

REMOVAL OF NUTRIENTS BY VEGETABLE CROPS CULTIVATED IN THE MID AND UP COUNTRY WET ZONE

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ABSTRACT

Nutrient removal by crops is an important consideration in formulating fertilizer recommendations for sustainable crop production as recommendations derived from field experiments alone may not fully reflect the long term changes in nutrient status of the soil. Removal of nutrients in plant parts of several important vegetable crops in the mid and up country areas, where crops are intensively fertilized was therefore studied. Total quantity of nutrients removed was very high in potato, cabbage, tomato, bean and carrot. Potassium was removed in large amounts by all the crops. Of the four micronutrients studied, more Mn and Fe were removed by all crops compared to Cu and Zn. The portion of nutrients available in the residue of certain crops was very high making it possible to return a major portion of nutrients removed back to soil through residue recycling. The pattern of nutrient removal provides some clues for combining crops for maximum crop production, with lower fertilizer application and minimum nutrient depletion.

KEY WORDS: Nutrient removal, Vegetables

INTRODUCTION

The amount of nutrients removed in a harvested crop may bear little semblance to the optimum fertilizer rate determined from extensive field experiments. For certain crop species the amount of a nutrient removed by the crop may be considerably higher than the amount supplied by application of the recommended rate while the opposite may be true for another nutrient or a crop. Potato removes from the soil much more potassium than the quantity applied as fertilizer, while the reverse is true in cowpea and mungbean.

The amount of nutrients removed with harvest varies very much between crops and is closely related to yield level. Where the amount removed in the crop is greater than the recommendation, the crop may draw on soil nutrient reserves (over and above amounts supplied

through air, rain and irrigation water) to make up the total need. Where it is lower, the surplus may be accumulated in the soil reserves or lost, depending on the buffering behaviour of the soil or characteristics of the nutrient. In designing fertilizer recommendation schemes therefore, it is important to take nutrient removal into account, particularly in intensively cropped high productive systems.

Vegetables bring high incomes to the farmers compared with most other crops. They are also cultivated under high intensive cropping systems. Most vegetables are grown as annuals (30 to 180 days). Vegetables produce high biomass within a short period of time and unlike other annuals are harvested succulent while the crop is still in a physiologically active state, for example, vegetables belonging to the families, cucurbitaceae, malvaceae and solanaceae.

Large amounts of vegetative material are removed as edible portion during harvest of certain vegetables, while the actual portion of edible material contained in others is relatively small. It is possible in the latter case to return some of the nutrients to the field by recycling the crop residues. Therefore, estimating nutrient removal by various plant parts will provide a basis for managing crop residue in a fertilizer programme.

Vegetables are cultivated across a vast range of climates, soil types and farming systems. In the mid country wet zone and in the upcountry wet zone predominant types of cropping system include vegetables as a component, as in the rice-vegetable cropping system and year round vegetable system with potato as one crop of the system.

Amarasiri and Perera (1975) reported nutrient removal values for some of the vegetable crops. However, the locations where these vegetable crops were grown, were outside the major planting area for the crops. In the present study nutrient removal was studied for crops planted in the major cultivation areas under farmer management and also for a mix of popular crop varieties.

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MATERIALS AND METHODS

Plant samples were collected from farmers' fields at the time of harvest. Sample plots were 1m×1m. Crop yields were recorded for all sampled fields. For crops that were given wide spacings, 5 plants were collected randomly from the fields and plant densities recorded. From each type of crop, 10 samples were taken over a period of one year (usually 2 seasons).

Plant samples were cleaned and washed thoroughly with a final rinse in distilled water and were carefully separated into tubers, stems, leaves and pods or fruits as necessary and weighed. Whole plants were taken for crops such as cabbage, leek and lettuce. The samples were oven-dried to a constant weight at 65°C. For N analysis (Kjeldahl method) finely ground samples, and for P (colorimetry), K (flame photometry) and other nutrients (atomic absorption spectrophotometry) dry-ashed samples were used.

Total quantity of nutrients removed by different types of plant tissue samples was calculated from the tissue concentrations determined as above and the total oven-dry weight of the tissue.

RESULTS AND DISCUSSION

Botanical names, varieties and growth durations of the crops studied are shown in Table 1. Most popularly cultivated varieties of crops are included in each crop category. Table 2 contains the total quantity of nutrients removed by the individual crop species. This table also includes the nutrient contents in the harvested portions or aerial parts of the crops along with standard deviations and average yields observed. Table 3 shows the nutrient removal per day of crop growth.

NPK removal

Total nutrient removal was large (321—728 kg/ha) in all crops except lettuce (41 kg/ha), capsicum (135 kg/ha), spinach (155 kg/ha), snakegourd (172 kg/ha), radish (202 kg/ha), okra (240 kg/ha), and bittergourd (297 kg/ha). Highest removal was by the potato crop (728 kg/ha).

Daily NPK removal was over 4.0 kg/ha for beet, radish, cabbage, knol khol, carrot and potato (Table 3). Spinach, sweet potato, bean and tomato had the removal rates ranging from 3.19 to 3.51 kg/ha/day. Other vegetable crops had lower NPK removal rates (0.94 to 2.87 kg/ha/day).

Total N removed by crops ranged from 16-222 kg/ha. Except for lettuce (16 kg N/ha), spinach (58 kg N/ha), capsicum (62 kg N/ha), snakegourd (73 kg N/ha) and okra (95 kg N/ha) all other vegetable crops removed more than 100 kg N/ha; the highest removal was by potato (222 kg N/ha).

Potassium is the nutrient removed most by almost all vegetable crops. The amounts of K removed in most vegetable species are much greater than the amounts supplied by the application of recommended levels of fertilizer while the opposite is true for P. For example, potato removes three and a half times more K than that applied as fertilizer.

Removal of P is quite small compared to N and K. The amounts of P removed by cabbage, potato, carrot and luffa are greater than the quantities removed by other crops.

The vegetables cultivated in the upcountry soils have shown a response to P application even when the soil test P levels were quite high (J. D. H. Wijewardene, Unpubl., 1990). This could be due to the very high growth rate of potato and most types of vegetables, and the shallow root systems that require a ready supply of P in close proximity to the plant. As a result of heavy fertilizer applications, soil test levels of P (Table 4) and K (Table 5) in majority of cultivated soils in these areas have been found to be very high. A majority of farmers' fields where year round cultivation of vegetables is practised, exhibited significantly higher soil test levels of P and K in comparison to the levels recorded under the rice-vegetable and rice-rice cropping systems (Tables 4 and 5).

Although the removal of P by all aerial parts of tomato is about 18 kg P/ha, tomato grown in the rice-vegetable system in the mid country shows response to application of levels as high as 180 kg P_2O_5 /ha (Division of Agricultural Chemistry, CARI, Gannoruwa,

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Unpubl., 1990). Doris Fohse *et al.* (1988) reported crop species like tomato, bean and onion as having low P uptake efficiency as opposed to spinach for which uptake efficiency was rated high.

Secondary and micronutrient removal

Calcium removals were higher (>50 kg/ha) for luffa, bean, okra, brinjal, carrot, cabbage and potato; for Mg, removal values ranged from 2 to 33 kg/ha. Of the various micronutrients, Mn and Fe were removed more than Cu and Zn by all crops. Tomato removed more Cu (346 g/ha) than other vegetables studied (9-141 g/ha), while potato, carrot and beet removed more Zn than others. Some of the reported levels of Cu, Zn and Mn compare well with those reported by Eakin cited in Mengel and Kirkby (1979) for the edible portions of vegetables such as tomato, potato and cabbage at harvest. The levels of Zn and Mn removed in cabbage, according to the present study, were significantly higher than the levels reported in the above study.

Although there are no applications of these nutrients as chemical fertilizer, heavy doses of organic manure that are applied to vegetable crops could provide most of the micronutrient requirement. Research elsewhere has shown that application of poultry manure, which is frequently used by the upcountry farmer in Sri Lanka, increases the plant tissue concentrations of Zn and Mn (Kaddous and Morgans, 1986). Leaf tissue concentrations of the two nutrients, Zn and Mn, and B were reduced by application of lime (Smith *et al.*, 1989). The great variation of the tissue concentrations of micronutrients observed in the samples may be explained by variations in the adoption of the above practices by the farmers.

Nutrient removed by plant parts

There is great variation among different vegetables in the amount of nutrients contained in different plant parts. Certain vegetables remove most of the nutrients in edible parts while others contain more in the residue. Over 75% of the nutrients removed by potato is found in the aerial parts of the plant that has no economic use.

Fig. 1 shows the variation of N, P and K removal by different plant parts of several vegetables. Crops other than tomato, okra, snakegourd and bittergourd remove more N, P and K in the stems and leaves than in fruits. Of the vegetables in the root and tuber crop category (Fig. 2), potato and sweet potato contain more nutrients in the non-edible parts. Therefore, more than a half of the nutrients removed by these crops can be returned to the soil by recycling their crop residues.

However, addition of plant residues as a nutrient source has several limitations. For example, in the vegetables from the family solanaceae, use of crop residue is limited by the presence of bacterial plant pathogens. They can only be used after composting which destroys the plant debris that can provide a habitat for pathogens. Potato removes the highest quantity of nutrients of all the vegetables studied and a major portion of these are contained in the residue. Yet the return of this residue to the field as fertilizer is not advised due to spread of bacterial wilt. Similarly in sweet potato use of plant residue is limited by auto-toxic effects (Walker *et al.*, 1986).

The amount of a nutrient contained in plant parts could vary depending on the crop yield, soil, climate and cultivation season, crop duration, and fertilizer and management conditions under which the crop is cultivated. However, the most important factor that determines the amount of a nutrient contained in the plant tissue harvested, is the yield. Nutrient concentrations in plant tissue tend to conform to fixed proportions as they are required in fixed amounts for the tissue building. However, the ratio of leaves, stems etc. to harvested tissue can be highly variable depending on the growth and yield and may therefore indicate variable amounts of removal. Another factor that may be of relevance in the situation under consideration is luxury consumption of certain plant nutrients. Vegetables in the upcountry are probably the most heavily fertilized among all cultivated crops in the country and this above is likely to be an important consideration.

CONCLUSION

Several principles useful in designing optimum fertilizer recommendations are demonstrated in the differences in the concentrations of nutrients in various plant tissue and crop species. Crops such as

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potato, cabbage, tomato, bean, beet and carrot remove large amounts of nutrients, but except in beet, cabbage and tomato, the proportion of nutrients contained in the harvested portion in the other crops is smaller making it possible to return more than 50% of the absorbed nutrients to the soil through residue recycling. Crops such as okra, radish, capsicum and snakegourd remove relatively small quantities of nutrients. Some of the crops in the latter group can thrive well on the residual fertilizer in the field from fertilizer applications to the previous crop making their use in crop rotations quite desirable in terms of efficiency of use of applied fertilizer and minimum soil depletion of nutrients.

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Table 1. Information on vegetable crops studied

Crop	Botanical name	Duration (days)	Variety
Amarylidaceae			
Leek	<i>Allium porrum L.</i>	150—165	Large Long Summer
Chenopodiaceae			
Beet	<i>Beta vulgaris L.</i>	75—90	Crimson Globe, Detroit, Dark Red
Spinach	<i>Spinacia oleracea L.</i>	45—60	Jiant, Bush
Compositae			
Lettuce	<i>Lactuca sativa L.</i>	30—45	Grand Rapids
Convulaceae			
Sweet potato	<i>Ipomoea batatas L.</i>	105—120	Wariyapola
Cruciferae			
Radish	<i>Raphanus sativus L.</i>	45—60	Japanese Ball
Cabbage	<i>Brassica oleraceu</i>	75—105	K-Y Cross, Hercules, Lankagova, Gloria Fl
Knol khol	<i>Brassica oleracea gongylorides L.</i>	45—60	Early White Vienna
Cucurbitaceae			
Bittergourd	<i>Momordica charantia L.</i>	120—135	MC 43, Thinnavelly
Luffa	<i>Luffa acutangula L.</i>	120—135	LA 33
Snakegourd	<i>Trichosanthes cucumerna L.</i>	135—150	TA2, M1 short, Thinnavelly
Leguminosae			
Pole bean	<i>Phaseolus vulgaris L.</i>	100—105	Kentucky Wonder Green, Kentucky Wonder Wax, Katugastota
Malvaceae			
Okra	<i>Abelmoschus esculentus</i>	75—105	MI 5, MI 7
Solanaceae			
Capsicum	<i>Capsicum annum L.</i>	100—135	CA 8, Hungarian Yellow Wax
Brinjal	<i>Solanum melongena L.</i>	135—180	SM 164, Thinnavelly Purple, Lena Eri
Potato	<i>Solanum tuberosum</i>	90—105	Desiree, Isna
Tomato	<i>Lycopersicon esculantum Mill.</i>	90—120	KWR
Umbeliferae			
Carrot	<i>Daucus</i>	90—105	Cape Market, Top Weight, Nantes Half Long

Table 2. Average values of removal of nutrients by vegetables at harvest and standard deviations

Crop	Yield (t/ha)	Amount removed (kg/ha)										Amount removed (g/ha)						Total NPK removal (kg/ha)		
		N		P		K		Ca		Mg		Cu		Zn		Fe		Mn		
		SD		SD		SD		SD		SD		SD		SD		SD		SD		
Leek	52	139	15.1	20	3.5	178	45.0	29	9.7	9	4.5	90	44	172	45	2397	1076	442	46	337
Beet (R)	44	77	13.0	12	6.2	149	70.8	9	6.2	8	2.6	48	37	349	136	1112	479	335	29	
Beet (L)		55	5.5	6	2.5	92	18.7	22	12.4	16	6.6	23	12	162	102	1502	1116	571	38	
Total		132		18		242		31		24		71		511		2614		906		392
Spinach	16	58	6.2	9	0.4	88	5.1	24	0.4	17	2.4	89	3	62	5	3371	765	371	41	155
Lettuce	10	16	1.5	2	0.6	23	14.1	5	0.5	2	0.8	9	2	35	22	430	1	46	1	35
Sweet potato (T)	23	48	12.8	13	2.2	83	16.9	10	1.5	5	1.1	26	5	14	4	416	47	70	8	
Sweet potato (L)		31	3.3	2	0.3	37	3.9	6	0.6	4	1.0	10	2	13	3	748	134	90	11	
Sweet potato (S)		29	6.1	5	0.8	87	11.1	7	0.6	6	1.1	22	5	11	3	983	138	95	15	
Total		108		20		207		23		15		58		38		2147		255		335
Radish (T)	35	28	5.1	4	1.1	48	15.4	16	19.2	5	3.9	10	6	50	15	287	66	120	11	
Radish (L)		45	4.9	7	2.2	70	19.0	26	14.0	6	2.6	15	3	62	30	1008	278	121	9	
Total		73		11		118		42		11		25		112		1295		241		202
Cabbage (L)	60	186	19.8	29	7.1	196	51.8	44	26.3	13	7.7	53	20	213	57	2800	539	835	100	411
Knol khol (R)	30	63	12.3	11	3.0	98	19.3	11	4.5	7	2.1	15	6	89	30	433	195	97	12	
Knol khol (L)		65	14.6	8	2.0	77	14.2	49	18.1	7	2.2	29	15	100	56	932	379	284	42	
Total		128		18		175		60		14		44		188		1365		382		321
Bittergourd (P)	30	80	20.7	12	1.3	88	20.3	6	2.6	10	4.0	83	65	80	13	447	311	113	7	
Bittergourd (L)		28	2.7	3	0.3	19	5.3	16	13.7	4	0.4	13	4	29	7	472	265	84	2	
Bittergourd (S)		22	4.7	5	0.8	42	12.7	8	1.8	7	1.2	31	11	42	8	645	223	83	4	
Total		130		19		148		30		21		127		150		1563		281		297
Luffa (P)	30	41	9.7	9	2.0	54	12.3	5	2.3	5	1.0	32	4	53	21	626	288	58	1	
Luffa (L)		78	12.6	7	1.2	43	9.4	74	18.3	19	6.3	38	17	89	31	2018	1828	97	1	
Luffa (S)		32	9.6	8	2.3	72	8.5	18	6.3	9	1.8	47	22	77	22	554	131	187	19	
Total		151		24		169		97		33		118		218		3198		342		344

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Snakegourd (P)	30	40	11.5	6	2.0	52	30.2	17	15.5	7	1.6	55	17	55	18	492	265	103	7	
Snakegourd (L)		21	2.4	2	0.4	15	3.7	16	6.8	4	1.3	21	8	22	6	356	130	114	6	
Snakegourd (S)		13	1.7	2	0.6	22	7.0	6	1.6	3	0.7	17	8	19	7	408	167	67	5	
Total		73		10		89		38		14		93		96		1256		285		172
Bean (P)	12	39	7.3	6	2.0	39	13.8	5	1.7	4	1.2	23	8	60	18	544	207	131	10	
Bean (L)		88	9.1	8	1.0	57	19.9	66	24.8	11	2.7	43	18	132	34	2738	1400	1047	87	
Bean (S)		39	10.9	5	0.8	47	7.7	14	7.9	5	1.2	40	16	195	53	548	443	428	37	
Total		166		19		143		86		19		106		388		3831		1606		328
Okra (P)	18	59	18.4	9	1.7	76	16.0	15	4.9	10	1.8	50	21	87	31	455	179	158	10	
Okra (L)		21	6.2	2	0.6	16	5.4	27	5.6	5	1.1	15	5	31	11	495	361	243	14	
Okra (S)		15	8.4	3	1.5	38	21.3	19	8.8	8	2.0	20	7	55	24	407	129	151	11	
Total		95		14		131		62		24		86		172		1357		553		242
Capsicum (P)	10	25	2.4	2	0.1	14	0.6	9	0.2	5	0.0	18	2	20	1	147	45	44	1	
Capsicum (L)		34	7.1	2	0.6	35	10.7	10	2.0	3	1.3	25	10	30	13	686	171	102	7	
Capsicum (S)		9	1.7	1	0.3	13	3.7	4	1.3	2	1.3	13	9	20	13	241	90	62	3	
Total		67		5		63		23		9		56		70		1074		208		135
Brinjal (P)	25	57	1.4	9	1.2	74	19.2	1	0.1	6	0.2	47	13	162	33	153	77	37	1	
Brinjal (L)		54	14.6	7	1.3	70	16.3	47	6.3	11	2.5	61	20	53	19	348	68	138	6	
Brinjal (S)		18	5.3	3	0.4	77	12.6	10	3.6	5	1.2	33	13	35	15	69	20	35	2	
Total		130		18		241		58		21		141		251		571		210		389
Potato (T)	20	38	6.3	7	1.5	81	36.4	3	2.1	4	4.3	32	7	155	135	652	396	89	6	
Potato (L)		106	15.2	9	1.6	175	59.3	36	14.1	9	3.9	37	17	286	141	4252	2246	1648	112	
Potato (S)		78	25.8	11	6.0	222	98.6	32	12.0	11	5.4	36	16	100	39	5642	6992	769	41	
Total		222		27		479		71		24		105		541		10546		2506		728
Tomato (F)	25	127	17.2	14	3.2	165	30.8	10	5.3	9	4.5	176	25	129	29	4103	661	126	4	
Tomato (L)		21	2.2	2	0.2	18	5.6	23	6.0	6	0.7	136	103	24	3	1789	948	139	6	
Tomato (S)		15	4.4	1	0.4	23	10.9	10	2.9	5	1.0	34	18	69	21	1817	150	78	4	
Total		163		18		206		42		20		346		222		7709		344		307
Carrot (R)	31	70	10.3	14	7.1	104	43.7	23	15.9	10	5.0	53	19	158	83	1491	468	267	21	
Carrot (L)		89	13.4	11	2.9	133	45.2	29	6.4	9	4.5	62	16	272	116	2202	625	432	20	
Total		159		24		237		52		20		114		430		3693		699		420

F=fruit; L=leaf; P=pod; R=root; S=stem; T=tuber; SD=standard deviation

Table 3. Average values of daily removal of NPK by vegetables

Crop	Duration (days)	Amount removed (kg/ha/day)			
		N	P	K	Total N, P & K
Potato	105	2.11	0.26	4.56	6.93
Knoi khol	60	2.13	0.30	2.91	5.35
Cabbage	90	2.07	0.32	2.17	4.57
Radish	45	1.62	0.24	2.62	4.49
Beet	90	1.47	0.20	2.69	4.35
Carrot	100	1.59	0.24	2.37	4.20
Tomato	110	1.48	0.16	1.87	3.51
Spinach	45	1.29	0.20	1.96	3.44
Bean	100	1.66	0.19	1.43	3.28
Sweet potato	105	1.03	0.19	1.97	3.19
Luffa	120	1.26	0.20	1.41	2.87
Brinjal	150	0.87	0.12	1.61	2.60
Bittergourd	120	1.09	0.16	1.24	2.48
Okra	105	0.90	0.14	1.24	2.28
Leek	165	0.84	0.12	1.08	2.04
Snakegourd	135	0.54	0.08	0.66	1.28
Capsicum	120	0.56	0.05	0.52	1.13
Lettuce	45	0.37	0.05	0.52	0.94

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Table 4. Distribution of soil K levels of different cropping systems in the mid and up country wet zone

<i>Soil K* range (meq/100g soil)</i>	<i>Cropping system</i>		
	<i>Rice Rice (% fields)</i>	<i>Rice Vegetable (% fields)</i>	<i>Vegetable Vegetable (% fields)</i>
>0.01	19	17	
0.01—0.19	45	23	10
0.20—0.29	25	33	6
0.30—0.39	11	27	8
0.40—0.75			37
0.76—1.50			32
>1.50			7

*Ammonium acetate extractable K

Table 5. Distribution of soil P levels in different cropping systems in the mid and up country wet zone

<i>Soil P* range (ppm)</i>	<i>Cropping system</i>		
	<i>Rice Rice (% fields)</i>	<i>Rice Vegetable (% fields)</i>	<i>Vegetable Vegetable (% fields)</i>
<5	9		
6— 10	35		
11— 15	24	5	
16— 25	29	20	
26— 50	3	32	15
51—100		14	17
101—300		29	32
301—600			21
>600			15

*Olsen's available soil P

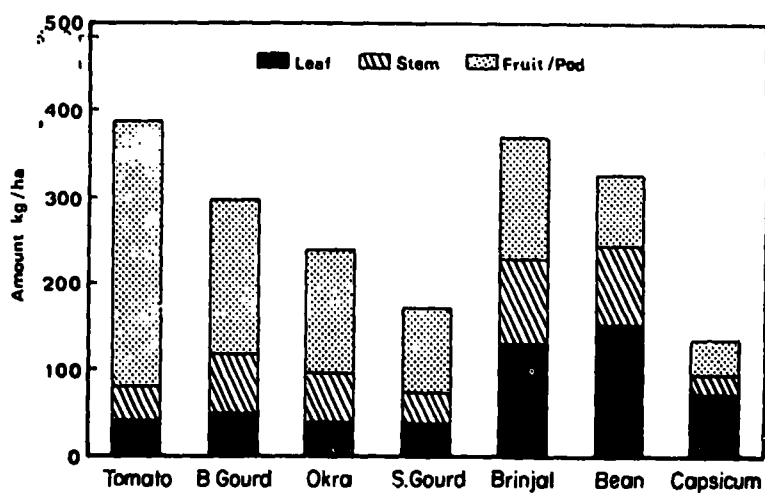


Fig. 1. Removal of N, P and K by plant parts of vegetable crops

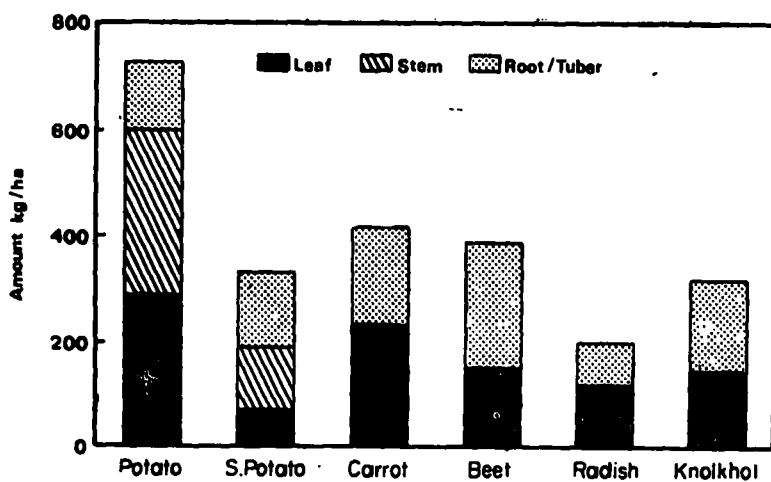


Fig. 2. Removal of N, P and K by plant parts of root and tuber crops