66	7.76

*Denotes 3 splits deferred by 10 days after planting

Table 2 Effect of number of splits, time and level of N application on the parameters of N use by 2 varieties of chilli

Treatment (per cent N dose)	'Arka Lohit'					'ECL'				
	N content (%)	N uptake (g/plot)	Ndff (%)	Fertilizer N uptake (g/plot)	Fertilizer utilization (%)	N content (%)	Nuptake (g/plot)	Ndff (%)	Fertilizer N uptake (g/plot)	Fertilizer utilization (%)
Control	0.87	2.44				0.74	1.90			
100% (basal + top-dress)	1.02	6.77	13.24	1.79	16.91	1.16	6.83	14.53	1.98	10.66
100% (basal +2 top-dresses)	1.28	8.79	8.11	2.17	30.39	1.24	7.83	12.04	2.65	22.07
100% (3 splits deferred) §	1.13	7.37	8.90	1.96	27.08	1.25	6.42	12.10	2.58	19.11
80% (3 splits deferred) §	1.14	6.08	7.32	1.34	23.34	1.04	4.29	12.16	1.56	15.70
60% (3 splits deferred) §	1.01	5.25	7.57	1.16	26.60	0.94	3.65	10.78	1.12	15.46
SEm (±)	0.018	0.085	0.072	0.032	0.454	0.015	0.090	0.083	0.041	0.377
CD (*P*=0.05)	0.056	0.267	0.236	0.104	1.480	0.047	0.282	0.272	0.135	1.231

§ denotes 3 splits deferred by 10 days after planting; Ndff, nitrogen derived from fertilizer

Table 3 Residual effect of N applied to 'Arka Lohit' chilli on the yield of 'Arka Nishant' radish and its N-use efficiency

Treatment (per cent N dose)	Fresh yield (g/plot)	Dry matter (g/plot)	N content (%)	N uptake (g/plot)	Ndff (%)	Fertilizer N uptake (g/plot)	Fertilizer utilization (%)
Control	4 001	265.5	0.68	1.92			
100% (basal + top-dress)	7 050	420.0	1.06	4.75	1.75	0.156	0.87
100% (basal +2 top-dresses)	5 751	357.3	0.91	3.47	1.25	0.126	0.70
100% (3 splits deferred) §	6 535	408.6	0.92	4.11	1.22	0.147	0.82
80% (3 splits deferred) §	7 398	448.6	0.92	4.38	1.15	0.147	0.84
60% (3 splits deferred) §	5 681	345.3	0.87	3.04	1.04	0.089	0.50
SEm (±)	36.8	2.84	0.012	0.043	0.032	0.0022	0.012
CD (*P*=0.05)	118.6	8.96	0.038	0.134	0.103	0.0071	0.039

§ denotes 3 splits deferred by 10days

Table 4 Residual effect of N applied to 'ECL ' hybrid chilli on the yield of 'Arka Nishant' radish and its N-use efficiency

Treatment (per cent N dose)	Fresh yield (g/plot)	Dry matter (g/plot)	N content (%)	N uptake (g/plot)	Ndff (%)	Fertilizer N uptake (g/plot)	Fertilizer utilization (%)
Control	4 488	287.5	0.64	1.83			
100% (Basal + top-dress)	8 604	489.3	1.01	4.72	2.73	0.273	1.52
100% (Basal +2 top-dresses)	10 044	600.0	0.93	5.52	2.06	0.355	1.98
100% (3 splits deferred) §	11 571	677.9	0.98	6.67	2.35	0.464	2.58
80% (3 splits deferred) §	8 204	499. 4	0.90	4.45	1.79	0.251	1.40
60% (3 splits deferred) §	7 452	437.6	0.93	4.08	1.64	0.207	1.15
SEm (±)	63.7	3.75	0.009	0.087	0.047	0.0091	0.053
CD (*P*=0.05)	185.4	11.82	0.029	0.274	0.153	0.0295	0.1739

§ denotes 3 splits deferred by 10days

different parameters of N-use compared with the control. In general, the response of the crop decreased as the dose of N input to chilli crop decreased. Therefore, the yield and N recovery was higher in radish where 'ECL' hybrid chilli was grown earlier (Table 4) compared to that grown after 'Arka Lohit' chilli (Table 3). The highest overall recovery of residual fertilizer N (0.82 and 2.58% after 'Arka Lohit' and 'ECL' chilli respectively) was observed under 100% N dose applied to chilli crop as 3 splits (basal + 2 top-dresses, deferred by 10 days), followed by the same dose applied in 2 splits (basal + top-dress) after 'ECL' chilli (0.87%) and 3 splits (basal + 2 top-dresses) after 'Arka Lohit' chilli (1.98%)

in radish. The total of 0.50–2.58% of utilization by radish crop from the fertilizer N applied to previous chilli crop indicates a low recovery that appears to be common in crops. Similar low recoveries by the succeeding crops have been reported by Shivananda *et al.* (1996), Ichir *et al.* (2003) and Sampio *et al.* (2004). Utilization of such small proportion of fertilizer residue by the crop from the fertilizer N applied to previous crop was attributed mainly to immobilization of fertilizer N in soil organic matter that mineralizes rather slowly (Ichir *et al.* 2003) and to poor synchrony between mineralization of ^{15}N-labelled organic residues and crop uptake (Macdonald *et al.* 2002). The significant response of radish to residual fertilizer despite such low recovery of residual N may be attributed to the residual fertilizer effect of other nutrients like P (Sampio *et al.* 2004).

The results showed that the growth habit of the variety is decisive in the manipulation strategy of management of N fertilizer to achieve high use efficiency. It was beneficial to apply the full dose of N in 2 equal splits in slow growing high yielding 'Arka Lohit' chilli and increase the number of splits to 3 and applying as basal and 2 top dresses in fast growing and quick yielding 'ECL' hybrid chilli.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support granted by the Board of Research in Nuclear Studies, Department of Atomic Energy, Government of India, Mumbai; and Shri N K Kacker, Technical Officer for valuable technical support.

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