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Comparison of DRIS ratio norms of selected fruit crops

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ABSTRACT

Diagnosis and recommendation integrated system (DRIS) ratio norms were developed for major fruit crops grown in peninsular India was complied and the relative ratios of different nutrient elements were compared. The mean nutrient values of different fruit crops showed wide variation for various nutrients. Thirty six nutrient expressions were compared. Based on physiological role the imbalances of certain nutrient ratios were found more important compared to others. The ratio served as guide in identification of common yield limiting nutrients of selected fruit crops in peninsular India. Among different forms of expression Zn/Ca, N/K, Fe/Ca were found more important as the deficiency of these nutrients have become more common in recent past. The ratio of K/N was widest in case of Anab-e-Shahi grape at bud differentiation stage. Overall the K/N ratio among different fruit crops showered greater uniformity when compared to P/N ratio indicating greater balance in N and K application compared to N and P application of nutrients. The wide range noticed in different ratios indicated the need for developing crop specific and region specific nutrient management strategies in fruit crops to realized high yield potential. The P/Zn ratio was as wide as from 1.023 to 14.49 indicating mutual interaction among nutrients and thereby emphasising the need for developing multivariate diagnostic norms with higher diagnostic sensitivity.

Key words: DRIS norms, fruit crops, nutrient interaction.

INTRODUCTION

Interpretation of leaf analysis data for understanding the magnitude of nutrient imbalance still remains a major area of research requiring attention. The problem associated with leaf analysis need to be understood from physiological and mathematical point of view. DRIS proposed by Beafuils (2), became important tools for developing norms for diagnosis of nutrient imbalance. Several soil and leaf analysis laboratories developed DRIS ratio norms for variety of crops. Developing DRIS ratio norms require substantial amount of research as developing leaf nutrient concentration vs. yield data bank is a prerequisite for norm deriving exercise. The data bank developed needs to be reliable in the sense there should be a reasonably well established relationship between yield and nutrient concentration in the cop under study or the yield is limited to a large extent due to nutritional factor alone.

Maintaining optimum nutrient balance in plant is essential. Plant analysis plays a crucial role in nutrient management in fruit crops as a guide for fertilizer application. The visual recognition of nutrient deficiency caused by sub-optimal nutrition has also been used for diagnosis of nutrient deficiency. Such diagnoses; however are reliable only when symptoms of nutrient imbalance are characteristic. Often it becomes necessary to make detailed investigations into the nutrient concentration in plant. Most often the probable yield loss is very considerable by the time deficiency symptoms appear or detected (Bould, 4). Therefore, constant monitoring of nutrient status in plant is required to sustain the yield level. The determination of the nutritional needs of some of the fruit crops like grape fruit etc. is made during bud differentiation stage (Bhargava and Sumner, 3) to improve yield potential in the current season itself. However, reliable information is needed to decide how much manures and fertilizers should be applied to fruit trees for an economic response. This can be obtained best by use of one or more of the diagnostic methods or leaf nutrient interpretation techniques. This review provides detailed, yet concise, information on DRIS norms developed interpretation of leaf analysis data for diagnosis of nutrient imbalance in major fruit crops grown in southern India.

MATERIALS AND METHODS

The DRIS ratio norms developed for different fruit crops were compiled for comparison of nutrient status in different fruit crops. These norms were essentially developed based on regional survey of cropping enterprises different crops from large

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number of locations earlier. DRIS ratio norms developed for different crops are summarized. Leaf analysis has been interpreted in several ways and the new concepts are being evolved (Table 1). DRIS technique for interpretation of plant analysis results as outlined by Walworth and Sumner (11) was adopted. The DRIS represents a holistic approach to the mineral nutrition of the crops and it is an integrated set of norms representing calibration of plant nutrient composition, soil composition, environmental parameters and farming practices as a function of yield of a particular crop. The premise that the concentration of nutrient changes with the age of the crop or as the concentration of other nutrients increase or decrease, whereas their ratio or product remain fairly constant over a period of time is the under principle of DRIS (Sumner, 10). Nutrient ratio pairs, rather absolute nutrient concentration is used as reference criteria, since they tend to be relatively stable with the age of the crop. The norm deriving exercise in DRIS involves grouping entire data bank as low and high yielding. Data is collected from cropping enterprises and or field experiments from large number of locations, in order to build up the data bank representative of the variation of the growth factors throughout the cropping industry (Jones *et al.*, 7), the objective being to establish a data bank that can be applied to the interpretation of soil and plant analysis data of the unknown samples. The DRIS concept is illustrated below;

Development of DRIS norms: The different steps involved are : (i) A data bank is established from survey and field experiments; (ii) Nutrient concentration is expressed in as many forms as possible; (iii) The whole population is divided in to two sub-groups based on yield performance as high and low yielding; (iv) The mean of each sub population is calculated for various forms of expression; (v) The variance ratios between yield of sub-population for all the forms of expressions are calculated together with the coefficient of variance; (vi) The form of expression for which significant variance ratios are obtained are selected as ratio norm; (vii) For calculation of DRIS index the formula is worked out as given below;

$$N = 1/9\,[f(N/P) - f(K/N) + f(N/Ca) + f(N/Mg) + f(N/S) - f(Fe/N) + f(N/Mn) + f(N/Zn) - f(N/Cu)]$$

$$\text{Where } f(N/P) = \left| \frac{N/P}{n/p} - 1 \right| \frac{1000}{CV}$$

Where, N/P > n/p

$$f(N/P) = \left| \frac{n/p}{N/P} - 1 \right| \frac{1000}{CV}$$

Where, N/P< n/p

N/P is the actual value of the ratio of nitrogen and phosphorus in the plant under diagnosis. The n/p is the value of the norm (mean of the high yielding population) and CV is coefficient of variation for the population of the high yielding orchards.

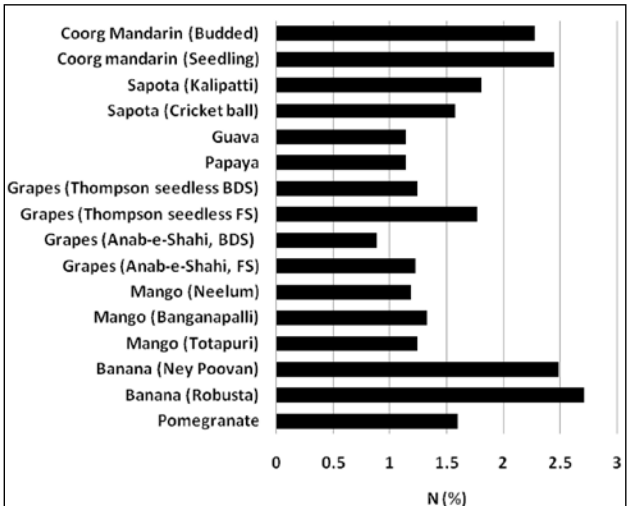
The value of each ratio function is added to one index sub-total and substracted from another prior to averaging. Therefore, all the indices are balanced around zero. The higher the negative index it shows that the corresponding nutrient is relatively deficient. Alternatively, a large positive index indicates that the nutrient is in excessive range. The advantages of DRIS is that it is a holistic approach, nutrient interaction and dilution is taken into account, identification of yield limiting nutrient in order of importance, diagnosis at any stage of crop growth and higher diagnostic precision.

Table 1. Leaf sampling technique followed in different fruit crops.

Fruit crop	Index tissue	Growth state / Time
Banana	Leaf lamina	Centre 20 cm^2 of leaf lamina on both sides of midrib. 3rd fully opened leaf at 16th to 20th leaves stage.
Grape	Petiole	Petiole from 5th leaf position (base of the shoot taken as one) 40 to 45 days after back pruning (bud differentiation stage) for yield forecast. Petiole opposite to flower at bloom time is collected for assessing fruit quality.
Citrus	Leaves	3 to 5 month-old leaf from new flush. 1st leaf of the shoot in the month of June
Guava	Leaves	3rd pair of recently matured leaves in bloom stage (August or December)
Mango	Leaves + petiole	4 to 7 month-old leaves from middle of shoot (non flowering terminal)
Papaya	Petiole	6th petiole from apex 6 months after planting
Pomegranate	Leaf	8th pair of leaf (counting from the growing tip) from new growth in the month of April and August for February and June crop respectively.
Sapota	Leaf	10th leaf from new flush initiated in the month of September

RESULTS AND DISCUSSION

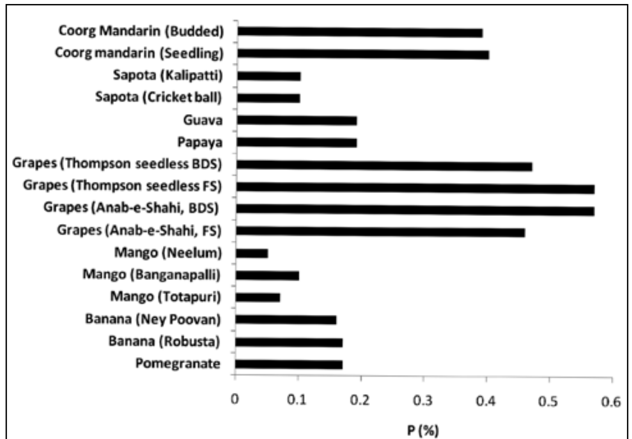
Nitrogen is one of the nutrient elements, the is most widely studied in fruit crops in India. The critical level of N varied widely depending on the crop (Fig. 1). For several crops, when the N level in leaves drops below 2.50%, N deficiency symptoms appear and yield and quality decline. Often, small changes in N content for some crops can result in large effects on yield, plant growth and quality fruit. Therefore, it is important that the N level be maintained within the optimum limits of the sufficiency range. The mean N concentration in banana and Coorg mandarin was generally higher compared to most of the other fruit crops (Fig. 1). Among different nutrients, the ratio of P/N very wide in case of grape in general indicating imbalance in the ratio because of indiscriminate application of nutrient especially that of P. The mean P concentration in most of the grape vineyards was generally higher when compared to other crops. The P/N ratio was very narrow in case of mango and sapota, which is primarily because of low concentration of P in mango and sapota leaves.



*FS = Flowering stage, BDS = Bud differentiation stage

Fig. 1. Mean concentrations of N in different fruit crops.

The critical range of P in most tree crops varies from 0.12 to 0.15% although high values are reported in crops like grape due to heavy application of P to soil. Phosphorus deficiency normally occurs early in the growth cycle of the plant when the P requirement is high. The P content of plants is initially high and declines with age. High P plant levels may cause imbalances and deficiencies of other elements, such as Zn, Cu, Fe, etc. The mean P content was highest in grape when compared to other fruit crops (Fig. 2).



*FS = Flowering stage, BDS = Bud differentiation stage

Fig. 2. Mean P concentrations in different fruit crops.

Plant P can be maintained within the sufficiency range by proper P fertilization although the magnitude of response varies greatly from crop to crop. The P ratio with that of K was one of the lowest in case of grape at flowering stage, whereas P/K ratio was wide in case of CM budded plants because of high concentration of K in relation to that of P (Raghupathi *et al.*, 9). The interaction between P and Zn is important in most of the fruit crops (Fageria, 5). Among different fruit crops the ration of Zn/P was highest in mango and lowest in sapota.

The K requirement of plants varied widely depending on plant species (Fig. 4). Literature is replete with information on K status and critical ranges for K. Potassium level in a plant change rapidly as it is mobile and moves readily within the plant. Due to high mobility of K both in the plant and soil, deficiency symptoms develop quickly. Deficiencies frequently occur during both the early and latter stages of growth, particularly during fruiting. Young plants may contain 3.00 to 5.00% K, although the actual requirement may not be that high especially in crops like banana. The K concentration in the plant decreases with age. The demand for K was highest in case of banana (Fig. 3). The K/(Ca+Mg) and K/N balances must be maintained at a proper level to avoid deficiencies of Mg in the first instance and K in the second. High K can induce Mg deficiency in most plant and tree crops. Plants which are Mg deficient may have high K and Ca contents. The K/Mg was very wide in case of Anab-e-Shahi because of low Mg, as large quantity of Mg is removed by seeds and therefore higher Mg level in plant needs to be maintained. The K/Mg ratio was also equally wide incase of banana as banana is having requirement of K and the interaction between

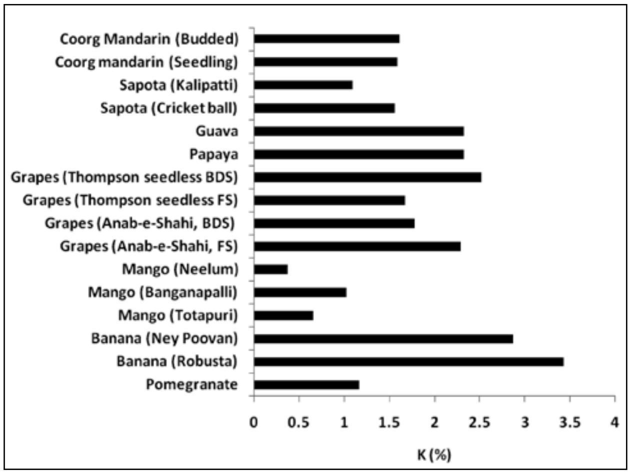


Fig. 3. Mean K concentrations in different fruit crops.

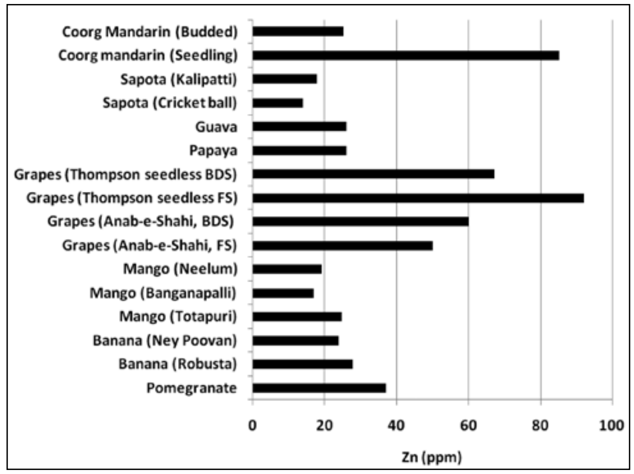


Fig. 4. Mean Zn concentrations in different fruit crops.

K and Mg is well established in banana (Gowen, 6). The mean K concentration in banana was twice higher when compared to many other fruit crops. Heavy applications of K or N fertilizers, respectively, can induce Mg or K deficiency. The ratio of K/N was widest in case of Anb-e-Shahi grape at BDS followed by Thompson Seedless. There was a greater uniformity in K/N ratio among different fruit crops when compared to P/N ratio indicating more balanced application of N and K when compared to N and P application in majority of fruit crops.

Although many nutrient ratios are obtained through DRIS technique, some expression for examples K/N and K/Zn have higher physiological rationale. Potassium is known to have the key role in N uptake and translocation in many fruit crops. The rationale for having S/K and Mn/K (having small variance ratios and high CV values, data not shown) is less obvious and indeed their relatively high CV values indicate that maintaining their balance at optimum level is much less critical for crop performance in fruit crops. None the less the three nutrients in question being the major yield building component, they do need to be kept in a state of relative balance for maximum efficiency of dry matter production (Tables 2 & 3).

The Ca requirement for plants varies widely. Calcium deficiencies are not unusual, although the crops where Ca is particularly important are the fruit crops. Calcium deficiency will significantly affect fruit quality. Sometimes, deficiencies are not easily detected by leaf analysis. It is known that relatively little Ca is in a soluble form in many plants. The uptake of K and Mg decreases at higher Ca concentration. Besides, Ca is having inhibitory effect on Fe and Zn as well. From among the different fruit crops the Fe/Ca ratio was lowest in papaya and highest in sapota. Similar wide variation was noticed with reference to Ca and Zn ratio. The mean ratio of Ca/Zn was highest (0.1447) in case of mango (Totapuri) indicating a higher accumulation of Ca in leaves in mango compared to Zn in the surveyed areas. Ca/Zn was also relatively low in pomegranate (Raghupathi and Bhargava, 8).

Many fruit crops exhibit magnesium deficiency when its concentration is below 0.10 to 0.15%, However, most often the Mg deficiency is caused by its interaction with other nutrients within plant like K rather than due to low availability in soil. Magnesium is a fairly mobile element in the plant, therefore, deficiency symptoms occur in the older plant tissue. The Mg concentration in the plant tends to increase with age. The ratio of Ca/Mg reflects the degree to which growth is limited by non-nutritional factors relative to nutritional factors. In most crops being complementary in nature DRIS indices for Ca and Mg were quite often taken as a single reference index reflecting dry matter accumulation in plant (Bailey, 1). The Ca/Mg ratio was widest in case of mango and narrowest in case of sapota.

Sulphur is not a mobile element in the plant, deficiency symptoms tend to first appear in the upper or newly emerging leaf tissue. In general, the S requirement of plants was comparable to that of P. There is a critical N to S percentage ratio, which needs to be maintained to improve productivity. The reciprocal of S/N ratio varied from 2.77 to 25.64. Ideally, the N/S ratios vary between 13 to 16 and is optimum in most of the crops. The ratio was widest in case of sapota and narrowest in case of banana.

High levels of several minerals, *viz*., Ca, P, N, Mn and Cu in soil or high HCO_3 in irrigation water often results Fe chlorosis, although its deficiency itself may

Table 2. DRIS ratio norms for selected fruit crops.

Ratio	Pomegranate	Banana (Robusta)	Banana (Ney Poovan)	Mango (Totapuri)	Mango (Banganapalli)	Mango (Neelum)	Papaya	Guava
P/N	0.12	0.068	0.063	0.043	0.0770	0.076	0.157	0.105
K/N	0.78	1.32	1.088	0.84	1.3000	0.972	1.751	0.727
Ca/N	1.18	0.31	0.511	2.02	0.61	0.54	0.34	0.559
N/Mg	4.64	7.35	6.255	4.608	5.49	5.260	1.11	4.59
S/N	0.19	0.03	0.040	0.079	0.074	0.076	0.243	0.194
Fe/N	76.20	46.63	43.48	120.40	34.74	29.54	55.8	75.97
Mn/N	33.82	102.0	10	181.6	26.82	50.00	40.00	26.32
Zn/N	30.08	10.8	11.55	13.96	12.76	12.31	22.22	17.54
P/K	0.15	0.057	0.0606	0.049	0.098	0.07	0.026	0.144
P/Ca	0.12	4.99	0.178	0.0218	0.1200	0.136	0.059	0.185
Mg/P	1.94	2.22	2.800	4.202	2.3800	2.61	5.54	2.062
S/P	1.69	1.72	0.835	1.751	1.00	1.02	1.266	1.808
Fe/P	642.3	747.6	897.8	2500.00	450.8	391.0	352.00	743.1
Mn/P	284.3	152.0	1805.0	769.00	381.8	606.0	262.9	250.0
Zn/P	200.0	166.51	157.84	303.00	166.6	160.5	125.00	166.67
Ca/K	1.35	0.275	0.441	2.381	0.786	0.59	1.50	0.779
K/Mg	3.45	9.009	5.988	4.344	4.27	5.17	2.008	3.311
S/K	0.13	0.0329	0.040	0.0899	0.094	0.07	0.137	0.267
Fe/K	62.50	37.67	897.8	154.24	43.9	33.81	31.29	103.8
Mn/K	30.30	107.41	107.98	196.1	35.38	50.00	23.26	39.02
Zn/K	47.00	9.03	9.325	17.81	16.55	11.11	10.75	23.81
Ca/Mg	5.15	2.128	2.198	9.009	3.21	2.80	2.98	2.523
Ca/S	5.56	9.23	7.353	26.38	9.29	8.02	11.39	2.867
Fe/Ca	72.80	122.0	146.43	60.39	50.0	56.40	20.00	152.1
Mn/Ca	30.60	342.47	275.0	81.30	49.67	9.09	16.13	47.60
Ca/Zn	0.05	0.0334	0.0419	0.1447	0.051	0.05	0.115	0.032
S/Mg	0.87	0.262	0.315	0.3534	0.408	0.035	0.249	0.872
Fe/Mg	336.6	312.5	353.07	618.12	188.5	158.7	63.92	354.1
Mn/Mg	146.4	719.42	713.07	730.00	144.79	250.0	45.45	125
Zn/Mg	134.2	65.79	58.02	70.65	69.89	63.34	25.64	76.92
Fe/S	828.6	1000	1000.0	1572.5	500.0	454.9	244.46	407.8
Mn/S	383.7	2770.1	2777.0	2041	433.2	666.6	1127.0	142.9
S/Zn	0.00	0.0042	0.00615	0.0056	0.002	0.002	0.01	0.011
Fe/Mn	1.80	0.423	0.574	0.727	0.92	0.61	1.371	2.881
Fe/Zn	4.21	4.715	0.710	9.31	2.78	2.86	2.36	4.302
Mn/Zn	1.64	10.41	9.43	0.086	2.28	3.84	1.83	1.643

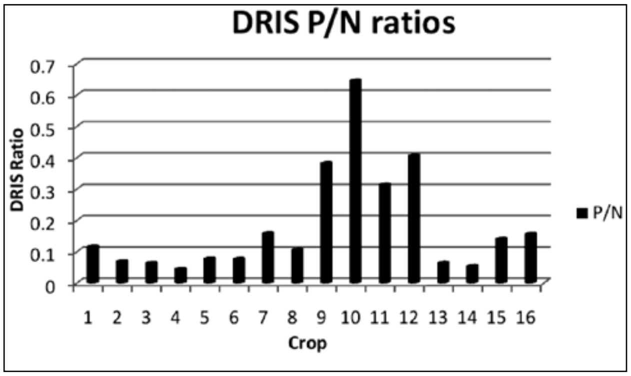
inhibit absorption of some elements, with possible deficiency occurring only on soils with pH at 7.0 or above. Iron deficiency is very difficult to correct in some crops. Foliar applications of Fe have been found to be effective in correcting its deficiencies in plants. Since Fe is an immobile element in plants, its deficiency appears in the new tissue or upper portion of the plant. Iron deficiency symptoms may appear early in the growth of the plant only to disappear in several days or weeks. The Fe level in the plant usually remains fairly constant during the growing season. The mean Fe concentration varied from 44 ppm in mango to 176

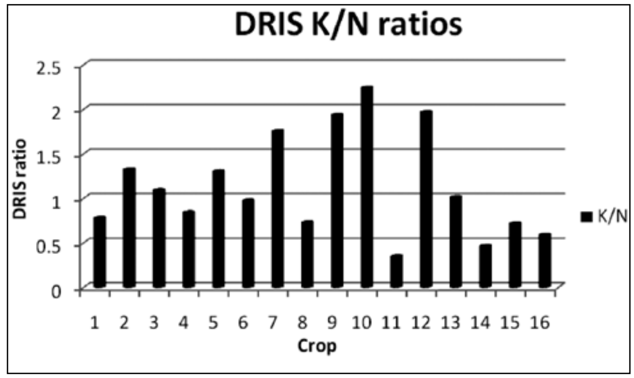
Table 3. DRIS ratio norms for selected fruit crops.

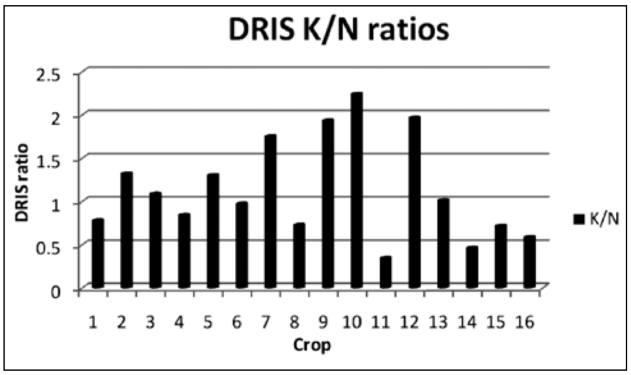
Ratio	Ana FS	Ana-BDS	TS FS	TS BDS	Sapota	Sap Kali	CM Se	CM bud
P/N	0.381	0.645	0.313	0.405	0.063	0.053	0.13947	0.155
K/N	1.934	2.240	0.346	1.9646	1.011	0.461	0.716	0.587
Ca/N	0.372	2.180	1.004	2.553	0.559	1.119	0.645	0.7057
N/Mg	5.556	2.140	2.457	1.489	3.79	2.78	9.42	6.449
S/N	0.308	0.137	0.119	0.097	0.178	0.36	ND	ND
Fe/N	20.41	89.25	217.00	56.73	71.71	100.0	38.04	47.39
Mn/N	96.95	61.160	220.00	112.4	13.69	33.33	18.18	17.76
Zn/N	37.037	2.020	54.00	58.18	8.55	9.01	0.0927	17.95
P/K	0.196	0.340	0.309	0.195	0.062	0.122	0.231	0.399
P/Ca	0.976	0.330	0.538	0.413	0.165	0.048	0.21	0.361
Mg/P	2.075	0.74	1.288	1.770	4.543	6.74	0.795	0.777
S/P	0.978	0.216	0.381	0.242	3.043	0.16	ND	ND
Fe/P	55.56	130.89	111.1	154.15	1219.0	169.49	276.66	253.16
Mn/P	258.2	85.66	71.00	274.92	200.00	495.05	117.64	65.35
Zn/P	115.8	105.26	51.00	153.16	152.7	15.576	77.8	74.62
Ca/K	4.878	3.120	0.604	0.476	0.336	2.41	0.91	1.587
K/Mg	10.82	4.348	2.110	3.072	3.88	1.287	6.62	3.215
S/K	0.1582	0.126	0.134	0.048	0.173	0.758	ND	ND
Fe/K	11.90	42.71	37.03	27.28	70.44	211.84	53.81	75.187
Mn/K	47.84	27.84	80.00	51.25	13.34	67.7	23.86	24.57
Zn/K	20.41	35.43	58.00	27.43	8.609	19.27	14.74	25.64
Ca/Mg	2.101	4.348	1.431	1.392	1.292	3.08	5.92	5.828
Ca/S	1.227	4.348	4.80	10.383	2.004	3.21	ND	ND
Fe/Ca	58.82	42.47	66.67	57.75	228.6	71.429	52.91	52.91
Mn/Ca	245.4	92.93	135.00	104.44	35.71	8.1967	27.54	18.18
Ca/Zn	0.009	0.0094	0.011	0.018	0.039	0.122	0.0641	0.0564
S/Mg	0.482	0.298	0.312	0.312	0.666	0.9671	ND	ND
Fe/Mg	125	125.00	593.00	80.105	274.7	278.47	346.91	312.5
Mn/Mg	525.21	18.91	196.00	140.39	45.45	78.12	166.11	88.49
Zn/Mg	200	24.65	141.00	78.91	32.26	25.64	100.09	100
Fe/S	81.06	9.75	1410.00	593.7	434.5	333.0	ND	ND
Mn/S	2041	267.8	371.34	500.00	166.67	77.52	ND	ND
S/Zn	0.009	0.375	0.0022	0.0017	0.019	0.0378	ND	ND
Fe/Mn	0.285	2.02	2.142	0.541	5.892	3.57	2.02	1.754
Fe/Zn	14.490	1.56	2.491	1.023	8.386	11.026	3.585	1.78
Mn/Zn	2.274	0.92	0.80	1.781	0.026	3.049	1.748	0.915

ppm in sapota. The relative proportion of Fe to Ca was high in sapota, while it was lowest in papaya.

Deficiency or toxicity of many micronutrients are often caused by their form of existence or interaction with other nutrients rather than their individual concentration in lesser or greater amounts. Several plant species have high Mn critical levels and tolerate extremely high Mn levels without showing any toxicity symptoms. A high Mn level in plants may be associated with Mg deficiency. The Mn level in plants is usually quite high at the initial period of growth. It decreases rather rapidly and then levels off to remain







1 Pomegranate
2 Banana (Robusta)
3 Banana (Ney Poovan)
4 Mango (Totapuri)
5 Mango (Banganapalli)
6 Mango (Neelum)
7 Papaya
8 Guava
9 Grape (Anab-e-Shahi, FS)
10 Grape (Anab-e-Shahi, BDS)
11 Grape (Thompson Seedless FS)
12 Grape (Thompson seedless BDS)
13 Sapota (Cricket ball)
14 Sapota (Kalipatti)
15 Coorg mandarin (Seedling)
16 Coorg Mandarin (Budded)

Fig. 5. DRIS ratio norms for different fruit crops.

fairly constant during most of the season. Since Mn is not a mobile element, deficiency symptoms will occur in the newer leaves or upper portion of the plant. Among the fruit crops, the Mn concentration was noticed highest in case of banana. Therefore, the Fe/Mn ratio was one of the lowest in case of banana where because of relatively more Fe the Fe/Mn ratio was widest in case of crops like sapota. The reduced conditions in the rhizosphere could result in high Mn in leaf. Mn concentration up to 2000 ppm has been reported in case of banana

The normal range of Zn in most plants is between 20 to 100 ppm (Fig. 4). Zinc deficiencies occur in a wide variety of plants when the leaf Zn concentration is below 15 ppm. Barring that of few crops most Zn level was less than 40 ppm in most of fruit crops. Zinc levels in most crops should be maintained at 20 ppm or higher. Excessive Zn also interferes with the normal function of Fe in plants giving rise to symptoms similar to Fe deficiency. Stunting is a frequent symptom associated with Zn deficiency. Zn concentration in leaves remains fairly constant with a fairly rapid increase at the end of the growth cycle. The Fe/Zn was one of the lowest in banana because of low Zn and its deficiency is very common in peninsular India, while in crops like grape, where large quantity of Zn is added through to soil, the ratio of Fe /Zn was very wide. In some crops, however, the increased Zn was reported to have favorable influence on Mn content in plant.

Some of the fruit crops and their cultivars for which K/N and P/N ratios have been estimated are given in Fig. 5. It is clear the DRIS offers a pratical tool to estimate the critical limits of different plants nutrients and their effect on other elements at critical growth stages.

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