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Nutrient content in the leaves of cashew (*Anacardium occidentale* L.) in relation to variety

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Cashew (*Anacardium occidentale* L.) is a very important horticultural crop of India having very significant contribution in India's economy. Cashew has unique importance in human life for varied uses in agriculture, domestic, industry and medicine. Cashew kernel is a rich source of protein (21%), carbohydrate (22%) and fat (47%). Besides these, it contains several minerals and vitamins. In India, cashew is grown in 9.82 lakh ha area with total production of 7.28 lakh tonnes and productivity of 772 kg ha^{-1} (DCCD, 2013). It is predominantly grown in Maharashtra, Goa, Karnataka and Kerala along the West Coast and Tamil Nadu, Andhra Pradesh, Odisha and West Bengal along the East Coast. It is also grown to a limited extent in non-traditional areas such as Bastar region of Chhattisgarh and Kolar (Plains) region of Karnataka, Gujarat, Jharkhand and in North Eastern Hill region. Though cashew is a hardy crop which can be grown in wastelands and degraded/marginal lands, it responds very well to applied nutrients and water. Cashew being a regular bearer which puts forth flowering and sets fruit on the current season flush, the plant needs sufficient and continuous supply of nutrients for the growth of new flush, flowering, fruit set and development of nuts. Absence or scarcity of essential elements in the soil cause nutrient deficiencies in the plant and so affect vital processes.

Soil nutrient status and leaf analysis can give better indication of nutrient requirement. Inorganic leaf analysis has been used extensively as a diagnostic tool for assessment of the nutritional status of crop plants, especially of fruit trees. This method of diagnosis is based on the relationship between the concentration of nutrient elements in specific leaves at certain stages of plant development and the growth performance of plants (Monastraf, 1975; Munson and Nelson, 1973; Smith, 1962). The nutrient content of cashew leaves vary depending on the variety. The present investigation was undertaken to evaluate the nutrient content of index leaves (4th and 5th leaf from tip of matured branches) of selected cashew varieties with a view to diagnosing the nutritional status of the plant system. In cashew, no previous work has been reported investigating the effect of variety on nutrient content of leaf.

The study was conducted at Directorate of Cashew Research Experimental Station, Puttur, D.K., Karnataka in 2011. The experimental site is situated at 12°45'N latitude, 75°4'E longitude and 90 m above MSL, receiving average annual rainfall of 3500 mm. The soil is lateritic and sandy clay loam. To determine the nutrient concentration of leaf as influenced by variety, index leaf samples (4th and 5th leaf from tip of matured branches) from sixteen cashew varieties *viz.,* NRCC Selection-2, Bhaskara, Ullal-1, Ullal-2, Ullal-3, Vengurla-1, Vengurla-3, Vengurla-4, VRI-3, Madakkathara-2, Dhana, K-22-1, Priyanka, Kanaka, VTH- 30/4 and VTH-174 were collected in the month of June from 10 years old trees. Twenty leaf samples, five leaves each from east, west, north and south were taken individually

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from four trees of a variety from non-bearing fruit terminals. The samples were washed first under tap water followed by 0.1 N HCl, distilled water and double distilled water. The samples were then dried by spreading on clean blotting papers and final drying was done in an oven at 68 °C (Chapman and Pratt, 1961). The samples were sequentially ground by electrical grinder for further analysis. The nitrogen (N) content in the leaf samples was analysed by Kjeldahl method (AOAC, 1970). Phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were estimated by triacid mixture (9:4:1 HNO_3: $HClO_4$: H_2SO_4) as given by Jackson (1973).

Four soil samples, one in each direction of the cashew orchard were collected at the time of leaf sampling. Soils from three different depths (0-30 cm, 31-60 cm and 61-90 cm) were sampled from base of the plant at 1.5 m radius from 10 random locations from east, west, north and south directions of cashew orchard. The soil samples from each direction were bulked for each depth, thoroughly mixed and a composite sample taken for analysis. The soil samples were air dried and passed through 2 mm sieve. Soil pH and electrical conductivity (EC) were measured in a 1:2.5 (w/v) soil/water mixture. Organic carbon was determined by the wet oxidation method of Walkley and Black (1934), available N was estimated using the method of Subbiah and Asija (1956). Available phosphorus by Brays extractant - molybdophosphoric blue colour method (Jackson, 1973), available K extracted in 1 M NH_4OAc (Hanway and Heidel, 1952), and, exchangeable Ca and Mg by versenate (EDTA) titration method (Jackson, 1973). Available micronutrients *viz.,* Fe, Mn, Zn and Cu were extracted by DTPA extractant and estimated by atomic absorption spectrophotometer (Lindsay and Norwell, 1978). The data were statistically analysed using SAS 9.3.

Leaf macronutrients

Index leaf samples of sixteen cashew varieties were analyzed for N, P, K, Ca, Mg, Fe, Mn, Zn and Cu contents (Table 2). The concentration of different nutrients in leaf exhibited a wide range among the varieties. The N concentration of leaves differed significantly among 16 cashew varieties. Variety VRI-3 had the highest leaf N (1.70%) and variety Kanaka had the lowest leaf N (1.02%). Though the concentration of leaf N was the highest in VRI-3 but the reverse was true for the concentration of leaf Mg, Fe and Mn. The concentration of leaf N was more or less at par in seven varieties *viz.,* NRCC selection-2, Ullal-1,

Table 1. Physico-chemical properties of cashew orchard soils

S.No.	Depth (cm)	pH	EC (dS m^{-1})	Organic carbon (%)	Exch. Ca [cmol (p^+) kg^{-1}]	Exch. Mg [cmol (p^+) kg^{-1}]	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	DTPA -Fe (ppm)	DTPA -Mn (ppm)	DTPA -Zn (ppm)	DTPA -Cu (ppm)
1.	0-30	5.97	0.220	2.38	1.18	2.26	441	29.6	418	33.59	46.27	0.72	1.88
	31-60	5.90	0.049	1.04	0.49	0.98	258	21.5	130	13.69	22.92	0.54	0.41
	61-90	5.46	0.039	0.70	0.59	1.14	167	8.9	46	12.74	15.85	0.65	0.10
2.	0-30	6.09	0.321	1.79	2.09	1.19	437	26.3	416	28.85	49.58	0.84	1.76
	31-60	5.63	0.039	1.25	0.69	0.61	347	20.9	216	20.32	22.92	0.66	0.84
	61-90	5.52	0.036	0.88	1.16	0.41	197	11.2	77	11.79	13.52	0.78	0.45
3.	0-30	6.77	0.353	1.90	3.89	3.12	411	22.9	402	30.75	43.96	0.79	2.34
	31-60	5.73	0.035	1.19	0.87	0.66	256	17.0	238	17.48	21.75	0.78	1.17
	61-90	5.67	0.039	0.98	1.11	1.19	227	10.3	87	10.84	17.03	0.65	0.33
4.	0-30	5.68	0.338	2.23	2.52	1.86	346	27.9	600	24.11	33.54	0.82	1.48
	31-60	6.22	0.048	1.75	2.43	1.20	317	19.6	345	16.53	23.16	0.72	0.84
	61-90	6.59	0.222	1.03	0.89	0.61	167	7.2	36	5.16	7.83	0.65	0.24

Table 2. Leaf nutrient content in different varieties of cashew

S. No	Variety	Macronutrients (%)			Secondary nutrients (%)		Micronutrients (mg kg^{-1})			
		N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
1.	NRCC Sel-2	1.68	0.12	0.46	0.43	0.26	46.56	21.30	17.87	12.56
2.	Bhaskara	1.35	0.11	0.43	0.33	0.19	56.69	21.40	17.29	13.20
3.	Ullal-1	1.62	0.10	0.43	0.25	0.14	48.44	21.28	17.56	11.8
4.	Ullal-2	1.48	0.14	0.42	0.20	0.15	63.81	31.06	12.85	8.94
5.	Ullal-3	1.10	0.12	0.55	0.35	0.24	72.71	32.69	17.25	12.80
6.	Vengurla-1	1.51	0.10	0.41	0.21	0.20	38.17	18.21	21.71	10.00
7.	Vengurla-3	1.64	0.11	0.47	0.22	0.18	59.79	21.37	15.37	12.62
8.	Vengurla-4	1.69	0.11	0.43	0.30	0.25	43.50	17.09	14.56	14.06
9.	VRI-3	1.70	0.10	0.39	0.26	0.14	34.58	12.86	16.92	13.30
10.	Madakkathara-2	1.12	0.12	0.47	0.25	0.20	56.16	24.92	15.35	11.17
11	Dhana	1.50	0.12	0.53	0.23	0.18	69.23	28.86	19.01	10.10
12	K-22-1	1.68	0.11	0.44	0.40	0.25	71.34	33.95	16.76	8.00
13	Priyanka	1.57	0.15	0.47	0.21	0.27	51.45	25.28	15.53	9.95
14	Kanaka	1.02	0.14	0.60	0.26	0.30	48.27	20.86	15.29	7.66
15	VTH- 30/4	1.62	0.10	0.36	0.23	0.16	46.42	16.86	16.99	13.10
16	VTH-174	1.65	0.12	0.62	0.45	0.23	51.56	21.69	21.25	15.29
	Range	1.02-1.70	0.10-0.15	0.36-0.62	0.20-0.45	0.14-0.30	34.58-72.71	12.86-33.95	12.85-21.71	7.66-15.29
	Mean	1.496	0.117	0.468	0.286	0.209	53.67	23.11	16.97	11.53
	SEm	0.0403	0.0051	0.0122	0.0201	0.0120	2.3635	1.7517	0.2222	0.6280
	CD (P=0.05)	0.1163	0.0148	0.0353	0.0582	0.0347	6.8255	5.0587	0.6415	1.8135

Vengurla-3, Vengurla-4, K-22-1, VTH-30/4 and VTH-174. The concentration of leaf N was above the critical value of 1.4 per cent except in four varieties Kanaka, Madakkathara-2, Ullal-3 and Bhaskara. The concentration of N in leaves of cashew varieties compared well with the reported values of 1.19-1.79 per cent (Harishu Kumar *et al.*, 1982) and 0.96-1.43 per cent (Aikpokpodion *et al.*, 2009). Leaf N content of 1.51 per cent in the month of April is considered optimum for higher nut yield (Ghosh and Bose, 1986). Haag *et al.* (1975) reported that leaf N content ranging from 2.4 to 2.58 per cent indicated sufficiency whereas N content ranging from 0.98 to 1.38 per cent indicated N deficiency in cashew.

The varieties influenced the P concentration of leaves significantly. The values ranged from 0.10 to 0.15 per cent with a mean value of 0.117 per cent. The range of P levels in leaf compared well with the values 0.01-0.7 per cent reported by Aikpokpodion *et al.* (2009) and 0.06-0.18 per cent reported by Harishu Kumar *et al.* (1982). The concentration of leaf P was the highest in the variety Priyanka and was the least in varieties Ullal-1, Vengurla-1, VRI-3 and VTH-30/4. Varieties Priyanka, Ullal-2 and Kanaka were at par with respect to concentration of leaf P. Of the sixteen varieties, the values of P in the foliage of eight varieties were below the critical value of 0.12 per cent. According to Haag *et al.* (1975), leaf P content ranging from 0.16 to 0.20 per cent indicated sufficiency whereas P content ranging from 0.11 to 0.14 per cent indicated P deficiency in cashew. The leaf K concentration ranged from 0.36 to 0.62 per cent with a mean value of 0.468 per cent. Leaf K was significantly higher in the varieties VTH-174 (0.62%) and Kanaka (0.60%) while, other varieties did not differ significantly. However, the concentration of leaf K was below the critical value of 0.68 per cent in all the cashew varieties. The range of K levels in leaf were almost similar to that reported by Aikpokpodion *et al.* (2009) (0.31-0.62%) but were appreciably lower than those reported by Calton (1961) (0.97-1.69%). According to Haag *et al.* (1975), the leaf K content ranging from 1.11 to 1.29 per cent indicated sufficiency while 0.20 to 0.26 per cent indicated deficiency.

The concentration of Ca and Mg in leaf of cashew varieties exhibited wide variation. Highest concentration of 0.45 per cent was observed in variety VTH-174 and the lowest concentration of 0.20 per cent was in variety Ullal-2. The Ca concentration of leaf was at par in VTH-174, NRCC selection-2 and K-22-1 varieties. The range of Ca level in leaf was higher than the range reported by Calton (1961) (0.09-0.16%) but were compared well with Aikpokpodion *et al.* (2009) (0.28-0.76%). The concentration of leaf Ca in all the varieties was higher than the critical level (0.11% deficient). This could be ascribed to higher content of exchangeable Ca (1.18 to 3.89 cmol (p^+) kg^{-1}) in the soils. The concentration of Mg in leaves of cashew varied from as low as 0.14 per cent in variety Ullal-1 to as high as 0.30 per cent in variety Kanaka which fell below the critical levels (0.88%). The range of Mg level in leaf was compared well with standards of Calton (1961) (0.17-0.20%) and Aikpokpodion *et al.* (2009) (0.16-0.25%).

Leaf micronutrients

Considerable difference was also noted in the micronutrient concentration in the leaf of cashew varieties. A relatively wide range of leaf Fe was found among the varieties. The concentration of leaf Fe was found to be statistically significant in varieties Ullal-3, K-22-1 and Dhana (72.71, 71.34 and 69.23 ppm, respectively). The range of Fe levels in leaf (34.58-72.71 ppm) in the present study was lower than the range (200-620 ppm) reported by Aikpokpodion *et al.* (2009) but compared well with standards of Calton (1961) (45-95 ppm). Varieties differed significantly with respect to leaf Mn concentration. Higher concentration of Mn was recorded in varieties K-22-1 (33.95 ppm), Ullal-3 (32.69 mg kg^{-1}) and Ullal-2 (31.06 mg kg^{-1}). The range of Mn levels in leaf (12.86-33.95 ppm) were appreciably lower than those reported by Aikpokpodion *et al.* (2009) (40-210 ppm) and Calton (1961) (95-260 ppm). The concentration of leaf Zn ranged from 12.85 to 21.71 per cent with a mean value of 16.97 per cent. The variety Vengurla-1 recorded the highest concentration of 21.71 per cent whereas; variety Ullal-2 had the lowest concentration of 12.85 per cent. The values of Zn levels in leaf were appreciably lower than those reported by Aikpokpodion *et al.* (2009) (50-80 ppm). The concentration of Zn in the leaf were in the deficient range (<20 ppm) in all cashew varieties except VTH-174 and Vengurla-1. Copper concentration of the leaf ranged from 7.66 to 15.29 ppm with a mean of 11.53 ppm. Higher concentration of leaf Cu was noticed in varieties VTH-174 and Vengurla-4. The concentration of leaf Cu was not statistically significant in all the varieties except VTH-174 and Vengurla-4. The ranges of Cu levels in leaf were much lower than the values of 16-66 ppm reported by Calton (1961). The values of Cu in the foliage of all the varieties under study were above the critical value of 7 ppm.

Soil physico-chemical properties

Soil samples collected at three different depths (0-30, 31-60 and 61-90 cm) from base of the plant at 1.5 m radius were analysed for their physico-chemical properties (Table 1). The soil pH ranged from acidic (pH 5.46) to neutral (pH 6.77). No specific trend in soil pH along the depth of the soil was observed. The electrical conductivity (EC) of the surface soil (0-30 cm) varied from 0.22 to 0.35 dS m^{-1} with a mean value of 0.31 dS m^{-1}. The EC of the soil decreased with depth. On an average, the decrease in EC content of soil was about 86.1 and 89 per cent at 31-60 and 61-90 cm soil depths, respectively. The organic carbon content ranged from 1.79-2.38 per cent with a mean of 2.08 per cent in surface soils (0-30 cm), indicating that the soils were high in organic carbon. High organic carbon in the surface horizon could be due to litter fall and applied manure. The distribution of organic carbon in soils showed a decreasing trend with depth. A decrease in organic carbon content of about 37 and 56.7 per cent was noted at 31-60 and 61-90 cm soil depths as compared to 0-30 cm soil depth.

The exchangeable Ca content of the soil varied from 1.18 to 3.89 cmol (p^+) kg^{-1} soil with a mean value of 2.42 cmol (p^+) kg^{-1}. Except at one site of the orchard, the exchangeable Ca content of the orchard soil was above 1.5 cmol (p^+) kg^{-1} which is the critical value for ideal soils for cashew. Exchangeable Ca content of the soil showed a decreasing trend with depth. On an average there were about 64.4 and 55.6 per cent decrease in exchangeable Ca content at 31-60 and 61-90 cm soil depths, respectively compared to 0-30 cm soil depth. Exchangeable Mg content of the soils varied from 1.19 to 3.12 cmol (p^+) kg^{-1} with an average value of 2.11 cmol (p^+) kg^{-1}. Exchangeable Mg content of all four sites of the orchard was higher than the critical value of 1.0 cmol (p^+) kg^{-1} soil. Depth wise distribution of Mg also followed a similar trend to that of exchangeable Ca. On an average, 59.1 and 60.3 per cent decrease in exchangeable Mg content was observed at 31-60 and 61-90 cm soil depth as compared to surface soil (0-30 cm).

Based on the nutrient indexing in soils (Arora, 2002), the surface soil was medium in available N (346 to 441 kg ha^{-1}), medium to high in available P (22.9 to 29.6 kg ha^{-1}) and high in available K (402 to 600 kg ha^{-1}). A consistent decrease in the concentration of available N, P and K with the increase in soil depth was noted. A decrease of about 28.1 and 53.6 per cent available N, 26 and 64.8 per cent available P and 49.4 and 89.1 per cent available K was recorded at 31-60 and 61-90 cm soil depths, respectively as compared to 0-30 cm soil depth. Higher content of available N, P and K in surface soil as compared to sub soil could be ascribed to the accumulation of leaf litter besides supplementing the depleted nutrients through external sources. The lower phosphorus content in sub-surface horizons could be attributed to the fixation of released phosphorus by clay minerals and oxides of iron and aluminum (Leelavathi *et al*., 2009).

The DTPA extractable Fe, Mn, Zn and Cu contents in surface soils ranged from 24.11 to 33.59, 33.54 to 49.58, 0.72 to 0.84 and 1.48 to 2.34 mg kg^{-1}, respectively and were sufficient in the surface soils. The high contents of DTPA extractable Fe, Mn, Zn and Cu could be due to the high organic matter content of the soil and addition of sufficient organic manures to the cashew orchard. The critical limit for deficiency of the DTPA extractable Fe, Mn, Zn and Cu is 4.5, 2.0, 0.6 and 0.2 mg kg^{-1}, respectively (Tandon, 1999). The contents of DTPA extractable Fe, Mn, Zn and Cu decreased with the increase in soil depth. On an average, the available Fe, Mn, Zn and Cu contents decreased to an extent of about 12 per cent and 65.4 per cent (Fe), 47.6 per cent and 68.7 per cent (Mn), 14.8 per cent and 13.9 per cent (Zn) and, 56.3 per cent and 85.0 per cent (Cu) at depths 31-60 cm and 61-90 cm, respectively.

The analysis of leaf samples showed that K and Mg contents were not sufficient, while Ca and Cu contents of the all cashew varieties were sufficient. Out of 16 cashew varieties studied, the N content in the leaf of four varieties, P content of the eight varieties, Zn content in the leaf of fourteen varieties were below the critical value. Irrespective of the variety, the K and Mg content of the leaves in all the cashew varieties were below the critical value. Soil analysis up to 90 cm soil depth revealed that cashew orchard was high in organic carbon, medium in available N, medium to high in available P, high in available K, high in exchangeable Ca and Mg, and sufficient in DTPA extractable Fe, Mn, Zn and Cu. All the nutrients were higher in surface than subsurface soils. The results of the present study indicated that the leaf nutrient concentrations vary considerably among different varieties grown under the same conditions which emphasize due consideration while formulating leaf nutrient standards of cashew for diagnostic and fertilizer recommendation purpose.

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