DOI : 10.5958/0974-0112.2021.00010.4

Indian J. Hortic., 78(1), March 2021: 69-77

DRIS indices as nutritional guide for aonla cultivation

Arti Devi*, Parshant Bakshi, R.K. Samnotra, Vikas Sharma, A.K. Mondal, Kiran Kour, Nirmal Sharma, Mudasir Iqbal and Gurwinder Singh

Division of Fruit Science, S.K. University of Agricultural Sciences and Technology of Jammu-180009, J&K, India.

ABSTRACT

Diagnosis and recommendation integrated system (DRIS) norms were computed from the data on leaf mineral composition, soil available nutrients, and corresponding mean fruit yield of 100 Aonla orchards in Akhnoor, Raya and Purmandal areas of Jammu region during 2016 and 2017. The DRIS norms derived primarily from leaves suggested optimum leaf macronutrient concentration as 1.74-2.96% nitrogen (N), 0.13-0.23% phosphorus (P), 0.73-1.04% potassium (K), 0.18-0.27% sulphur (S), 1.72-1.93% calcium (Ca) and 0.35-0.55% magnesium (Mg) while, the optimum level of micronutrients as 9.34-11.93 ppm zinc (Zn), 89.24-156.98 ppm iron (Fe), 7.24-10.42 ppm copper (Cu) and 8.97-21.64 ppm manganese (Mn) concerning fruit yield of 16.55-114.24kg/tree. Likewise, DRIS indices for soil fertility developed from soil samples collected at 0-30 cm depth corresponding to a similar level of fruit yield, the optimum limit of available soil nutrients (mg/ Kg) was observed as 109.44-442.78 kg/ha N, 8.84-15.46 kg/ha P, 93.17-199.15 kg/ha K, 6.79-11.42 mg/kg S, 0.35-4.36 mg/kg Zn, 2.81-13.42 mg/kg Fe, 1.44-4.43 mg/kg Cu and 0.28-2.84 mg/kg Mn. Primary DRIS indices developed based on leaf revealed K as deficient in 55 per cent of the orchards, followed by N in 25 per cent and Ca and Mg in 15 and 5 per cent, respectively, whereas Mg was identified as excess in 45 per cent orchards, followed by N, P, K and Ca.

Keywords: *Emblica officinalis*, Leaf and soil nutrients, Micro-nutrients, Deficiency and excess, DRIS

INTRODUCTION

Plant nutrition plays an important role on production of quality fruits of any fruit orchard and is directly related to the nutritional status of trees and soil. Nutrients are known to influence each physiological process within plant system. A considerable amount of various nutrients has been reported to drain off every year with yield, pruning wood and fallen leaves from the plant and soil system. The key to mineral nutrition of any orchard is the judicious application of fertilizers on the basis of leaf and soil analysis. Development of soil-plant nutrient diagnostic tool has been the key area of research, world-wide using a variety of diagnostic methods. The scope of traditional diagnostic tool is limited because of strong influence of leaf age. The sufficiency range limit and critical nutrient concentration developed by using leaves index as interpretation method, provides little time in the plant active growing season for fertilizer application to be more effective. Therefore, to define the existing fertility of soil and availability of nutrients to the plants, survey of orchards for leaf and soil nutrient status has been carried out by several workers (Wallace and Proebsting, 17).

DRIS based on nutrient balance indicates not only the most limiting nutrient, but also the order, where the other nutrients are likely to become limiting and was able to diagnose plant nutrient needs early in the life of crops than sufficiency range method (Mourao, 11). DRIS norms for fruit plants (Apparao *et al*., 3) have been developed for interpreting leaf tissue analysis. In order to set up the DRIS norms, it is necessary to use a representative value of leaf nutrient concentrations with their yields to get accurate estimates of means and variances of certain nutrient ratios that discriminate between high and low-yielding groups. In this study, DRIS approach employed for interpreting leaf nutrient analysis data collected from different aonla orchards of Jammu region. The sufficiency and deficiency ranges derived with the DRIS technique, were used for interpreting leaf and soil nutrients analysis with fruit yield and quality data of aonla orchards.

MATERIALS AND METHODS

The present study was carried out during 2016 and 2017 at farmer's field of Akhnoor, Raya and Purmandal areas of Jammu region of JK UT. One hundred aonla orchards were selected; among them sixty were selected in Akhnoor, ten in Raya and thirty orchards in Purmandal. The site of study area falls in subtropical aonla growing region of Jammu province lying between 33° 05' 06'' to 32^0 30' 987'' North of equator and 75° 02' 861'' East of prime meridian. In each orchard, ten uniform healthy aonla trees in the age of 10-25 years and having good yield record in the preceding years were selected.

*Corresponding authorl: artiskuastj@gmail.com

The soil samples were collected from the basin of the tree at two different depths i.e. 0-15 cm and 15-30 cm, air dried in shade and ground with the help of pestle and mortar and passed through a 2 mm sieve. Available nitrogen, phosphorus and potassium content were determined as per the methods described by Subbiah and Asija (16), Olsen *et al*. (12) and Jackson, (8), respectively. The soil available sulphur and available micronutrients (DTPA extractable) Zn, Cu, Fe and Mn content were determined as described by Lindsay and Norvell (10).

For leaf analysis, the washed leaf samples were cleaned, dried, ground and stored as per the method outlined by Chapman (6). Total nitrogen was estimated by method as suggested by Jackson (8), phosphorus by Chapman and Pratt (7), potassium by A.O.A.C (1), while nutrients such as (Ca, Mg, Cu, Zn, Fe and Mn) were determined as per the methods described by Bradfield and Spencer (5).

DRIS norms were derived by using the procedure developed by Walworth and Sumner (18). DRIS norms were derived from a database of 2000 observations of leaf nutrient compositions and yield gathered during 2016 and 2017 from major aonla growing areas of Jammu region. High yielding population was separated from the low yielding population at an average yield level of 55 kg/tree. The yield population above of 55 kg/tree was treated as high yielding sub-population and the yield population below of 55 kg/tree was treated as low yielding population. For the two sub-population, the means, standard deviations, variances and coefficient of variation (CV) were calculated for each nutrient element concentration as well as for ratios, their reciprocals and their products (e.g., N/P, P/N and NxP) of all the 55 nutrient pairs. Variance ratio was calculated by dividing the variance of low yielding sub-population with that of high yielding sub-population. The expression having the highest and significant variance ratio, for each pair of nutrient was selected as DRIS norm expression with corresponding mean value in the high yielding sub-population, considered as norm value for the selected expression.

RESULTS AND DISCUSSION

DRIS norms were calculated and are presented in Table 1, using leaf N, P, K, Ca, Mg, S, Fe, Zn, Cu, Mn and B contents and yield observations. In all, 55 nutrient expressions producing highest variance ratios were selected as DRIS norms expression. The mean values of expressions in the high yielding sub-populations were selected as the norm values which were then compared with norms derived from mean of the sufficiency ranges. The nutrient pairs involving N/K, N x S, N/Mg, N/Zn, N/Fe, N/Cu, P/N, P/K, P x S

Table 1. Diagnosis and Recommendation Integrated System (DRIS) norms for *aonla*.

S. No.	Nutrient expression	Mean	SD	CV (%)
1.	N	2.337	0.458	19.601
2.	P	0.184	0.037	20.282
3.	K	0.882	0.117	13.298
4.	S	0.229	0.033	14.628
5.	Ca	1.829	0.077	4.222
6.	Mg	0.451	0.077	17.151
7.	Zn	0.001	0.000	8.972
8.	Fe	0.012	0.003	20.633
9.	Cu	0.001	0.000	13.470
10.	Mn	0.002	0.001	31.044
11.	P/N	0.081	0.021	26.343
12.	N/K	2.633	0.260	9.890
13.	N×S	0.529	0.110	20.883
14.	Ca/N	0.810	0.144	17.764
15.	N/Mg	5.161	0.352	6.821
16.	N/Zn	2178.943	294.193	13.502
17.	N/Fe	191.123	18.327	9.590
18.	Mn /N	0.001	0.000	15.851
19.	N/Cu	2622.902	258.072	9.900
20.	P/K	0.211	0.047	22.032
21.	P×S	0.042	0.010	22.888
22.	Ca/P	10.395	2.358	22.683
23.	P/Mg	0.417	0.100	24.066
24.	P/Zn	173.494	35.612	20.529
25.	P/Fe	15.496	4.139	26.715
26.	P/Mn	133.407	53.128	39.787
27.	P/Cu	210.475	46.015	21.854
28.	S/K	0.265	0.058	21.796
29.	Ca/K	2.099	0.191	9.097
30.	K/Mg	1.969	0.119	6.066
31.	K/Zn	825.512	51.432	6.230
32.	K/Fe	72.999	7.874	10.789
33.	K/Mn	619.482	163.871	26.453
34.	K/Cu	999.621	22.709	2.279
35.	SxCa	0.418	0.060	14.315
36.	S/Mg	0.526	0.140	26.608
37.	S/Zn	216.775	40.039	18.470
38.	S/Fe	19.555	5.748	29.396
39.	S/Mn	169.624	72.300	42.624

S. No.	Nutrient expression	Mean	SD	CV (%)
40.	S/Cu	264.163	58.676	22.212
41.	Ca/Mg	4.148	0.581	13.996
42.	Ca/Zn	1724.829	89.143	5.168
43.	Ca/Fe	153.925	26.905	17.484
44.	Ca/Cu	2091.779	192.738	9.214
45.	Ca/Mn	1320.317	438.007	33.174
46.	Mg/Zn	421.538	44.530	10.564
47.	Mg/Fe	37.065	3.151	8.501
48.	Cu/Mg	0.002	0.000	5.890
49.	Mn/Mg	0.003	0.001	17.509
50.	Fe/Zn	11.490	1.756	15.280
51.	Cu/Zn	0.827	0.050	6.019
52.	Mn/Zn	1.417	0.353	24.937
53.	Cu/Fe	0.073	0.008	10.763
54.	Mn/Fe	0.123	0.021	17.284
55.	Mn/Cu	1.700	0.357	20.993

, P/Mg, P/Zn, P/Fe, P/Cu, P/Mn, K/Mg, K/Zn, K/Fe, K/Cu, K/Mn, S/K, S/Mg, S/Zn, S/Fe, S/Cu, S/Mn, Ca/N, Ca/P, Ca/K, Ca/Mg, Ca/Zn, Ca/Fe, Ca/Cu, Ca/Mn, Mg/Zn, Mg/Fe, Fe/Zn, Cu/Mg, Cu/Zn, Mn/N, Mn/Mg, Mn/Zn, Mn/Fe and Mn/Cu with corresponding mean values of 2.63, 0.53, 5.16, 0.22, 0.02, 0.26, 0.08, 0.21, 0.04, 0.41, 0.02, 0.55, 0.002, 0.02, 0.01, 1.96, 0.08, 0.007, 0.10, 0.06, 0.26, 0.53, 0.02, 0.002, 0.02, 0.12, 0.81, 10.39, 2.11, 4.15, 0.17, 0.01, 0.21, 0.13, 0.04, 0.004, 11.49, 19.72, 0.83, 0.07, 33.22, 1.42, 0.12 and 1.70, respectively, highest variance ratios among the particular nutrient pairs, were selected as DRIS norms. Similarly, Savita *et al*. (14) reported that the nutrient pair in litchi are P/N (0.292), Ca/N (1.274), Mg/N (0.438), P/Mg (0.667), Ca/S (10.08), Zn/S (116.7), Fe/Cu (17.13) and Cu/B (0.252).

The variations in some of the norm values from the means of published sufficiency ranges could be attributed to variation in management, cultural, manorial and agro-climatic conditions rather than changes in the physiological processes within the plant system (Kenworthy, 9). Diagnosis nutrient status of aonla orchards using DRIS Diagnostic Approach and Sufficiency Range Approach: DRIS norms for N, P, K, Ca, Mg and S derived in the current study were used to calculate the DRIS indices for N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn. DRIS diagnostic approach and sufficiency range approach (Shear and Faust, 15) were used to work out DRIS order of nutrient requirements, orchards having positive and negative indices and nutrient deficiencies and excesses are presented in Table 2- 3.

DRIS diagnostic approach diagnosed foliar N as the major relative excess in 12 per cent orchards. Positive DRIS indices for N were observed in 69 per cent orchards indicating nutrient status as sufficient to excess in different orchards. However, sufficiency range approach identified none of the orchards as deficient or excess in foliar N. DRIS approach identified foliar P as the major relative excess in 10 per cent orchards. Positive DRIS indices for P were observed in 67 per cent orchards. Major relative excesses in P were observed only in 7 per cent orchards whereas, sufficiency range approach identified 3 per cent orchards as deficient. Leaf K was identified as major relative excess in 3 per cent orchards. Positive DRIS indices for K were identified in 54 per cent orchards. Sufficiency range approach identified 15 per cent orchards as deficient in leaf K. DRIS approach diagnosed foliar S as the major relative excess in 6 per cent orchards with 70 per cent orchards were diagnosed to have positive DRIS indices for S which provide an indication of relative degree of leaf S sufficiency to excess in different orchards whereas, sufficiency range approach identified 10 per cent orchards as deficient for leaf S.

Diagnosis of leaf Ca status by DRIS approach identified 10 per cent having Ca as the major relative deficiency. In all, 55 per cent orchards were diagnosed to have negative DRIS indices for Ca which give an indication of widespread foliar Ca sufficiency in different orchards whereas, sufficiency range approach identified 26 per cent orchards as deficient in leaf Ca. Foliar Mg was diagnosed as the major relative deficient in 8.0 per cent orchards with negative DRIS indices for Mg were observed in 67 per cent orchards during which indicate relative degree of foliar Mg insufficiency in different orchards. On the other hand, sufficiency range approach identified 19 per cent orchards as deficient for leaf Mg.

DRIS diagnostic approach diagnosed foliar Zn as the major relative deficient in 4 per cent orchards with negative indices for Zn was observed in 54 per cent orchards indicating nutrient status as sufficient to excess in different orchards. However, sufficiency range approach identified 30 per cent of the orchards as deficient in foliar Zn. DRIS diagnostic approach revealed Fe as the major relative deficiency in 25 per cent orchards. However, sufficiency range approach could diagnose only 13 per cent orchards deficient in leaf Fe. Leaf Cu was identified as major relative excess in 22 per cent orchards. Positive DRIS indices for Cu were identified in 52 per cent orchards. Sufficiency range approach identified 17 per cent any orchards as deficient in leaf Cu. DRIS approach diagnosed foliar Mn as the major relative excess in 18 per cent orchards with 64 per cent positive indices. DRIS indices for Mn which provide an indication of relative degree of leaf Mn sufficiency to excess in different orchards, whereas

Table 2. DRIS indices, nutrient imbalance index (NII) and order of requirement of leaf of *aonla* orchards

Location	Orchard No.	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	Nutrient Imbalance Index (NII)	Order of requirement	Yield (kg/ plant)
Akhnoor	1.	31.63	5.38	3.86	5.29	23.46	-21.98	-10.13	-30.27	-1.66	-5.58	139.24	Fe>Mg>Zn>Mn>Cu>K>S>P>Ca>N	29.74
	2.	2.7	5.6	-3.07	0.52	-9.5	-4.99	2.16	-1.47	10.01	-1.96	35.84	Ca>Mg>K>Mn>Fe>S>Zn>N>P>Cu	69.56
	3.	29.09	-13.64	16.05	4.5	38.64	-18.6	2.91	-17.68	-37.56	-3.71	182.38	Cu>Mg>Fe>P>Mn>Zn>S>K>N>Ca	24.37
	4.	-4.92	-21.95	6.78	9.31	-1.29	-9.22	8.45	0.03	16.77	-3.96	82.68	P>Mg>N>Mn>Ca>Fe>K>Zn>S>Cu	69.72
	5.	9.48	-24.85	1.47	0.5	-7.62	-5.42	2.45	8.92	10.65	4.42	75.78	P>Ca>Mg>S>K>Zn>Mn>Fe>N>Cu	84.90
	6.	8.13	-28.21	2.12	-16.51	-0.83	9.88	-2.75	9.52	8.95	9.7	96.6	P>S>Zn>Ca>K>N>Cu>Fe>Mn>Mg	96.15
	7.	5.05	-24.07	3.24	4.54	-13.06	3.38	4.24	5.33	2.62	8.73	74.26	P>Ca>Cu>K>Mg>Zn>S>N>Fe>Mn	88.35
	8.	3.69	-15.09	1.04	1.02	-8.62	2.11	-0.64	5.08	6.45	4.96	48.7	P>Ca>Zn>S>K>Mg>N>Mn>Fe>Cu	83.75
	9.	6.01	-16.87	-0.8	-0.04	-11.39	3.84	-3.9	5.58	8.98	8.59	66	P>Ca>Zn>K>S>Mg>Fe>N>Mn>Cu	88.60
	10.	16.68	-23.07	-4.13	15.23	15.32	-16.95	12.41	-26.35	-3.93	14.79	148.86	Fe>P>Mg>K>Cu>Zn>Mn>S>Ca>N	31.99
	11.	8.04	-12.55	2.55	15.82	15.15	-20.9	6.8	-27.75	-2.48	15.32	127.36	Fe>Mg>P>Cu>K>Zn>N>Ca>Mn>S	32.70
	12.	51.88	-2.86	68.15	24.66	121.56	-1.7	-332.61	-5.87	62.08	14.71	686.08	Zn>Fe>Mg>P>Mn>S>N>Cu>K>Ca	23.70
	13.	48.31	-0.59	54.14	19.61	101.37	20.89	-303.5	-11.75	47.76	23.76	631.68	Zn>Fe>P>S>Mg>Mn>Cu>N>K>Ca	25.20
	14.	-11.25	-15.12	-3.96	13.45	-0.51	-2.54	10.47	1.58	19.73	-11.85	90.46	P>Mn>N>K>Mg>Ca>Fe>Zn>S>Cu	66.40
	15.	-2.43	-13.11	-2.06	-9.57	-7.37	8.32	-3.41	9.16	7.28	13.19	75.9	P>S>Ca>Zn>N>K>Cu>Mg>Fe>Mn	99.82
	16.	-3.04	-15.99	12.53	-1.63	-4.88	7.9	-6.17	1.28	-0.76	10.76	64.94	P>Zn>Ca>N>S>Cu>Fe>Mg>Mn>K	95.71
	17.	5.25	-19.28	4.57	-4.52	-13.95	7.03	0.42	5.08	4.8	10.6	75.5	P>Ca>S>Zn>K>Cu>Fe>N>Mg>Mn	111.45
	18.	-0.55	-13.97	3.89	-11.35	-8.96	0.86	3.57	8.77	7.12	10.62	69.66	P>S>Ca>N>Mg>Zn>K>Cu>Fe>Mn	97.72
	19.	1.98	-10.93	-2.08	-10.98	-16.98	3.95	3.89	20.25	7.83	3.07	81.94	Ca>S>P>K>N>Mn>Zn>Mg>Cu>Fe	114.24
	20.	16.27	-3.08	-2.64	4.3	-9.55	-4.56	0.65	-6.56	8.02	-2.85	58.48	Ca>Fe>Mg>P>Mn>K>Zn>S>Fe>N	70.51
	21.	-2.55	8.92	36.38	11.42	36.99	-20.75	-3.67	-22.04	-50.22	5.52	198.46	Cu>Fe>Mg>Zn>N>Mn>P>S>K>Ca	22.90
	22.	11.56	-15.37	1.06	-5.47	-7.41	7.01	-8.4	5.39	0.37	11.26	73.3	P>Zn>Ca>S>Cu>K>Fe>Mg>Mn>N	98.15
	23.	4.86	-0.47	-1.82	1.22	-10.11	-2.92	5.18	-4.8	9.8	-0.94	42.12	Ca>Fe>Mg>K>Mn>P>S>N>Zn>Cu	76.73
	24.	32.38	4.93	-5.73	7.82	7.55	-19.63	0.85	-19.36	1.9	-10.71	110.86	Mg>Fe>Mn>K>Zn>Cu>P>Ca>S>N	37.85
	25.	34.6	4.42	-2.84	8.79	4.72	-22.89	-0.05	-19.31	-7.29	-0.15	105.06	Mg>Fe>Cu>K>Mn>Zn>P>Ca>S>N	39.35
	26.	13.53	3.71	-7.65	8.51	11.1	-20.56	1.09	-22.91	-2.99	16.17	108.22	Fe>Mg>K>Cu>Zn>P>S>Ca>N>Mn	34.86
	27.	28.26	1.04	-3.05	4.13	8.16	-24.16	-0.16	-23.41	-7.79	16.98	117.14	Mg>Fe>Cu>K>Zn>P>S>Ca>Mn>N	36.55
	28.	19.71	3.69	-1.83	5.06	7.59	-23.84	0.26	-22.29	-6.01	17.66	107.94	Mg>Fe>Cu>K>Zn>P>S>Ca>Mn>N	37.86
	29.	31.82	2.68	-1.69	4.84	13.41	-29.68	2.02	-29.86	-6.74	13.2	135.94	Fe>Mg>Cu>K>Zn>P>S>Ca>Mn>N	32.75

Location	Orchard No.	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	Nutrient Imbalance Index (NII)	Order of requirement	Yield (kg/ plant)
	30.	28.26	1.65	0.93	4.78	19.51	-27.47	-9.94	-30.03	-2.21	14.52	139.3	Fe>Mg>Zn>Cu>K>P>S>Ca>Mn>N	31.99
	31.	12.11	2.13	5.17	7.3	24.62	-19.1	-12.72	-25.07	-3.41	8.97	120.6	Fe>Mg>Zn>Cu>P>K>S>Mn>Ca>N	25.20
	32.	-4.83	3.02	-1.62	-0.53	-12.07	3.18	-0.08	1.08	8.89	2.96	38.26	Ca>N>K>S>Zn>Fe>Mn>P>Mg>Cu	86.18
	33.	2.38	-15.97	0.51	-3.06	-11.44	4.09	0.64	4.88	8.84	9.13	60.94	P>Ca>S>K>Zn>N>Mg>Fe>Cu>Mn	89.10
	34.	3.04	-15.57	-0.06	-3.13	-1.8	4.54	1.72	5.02	-2.32	8.56	45.76	P>S>Cu>Ca>K>Zn>N>Mg>Fe>Mn	90.52
	35.	10.1	0.41	-4.24	-15.04	-5.21	0.36	1.87	2.82	-1.27	10.2	51.52	S>Ca>K>Cu>Mg>P>Zn>Fe>N>Mn	93.47
	36.	-24.13	4.43	-6.26	4.7	-6.93	-13.68	0.48	68.22	2.72	-29.55	147.24	Mn>N>Mg>Ca>K>Zn>Cu>P>S>Fe	65.28
	37.	-11.67	7.31	3.5	7.57	0.51	-2.49	8.27	-1.24	16.54	-28.3	87.4	Mn>N>Mg>Fe>Ca>K>P>S>Zn>Cu	58.16
	38.	17.19	6.46	1.06	8.27	23.01	-24.3	-9.61	-30.32	-1.36	9.6	131.18	Fe>Mg>Zn>Cu>K>P>S>Mn>N>Ca	28.59
	39.	2.67	5.29	16.01	16	36.57	-9.91	-1.51	-15.72	-46.44	-2.96	153.08	Cu>Fe>Mg>Mn>Zn>N>P>S>K>Ca	22.76
	40.	12.08	5.13	-3.42	1.67	17.55	-10.89	10.87	-42.43	-7.15	16.59	127.78	Fe>Mg>Cu>K>S>P>Zn>N>Mn>Ca	32.81
	41.	-10.32	8.31	3.34	12.34	-4.4	-13.63	4.32	-6.28	13.6	-7.28	83.82	Mg>N>Mn>Fe>Ca>K>Zn>P>S>Cu	78.34
	42.	8.56	4.98	6.41	-5.29	-13.13	1.61	-8.14	0.08	-1.2	6.12	55.52	Ca>Zn>S>Cu>Fe>Mg>P>K>Mn>N	96.88
	43.	3.48	5.36	-1	-4	-8	4.18	-8.9	3.8	-0.69	5.77	45.18	Zn>Ca>S>P>Cu>N>Fe>Mg>P>Mn	97.76
	44.	14.21	2.26	-0.17	7.57	25	-7.31	-11.79	-27.83	-5.6	3.66	105.4	Fe>Zn>Mg>Cu>K>P>S>N>Mn>Ca	24.36
	45.	-27.85	5.76	3.01	15.3	19.44	-5	-0.31	-27.39	1.74	15.3	121.1	Fe>N>Mg>Zn>Cu>K>S>P>Mn>Ca	29.78
	46.	-27	5.75	1.74	11.28	14.91	-9.76	-0.99	-15.86	0.57	19.36	107.22	N>Mn>Fe>Mg>Zn>Cu>K>P>S>Ca	34.57
	47.	9.1	-20.42	9.17	-3.9	-10.35	3.37	-4.96	4.53	3.73	9.73	79.26	P>Ca>Zn>S>Mg>Cu>Fe>N>K>Mn	68.27
	48.	8.06	-17.78	7.28	-3.81	-12.6	3.16	-1.92	4.9	3.08	9.63	72.22	P>Ca>S>Zn>Cu>Mg>Fe>K>N>Mn	98.95
	49.	6.35	-18.94	-0.16	1.01	-8.37	1.77	-1.32	4.26	11.97	3.43	57.58	P>Ca>Zn>K>S>Mg>Mn>Fe>N>Cu	110.38
	50.	2.67	-19.77	1.32	-3.18	-2.34	10.6	-4.27	2.59	4.75	7.63	59.12	P>Zn>S>Ca>K>Fe>N>Cu>Mn>Mg	80.45
	51.	-1.44	4.25	-0.25	-6.38	-3.41	10.01	-9.12	-1.15	2.45	5.04	43.5	Zn>S>Ca>N>Fe>K>Cu>P>Mn>Mg	95.56
	52.	-23.85	5.52	0.69	7.3	-0.02	-6.49	12.03	-2.02	16.58	-9.74	84.24	N>Mn>Mg>Fe>Ca>K>P>S>Zn>Cu	94.20
	53.	3.56	5.31	1.82	-12.5	-9.71	4.79	-8.57	6.03	0.46	8.81	61.56	S>Ca>Zn>Cu>K>N>Mg>P>Fe>Mn	58.81
	54.	-1.66	2.8	-0.38	-28.81	-8.59	6.19	4.37	4.64	8.01	13.43	78.88	S>Ca>N>K>P>Zn>Fe>Mg>Cu>Mn	97.78
	55.	0.31	1.8	1.36	-19.09	-2.16	9.26	-6.95	0.98	1.61	12.88	56.4	S>Zn>Ca>N>Fe>K>Cu>P>Mg>Mn	99.35
	56.	-0.66	-0.86	-1.4	-15.39	-8.7	0.19	-9.56	19.56	-0.04	16.86	73.22	S>Zn>Ca>K>P>N>Cu>Mg>Mn>Fe	94.72
	57.	3.38	2.77	-2.85	-1.1	-13.97	0.21	-1.5	1.03	6.99	5.04	38.84	Ca>K>Zn>S>Mg>Fe>P>N>Mn>Cu	99.38
	58.	7.42	-1.41	-4.5	-14.17	-10.94	-1.32	-0.64	16.53	-3.01	12.04	71.98	S>Ca>K>Cu>Mg>P>Zn>N>Mn>Fe	87.56
	59.	6.36	4.26	0.65	-8.48	-13.83	2.48	-1.28	0.42	-2.24	11.66	51.66	Ca>S>Cu>Zn>K>Fe>Mg>P>N>Mn	98.48
	60.	2.18	6.44	-1.66	4.19	-11.38	-1.58	0.38	-3.32	7.25	-2.5	40.88	Ca>Fe>Mn>K>Mg>Zn>N>S>P>Cu	99.76

Location	Orchard No.	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	Nutrient Imbalance Index (NII)	Order of requirement	Yield (kg/ plant)
Raya	1.	-17.08	-0.96	4.39	9.34	11.68	-9.51	6.02	-11.43	3.02	4.53	77.96	N>Fe>Mg>P>Cu>K>Mn>Zn>S>Cu	31.74
	2.	-10.62	6.73	-0.44	10.8	-9.34	-3.09	1.88	-0.54	9.57	-4.95	57.96	N>Ca>Mn>Mg>Fe>K>Zn>P>Cu>S	78.22
	3.	-34.77	4.38	1.55	16.31	18.84	-1.7	7.14	-28.61	-0.54	17.4	131.24	N>Fe>Mg>Cu>K>P>Zn>S>Mn>Ca	17.74
	4.	12.92	19.54	71.59	37.56	69.18	-36.98	1.09	-67.06	-59.62	-48.22	423.76	Fe>Cu>Mn>Mg>Zn>N>P>S>Ca>K	23.36
	5.	-13.3	11.23	-0.88	11.97	-4.42	-1.92	4.3	-5.93	13.65	-14.7	82.3	Mn>N>Fe>Ca>Mg>K>Zn>P>S>Cu	70.32
	6.	-10.77	11.64	1.23	1.8	-5.52	-1.54	4.59	-6.19	12.86	-8.1	64.24	N>Mn>Fe>Ca>Mg>K>S>Zn>P>Cu	62.91
	7.	-7.61	2.87	2.7	10.59	-9	-1.6	5.57	-7.06	12.87	-9.33	69.2	Mn>Ca>N>Fe>Mg>K>P>Zn>S>Cu	68.20
	8.	-10.19	6.46	4.91	9.55	30.74	-4.88	-6.43	-26.17	-1.03	-2.96	103.32	Fe>N>Zn>Mg>Mn>Cu>K>P>S>Ca	21.53
	9.	-6.86	36.85	9.68	32.61	31.35	-34.95	-14.95	-31.5	-10.67	-11.56	220.98	Mg>Fe>Zn>Mn>Cu>N>K>Ca>S>P	17.44
	10.	7.37	24.46	61.69	34.3	60.28	-43.84	-11.19	-29.18	-85.49	-18.4	376.2	Cu>Mg>Fe>Mn>Zn>N>K>P>S>Ca	30.34
Purmandal	1.	13.4	-4.56	-0.71	16.93	17.17	-12.89	-8.39	-32.18	-1.96	13.19	121.38	Fe>Mg>Zn>P>Cu>K>Mn>N>S>Ca	31.32
	2.	10.36	17.64	-7.9	14.78	10.29	-19.23	-4.42	-28.74	-5.71	12.93	132	Fe>Mg>K>Cu>Zn>Ca>N>Mn>S>P	24.74
	3.	-11.98	6.44	1.01	10.3	-2.37	-10.61	19.57	-8.36	10.77	-14.77	96.18	Mn>N>Mg>Fe>Ca>K>P>S>Cu>Zn	67.20
	4.	3.71	16.99	-6.29	-3.4	-2.84	-3.01	0.82	-2.57	-2.21	-1.2	43.04	K>S>Mg>Ca>Fe>Cu>Mn>Zn>N>P	55.58
	5.	15.5	22.67	-3.49	16.35	20.2	-19.35	-17.05	-25.75	-10.75	1.67	152.78	Fe>Mg>Zn>Cu>K>Mn>N>S>Ca>P	28.73
	6.	13.02	14.53	4.53	5.55	25.29	-12.3	-29.52	-33.67	1.09	11.48	150.98	Fe>Zn>Mg>Cu>K>S>Mn>N>P>Ca	20.35
	7.	13.15	53.42	11.21	8.67	37.49	-47.78	-19.97	-28.74	-13.21	-14.24	247.88	Mg>Fe>Zn>Mn>Cu>S>K>N>Ca>P	22.24
	8.	1.95	2.22	-3.57	-4.77	-3.78	0.77	0.21	0.32	-2.51	9.16	29.26	S>Ca>K>Cu>Zn>Fe>Mg>N>P>Mn	74.45
	9.	-7.66	9.27	-0.26	14.43	-4.38	-9.83	3.72	-7.24	13.81	-11.86	82.46	Fe>Mg>Cu>K>Mn>Zn>Ca>N>S>P	72.68
	10.	17.08	34.16	1.33	17.62	29.22	-30.09	-17.81	-30.64	-8.54	-12.33	198.82	Fe>Mg>Mn>Cu>Zn>K>N>P>S>Ca	35.24
	11.	10.87	-9.66	-0.4	2.26	11.62	-16.1	3.53	-19.95	-3.11	20.94	98.44	Fe>Mg>P>Cu>K>S>Zn>N>Ca>Mn	20.89
	12.	10.27	12.72	12.36	38.36	35.48	-48.29	-15.03	-21.93	-8.95	-14.99	218.38	Mg>Fe>Zn>Mn>Cu>N>K>P>Ca>S	37.36
	13.	-12.06	7.27	0.4	12.99	-1.85	-7.67	5.99	-8.04	15.04	-12.07	83.38	Mn>N>Fe>Mg>Ca>K>Zn>P>S>Cu	64.25
	14.	17.04	19.77	-5.91	9.57	6.89	-14.78	-0.8	-20.17	-6.51	-5.1	106.54	Fe>Mg>Cu>K>Mn>Zn>Ca>S>N>P	37.36
	15.	10.97	1.02	-4.13	-1	11.89	-17.81	2.39	-19.3	-3.17	19.14	90.82	Fe>Mg>K>Cu>S>P>Zn>N>Ca>Mn	36.86
	16.	-9.12	5.69	4.73	5.81	-0.11	-4.02	7.34	-7.82	15.23	-17.73	77.6	Mn>N>Fe>Mg>Ca>K>P>S>Zn>Cu	60.54
	17.	11.51	4.17	-4.61	7.34	7.01	-16.16	-0.34	-21.17	-5.62	17.87	95.8	Fe>Mg>Cu>K>Zn>P>S>Ca>N>Mn	38.94
	18.	7.52	4.46	-1.72	8.55	13.83	-20.49	-1.6	-25.97	-0.74	16.16	101.04	Fe>Mg>K>Zn>Cu>P>N>S>Ca>Mn	33.86
	19.	9.05	5.12	-5.58	16.65	10.09	-20.56	-2.77	-23.36	-4.53	15.89	113.6	Fe>Mg>K>Cu>Zn>P>N>Ca>Mn>S	34.86
	20.	13.04	7.43	2.91	14.13	20.88	-15.99	-8.27	-39.05	-4.01	8.93	134.64	Fe>Mg>Zn>Cu>K>P>Mn>N>S>Ca	27.22

Location	Orchard No.	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	Nutrient Imbalance Index (NII)	Order of requirement	Yield (kg/ plant)
	21.	12.96	8.29	2.18	2.49	-0.49	9.48	4.29	10.05	2.62	-51.87	104.72	Mn>Ca>K>S>Cu>Zn>P>Mg>Fe>N	78.56
	22.	-5.08	-6.51	2.04	6.02	-0.82	3.05	7.65	-5.08	16.29	-17.56	70.1	Mn>P>Fe>N>Ca>K>Mg>S>Zn>Cu	68.53
	23.	27.69	14.1	26.13	28.23	43.19	-44.23	-11.72	-37.33	-8.81	-37.25	278.68	Mg>Fe>Mn>Ca>Zn>Cu>P>K>N>S	18.98
	24.	4.08	5.44	-3.08	-2.04	-2.32	1.5	-0.17	-0.34	-3.52	0.45	22.94	Cu>K>Ca>S>Fe>Zn>Mn>Mg>N>P	79.68
	25.	3.4	9.66	-3.94	0.73	-10.89	-2.22	0.04	-2.46	7.76	-2.08	43.18	Ca>K>Fe>Mg>Mn>Zn>S>N>Cu>P	72.86
	26.	2.8	7.81	-3.7	-1.6	-11.05	-2.28	-0.18	-1.51	8.96	0.75	40.64	Ca>Mg>K>S>Fe>Zn>Mn>N>P>Cu	77.36
	27.	-10.78	8.31	2.49	11.75	-3.69	-5.85	3.71	-9.95	12.38	-8.37	77.28	N>Fe>Mn>Mg>Ca>K>Zn>P>S>Cu	61.82
	28.	-10.75	7.47	0.02	13.09	-0.63	-7.56	6.19	-11.16	15.41	-12.08	84.36	Mn>Fe>N>Mg>Ca>K>Zn>P>S>Cu	56.26
	29.	3.39	5.88	-2.69	19.83	18.68	-14.42	-20.79	-22.45	-0.68	13.25	122.06	Fe>Zn>Mg>K>Cu>N>P>Mn>Ca>S	30.38
	30.	14.39	6.07	1.55	20.73	27.57	-17.23	-34.77	-20.23	-2.09	4.01	148.64	Zn>Fe>Mg>Cu>K>Mn>P>N>S>Ca	24.76

Table 3. Distribution of DRIS N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn indices at different locations

Location	Range of DRIS Indices										Orchards having positive indices (%)										Orchards having negative indices (%)									
	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn
Akhnoor	-27.85 -51.88	-28.21 -8.92	-7.65 -68.15	-28.81 -24.66	-16.98 -121.56	-29.68 -20.89	-332.61 -12.41	-42.43 -68.22	-50.22- 62.08	-29.55 -23.76	73	53	53	58	37	48	48	53	60	77	27	47	47	42	63	52	52	47	40	23
Raya	-34.77 -12.92	-0.96 -36.85	-0.88 -71.59	-1.8 -37.56	-9.34 -69.18	-43.84 - -1.54	-14.95 -7.14	-67.06 --0.54	-85.49- 13.65	-48.22 -17.4	20	80	80	100	60	0	70	0	50	20	80	20	20	0	40	100	30	100	50	80
Purmandal	-12.06 - 27.69	-9.66 -53.42	-7.9 -26.13	-4.77 -38.36	-11.05 -43.19	-48.29 -9.48	-34.77 -19.57	-39.05 -10.05	-13.21- 16.29	-51.87- 20.94	77	93	47	83	57	13	43	7	43	57	23	7	53	27	43	87	47	93	57	43
Overall	-34.77- 51.88	-28.21- 53.42	-7.9- 71.59	-28.81- 38.36	-16.98- 121.56	-48.29- 20.89	-332.61- 19.57	-67.06- 68.22	-85.49- 62.08	-51.87- 23.76	69	67	54	70	45	33	48	34	52	64	30	32	48	32	55	67	52	66	49	36

Table 4. DRIS approach in identifying deficiencies and excess of nutrients in aonla orchards (per cent) at different locations

Location	DRIS approach																				Sufficiency range approach																			
	Major relatively deficiency										Major relatively excess										Deficiency										Excess									
	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn
Akhnoor	2	30	0	9	15	8	5	15	5	2	20	0	2	2	17	5	0	3	23	25	0	4	17	10	26	20	27	11	16	0	0	0	0	0	0	0	0	0	0	0
Raya	40	0	0	0	0	10	0	20	10	20	0	10	10	10	30	0	0	0	40	0	0	0	0	40	40	30	50	30	40	0	0	0	0	0	0	0	0	0	0	0
Purmandal	3	0	3	3	7	10	3	47	3	20	3	26	0	13	17	0	3	0	20	16	0	0	13	0	23	13	30	10	13	0	0	0	0	0	0	0	0	0	0	0
Overall	6	18	1	7	11	8	4	25	5	10	12	10	3	6	2	3	1	4	22	18	0	3	15	10	26	19	30	13	17	0	0	0	0	0	0	0	0	0	0	0

sufficiency range approach identified none of the orchards as deficient or excess for leaf Mn.

The results presented in Table 4 reveal that DRIS diagnostic approach identified relative nutrient deficiencies and excesses in all the orchards while sufficiency range approach diagnosed deficiencies and excesses in 19 orchards. Quite comparable major deficiencies and excesses between DRIS and sufficiency range approach was observed, except few exceptions. Data showed the superiority of the DRIS approach over the sufficiency range approach. DRIS approach indicated not only the most limiting nutrient, but the order in which other nutrients would likely become limiting. The major advantage of DRIS approach lies in its ability to minimize the effect of leaf age on diagnosis (Angeles *et al.,* 2). The DRIS approach diagnosed Fe as the major relative deficiency in 25 per cent of the orchards followed by P in 18 per cent, Ca in 11 per cent, Mn in 10 per cent, Mg in 8 per cent, S in 7 per cent, N in 6 per cent, Cu in 5 per cent, zinc 4 per cent and K in 1 per cent of the orchard. On the other hand, sufficiency range approach observed Zn as the major relative deficiency in 30 per cent orchards followed by Ca in 26 per cent, Mg in 19 per cent, Cu in 17 per cent, K in 15 per cent, Fe in 13 per cent, S in 10 per cent and P in 3 per cent.

DRIS approach observed only relative nutrient deficiencies and excesses and not the absolute one as it provides relative measure of the nutrient status (Beverly *et al.,* 4). Therefore, best comparison between these two approaches is not possible. DRIS approach also measure the degree of nutrient balance within the plant system in the form of nutrient imbalance index (NII), which on the other hand is not possible by sufficiency range approach. Superiority of DRIS approach has also been reported by Parent and Granger (13).

It can be concluded that DRIS approach gives a measure of the concept of nutrient balance in the plant system by calculating nutrient imbalance index in relation to fruit yield. Therefore, while interpreting leaf and soil nutritional status of the orchard, DRIS diagnostic approach along with sufficiency range diagnostic approach should be used as a guide for fertilizer application of aonla trees for better fruit production.

AUTHORS' CONTRIBUTION

Conceptualization of research (Devi, A. and Bakshi, P.); Designing of the experiments (Devi, A., Bakshi, P., Samnotra, R.K., Sharma, V., Mondal, A.K., Kour, K. and Sharma, N.); Contribution of experimental materials (Devi, A., Samnotra, R.K., Sharma, N., Iqbal, M. and Singh, M.); Execution of field/lab experiments and data collection (Devi, A., Bakshi, P., Sharma, V., Mondal, A.K., Kour, K., and Iqbal, M.); Analysis of data and interpretation (Devi, A., Bakshi, P., Sharma, V., Mondal, A.K., Kour, K., and Sharma, N.); Preparation of the manuscript (Devi, A. and Bakshi, P., Kour, K., Iqbal, M. And Singh, G.).

DECLARATION

The authors declare no conflict of interest.

REFERENCES

1. A.O.A.C. 1990. *Official and Tentative Methods of Analysis*. 15th edition Washington, D.C., USA.
2. Angeles, D.E., Sumner, M.E. and Barbour, N.W. 1990. Preliminary N, P and K DRIS norms for pineapple. *HortSci*. **25**: 652-55.
3. Apparao, V.V., Singh, S., Sharma, B.D. and Meshram, D.T. 2006. DRIS norms in aonla (*Emblica officinalis* Gaertn). *Prog. Hortic*. **38**: 34-7.
4. Beverly, R.B., Stark, J.C., Ojaha, J.C. and Embleton, T.W. 1984. Nutrient diagnosis of Valencia oranges by DRIS. *Proc. Amer. Soc. Hortic. Sci.* **109**: 649-54.
5. Bradfield, E.G. and Spencer, D. 1965. Leaf analysis as a guide to the nutrition of fruit crops. Determination of Mg, Zn, Cu, by atomic Absorption Spectroscopy. *J. Sci. Food. Agric.***16**: 13-38.
6. Chapman, H.D. 1964. Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops. *Indian J. Hortic*. **21**: 97-119.
7. Chapman, H.D. and Pratt, P.F. 1961. *Methods of Analysis for Soils, Plants and Water*. Division of Agricultural Science, University of California. pp 25-53.
8. Jackson, M. L. 1973. *Soil Chem. Analysis.* Prentice Hall of India Pvt. Ltd., New Delhi.
9. Kenworthy, A.L. 1961. Interpreting the balance of nutrient elements in leaves of fruit trees. **In**: *Plant Analysis and Fertilizer Problems* (ed. T. Reuther). Publication No. 8, American Institute of Biological Sciences, Washington, D.C. pp 28-43.
10. Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron,

manganese and copper. *Soil Sci. Soc. Amer. J.* **42**: 421-28.

11. Mourao, F. A. A. 2005. DRIS and sufficient range approaches in nutritional diagnosis of "Valencia" sweet orange on three rootstocks. *J. Plant. Nutr.* **28**: 691-705.
12. Olsen, S.R., Cole, V.C., Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A., Washington, DC. **939**: 19.
13. Parent, L.E. and Granger, R.L. 1989. Derivation of DRIS norms from a high density apple orchard established in the Quebe Appalachian Mountains. *J. Amer. Soc. Hortic. Sci.* **114**: 915-19.
14. Savita, P.C., Srivastava, D.P., Krishnappa, R. and Shukla, A.K. 2017. Diagnosis of nutrient imbalances and yield limiting nutrients in low yielding orchards of litchi (*Litchi chinensis* Sonn.) in lower Himalayas through DRIS approach. *International J. Pure App. Biosci.* **5**: 368-78.
15. Shear, C.B. and Faust, M. 1980. Nutritional ranges in deciduous tree fruits and nuts. *Hortic. Rev.***2**: 142-63.
16. Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Curr. Sci.* **25**: 259-60.
17. Wallace, T. and Proebsting, E.L. 1933. The potassium status of soils and fruit plants in some cases of potassium deficiency. *J. Pomol. Hortic. Sci.***11**: 120-48.
18. Walworth, J.L. and Sumner, M.E. 1987. The Diagnosis and recommendation integrated system (DRIS). *Adv. Soil Sci.* **6**: 149-88.

Received : January, 2020; Revised : February, 2021;
Accepted : February, 2021