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Evaluation of cropping sequences of hybrid vegetables for N fertilizer recovery efficiency and utilization of residues using ^{15}N-enriched urea*

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In intensive cultivation of vegetables, several cropping sequences in each region are popular depending on market needs and profit. Since different vegetable crops differ in their nutrient needs, relative dependence on soil *vis-à-vis* fertilizer source of nutrients and fertilizer recovery efficiency, there is scope to evaluate different sequences of vegetable crops for high nutrient use efficiency. Stable isotope ^{15}N is highly useful to investigate N use efficiency by crops grown in different cropping systems (Bosshead *et al.* 2009). Since hybrid vegetables need higher fertilizer dosages, there is scope to identify the most nutrient efficient sequence for cost effectiveness and eco-safety. For the sake of such an evaluation the possible sequences of okra *(Abelmoschus esculentus)*–tomato *(Lycopersicon esculentum)*–cabbage *(Brassica oleracea* var. *capitata)* was considered. The crops of the sequence were chosen on area under these crops, their productivity, market arrivals in Bangalore (NHB 2010) and their popularity. The experiment was raised during 2003–04 on a sandy loam (typic Haplustalf) soil having a *p*H of 5.9, organic carbon of 0.30%, cation exchange capacity of 8.7 cmol (p^+)/kg and available N of 246 kg/ha. Six possible cropping sequences as listed in Tables 1 and 2 were raised in 3 series. In the first series of each sequence, the first crop, in the second series of the same sequence, the second crop and in the third series of the same series, the third crop received ^{15}N labeled fertilizer. For instance, in the first sequence: okra-tomato-cabbage, okra crop received ^{15}N labeled fertilizer in the first series. The second crop, tomato, and the third crop, cabbage, in the same sequence, received ^{15}N labeled fertilizer similarly. The remaining two crops, in the same series of the sequence, received N in unlabelled form. The same pattern was maintained in the remaining 5 series also. The varieties used were: cabbage, Krishna Mahyco hybrid, okra, Mahyco hybrid-1 (I series) and U.S. Agri 7109 (II and III series); tomato, Arka Abhijit (I series) and JK Asha (II and III series) to suit the season of planting. The fertilizer doses were: cabbage, 150: 125: 100; okra, 100: 50: 50, and tomato 180: 150: 120 N: P: K kg/ha. The spacing adopted was 60 cm × 25 cm (12 plants/plot) in okra and 60 cm × 50 cm (6 plants/plot) in tomato and cabbage crops. The first series was raised during August–November 2003 followed by II series during December 2003–March 2004 and III series during April–July 2004. The crops were irrigated at weekly intervals during dry periods. To assess the efficacy of each split application of N, each of them was applied through ^{15}N-enriched urea (1 atom% excess) 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. Nitrogen derived from fertilizer (Ndff), fertilizer N uptake and residual fertilizer N in soil in different crops receiving ^{15}N-enriched N was computed in each series. Nitrogen fertilizer recovery efficiency was calculated as:

$$\frac{\text{N fertilizer uptake by the crop}}{\text{N fertilizer received by the crop}} \times 100.$$

Residual N in the soil was calculated as described by Vose (1980):

$$A_2 = a_2 \times \frac{F}{f}$$

where A_2 denotes residual N in the soil (kg/ha); a_2, ^{15}N absorbed by the crop receiving ^{15}N in the first season; F, the ^{15}N fertilizer dose (kg/ha) applied in the second season and f, the fertilizer ^{15}N in the crop in the second season. On this basis, residual N in the soil was calculated for the 2nd and 3rd crops in all the sequences studied (Table 2).

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*Short note

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Yield and biomass production: From Table 1, it is evident that cabbage showed the highest yield among three crops especially when grown as the first crop. However, the yield declined markedly from the first to the third season. Tomato yields were next higher in quantum and the second season showed higher production. Okra yields were relatively higher in the first season and comparable in the following two seasons. The associated biomass production of different crops also showed a similar trend. The relative performance was thus related to both the characteristics of the crop and the season of production. However, cabbage–cabbage–cabbage sequence cannot be practiced to maintain crop rotation essential to conserve soil health and avoid pest/disease build up.

Fertilizer N uptake and recovery efficiency: Cabbage showed the highest uptake of fertilizer (9.409–10.349 kg/plot) followed by tomato (5.648–5.860) while okra recovered the least (2.295–2.349) when raised as the first crop. A similar trend was evident in the 2nd and 3rd crops also but the quantum of uptake gradually declined as observed in respect of yield (Table 1). Among different cropping sequences, the total N uptake the first sequence (cabbage-tomato-okra) showed the highest recovery of 17.925 kg/plot. The second and 3rd sequences followed closely (16.593 and 16.807) both being *at par* in which cabbage was the first and second crop, respectively. The least uptake of 10.810 kg/plot observed in the 4th sequence (tomato–okra–cabbage) and 11.187 in the 6th sequence (okra–tomato–cabbage) may be attributed the cabbage crop grown as the 3rd crop. The recovery of N from the fertilizer applied to the first crop in different sequences of okra, tomato and cabbage during the first season varied widely in the range of 12.31–38.44%. The N fertilizer recovery efficiency was distinctly higher when the first crop was cabbage (37.85–38.44%). When tomato was the first crop, the recovery was intermediate (17.39–18.09%). The least recovery was observed when the first crop was okra (12.31–13.05%). Okra as the second crop in the sequence significantly reduced the overall N fertilizer recovery efficiency of the sequence when the first crop was tomato. The ability of the crops to absorb N from the applied fertilizer or the uptake of fertilizer N as well as the associated fertilizer recovery efficiency was in the order: cabbage>tomato>okra when grown as first and second crops. Meager recovery of fertilizer N by the third crop from that applied to the 1st crop masked such a trend among the 3 crops.

Utilization of residual fertilizer N by the crops: In general, the recovery of N by the second crop from fertilizer N applied to the first crop was low (0.67–4.61%). However, cabbage showed the highest utilization of residual fertilizer N of 2.27–4.61% among the three vegetables. The recovery

Table 1 Yield and biomass production of three component crops in different cropping sequences

Cropping sequences	Yield (kg/plot*)			Biomass production (kg/plot)			
	I crop	II crop	III crop	I crop	II crop	III crop	Total
Cabbage–tomato–okra	29.590	17.642	1.718	1.195	1.273	0.935	3.403
Cabbage–okra–tomato	30.750	1.765	11.196	0.907	1.668	0.784	3.359
Tomato–cabbage–okra	10.985	22.238	2.014	1.824	0.548	0.832	3.204
Tomato–okra–cabbage	10.740	1.512	11.746	0.753	0.388	0.989	2.130
Okra–cabbage–tomato	3.195	17.012	10.936	0.859	1.349	1.020	3.228
Okra–tomato–cabbage	3.719	16.601	13.470	1.413	1.099	0.553	3.065
SEm (±)	0.3052	0.3246	0.3456	0.0241	0.0274	0.0225	0.0432
CD (*P* = 0.05)	0.6799	0.7233	0.7702	0.0537	0.0610	0.0501	0.0962

*Plot = 1 m × 1.8 m

Table 2 Nitrogen uptake, fertilizer recovery efficiency and residual N of three component crops in different cropping sequences

Cropping sequences	N uptake (g/plot)				Fertilizer recovery efficiency (%)				Residual N (kg/ha)	
	I crop	II crop	III crop	Total	I crop	II crop	III crop	Total	II crop	III crop
Cabbage–tomato–okra	10.349	5.589	1.987	17.925	38.44	1.08	0.21	39.63	11.17	1.92
Cabbage–okra–tomato	9.409	2.631	4.553	16.593	37.85	0.79	0.26	38.89	5.42	3.28
Tomato–cabbage–okra	5.648	8.140	3.019	16.807	17.39	4.61	0.39	22.39	22.95	2.51
Tomato–okra–cabbage	5.860	1.689	3.261	10.810	18.09	0.67	0.33	19.10	7.16	5.03
Okra–cabbage–tomato	2.295	5.922	5.390	13.070	12.31	2.27	0.20	14.69	15.54	2.19
Okra–tomato–cabbage	2.349	6.158	2.680	11.187	13.05	1.52	0.12	14.69	16.41	2.10
SEm (±)	0.2971	0.2745	0.1478	0.3922	0.321	0.098	0.014	0.363	0.912	0.168
CD (P = 0.05)	0.6613	0.6110	0.3289	0.8730	0.716	0.219	0.032	0.808	2.032	0.375

of fertilizer N in the third crop was very low (0.12–0.33%). The residual fertilizer N left behind by the first crop in the 2nd and 3rd crops as shown by the respective crops varied from 5.42–22.95 and 1.92–5.03 kg/ha respectively which led to such small values of N fertilizer recovery in the corresponding seasons. Similar low recoveries by the succeeding crops have been reported by 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 previous crop was attributed (i) mainly to immobilization of fertilizer N in soil organic matter that mineralizes rather slowly (Ichir *et al.* 2003); and (ii) to poor synchrony between mineralization of ^{15}N-labelled organic residues and crop uptake (Macdonald *et al.* 2002). The results indicated that the inherent capacity of the component vegetable crop in a cropping sequence to utilize the direct and residual N decides the overall N use efficiency of the cropping sequence. Since the residual effects are of smaller order, the scope of reducing N dosages of the succeeding crops of the sequence keeping in view the residual N from previous application is limited. The residual fertilizer N values in Table 1 in the 2nd crop show a similar trend as observed as in respect of N fertilizer recovery efficiency.

SUMMARY

Among six possible cropping sequences of okra *(Abelmoschus esculentus),* tomato *(Lycopersicon esculentum)* and cabbage *(Brassica oleracea* var. *capitata),* the sequence ‘cabbage-tomato-okra’ was the most N efficient showing 17.925 kg/plot (1 m × 1.8 m) of fertilizer N uptake and 39.6% recovery of N applied to the first crop, followed by that of ‘cabbage-okra-tomato’ (35.9). Cabbage as the second crop showed the highest recovery of residual fertilizer N of 2.27 – 4.61% compared to other crops. The ability of the crops in the uptake of fertilizer N and therefore the associated fertilizer recovery efficiency was in the order: cabbage> tomato>okra when grown as first and second crops. The recovery of residue by the third crop was meager (0.12–0.33%). Therefore, the inherent capacity of the component vegetable crop in a cropping sequence to utilize the direct and residual N decides the overall N-use efficiency of the cropping sequence.

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