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Abstract: Diagnosis and Recommendation Integrated System (DRIS) indices were developed to identify and prioritize the yield-limiting nutrients in mango orchards (cv. Baneshan) in Andhra Pradesh, India. The forms of expressions selected for computing the DRIS indices varied from the young (<20 years old) to aged (>20 years old) trees. The DRIS indices could reflect the long-term variations of different doses of nitrogen (N), phosphorus (P), and potassium (K) application in mango, thereby showing the sensitivity of the newly developed DRIS indices to fertilization practices. The nutrients identified as yield limiting by DRIS indices were observed to be not totally independent of the age of sampled tissue. The same nutrient was observed to be most yield limiting in 24.2% of sampled trees after a gap of 3 months. Similarly, the same nutrient was identified as one of the first two yield-limiting nutrients in 52.2% of sampled trees. The validity of the newly developed DRIS indices was tested by applying two of the most yield-limiting nutrients in 88 and 46 cases of young and aged trees. The yield-limitation due to individual nutrients was either totally eliminated or changed in ranking in 96.0 and 93.5% of the young and aged trees, respectively, after the application of yield-limiting nutrients, as indicated by the newly developed DRIS indices. The increase in the fruit yield with the application of yield-limiting nutrients identified by the DRIS indices varied from 11.5 to 45.9% in young trees and from 15.2 to 34.0% in aged trees over the control.

Keywords: DRIS indices, mango orchards, nitrogen, phosphorus, nutrients, yield-limitation

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INTRODUCTION

Nutrient management is an important aspect in the cultivation of mango (*Magnifera indica* L.), which is grown on about 10.6 m ha with a production of about 9.6 mt in India. Nutrient management is done at present mostly on an ad hoc fertilizer recommendation basis due to limitations of soil tests (Sekhon 1978). Diagnosis based on index leaf analysis (fourth and fifth recently matured leaves from terminal portion of the nonfruiting twigs) offers promise (Pathak and Pandey 1978; Kumar and Naurial 1979), but the interpretation of yield-limiting nutrients based on optimum or critical nutrient concentration does not take into consideration the level of other nutrients. With the Diagnosis and Recommendation Integrated System (DRIS) developed by Beaufils (1957, 1971, 1973), it was claimed that the final diagnosis by DRIS indices is fairly independent of the age of the tissue sampled (Walworth and Sumner 1987), which is not the case with the critical nutrient concentrations (range) method (CNC method). Schaffer et al. (1988), using this technique, found manganese (Mn), iron (Fe), or a combination of both these as being responsible for decline in the yield of mango (var. Tommy Atkins) in southern Florida in the United States.

The current investigations were conducted during 1993–96 to develop DRIS indices by following the technique of Beaufils (1973) as detailed by Walworth and Sumner (1987). The sensitivity of the developed indices to both long- and short-term fertilization practices, and the yield response to the application of limiting nutrients identified by the developed DRIS indices, were studied. The results obtained are presented in this article.

MATERIALS AND METHODS

Thirty-three mango orchards (cv. Baneshan) were selected from major mango growing tracts of Krishna, Khammam, Warangal, and Medak districts of Andhra Pradesh in India at random, covering the entire range of management and yield level. Within each selected orchard, individual trees ranging from 6 to 16 trees per orchard and covering the entire range from low to high yield were selected with the help of farmer.

About 50 leaf samples (fourth and fifth recently matured leaves from the terminal portion of nonfruiting twigs) from each selected tree were collected in the month of October 1993 (Chadha, Samra, and Thakur 1980) to find the nutritional status of trees and to develop DRIS indices. Samples collected in January 1994 (about 3 months after the first sampling) were used to find the effect of the age of tissue on the final diagnosis of yield-limiting nutrients by the DRIS indices. Samples collected in October and November 1995 were used to find the effectiveness of application of yield-limiting nutrients, as indicated by DRIS indices, on the fruit yield. Standard analytical procedures were used to estimate the concentration of different nutrients in the index leaf samples. Fruit yield from each tree was estimated in April and May 1994 to grade the population into high- and low-yielding and in April and May 1996 to find the effect of application of yield-limiting nutrients on the fruit yield. For estimating the yield, total number of fruits of varying sizes, were counted just before the week of harvest while they were on the trees. At the time of harvest, the actual number of fruits harvested from the trees were physically counted and also number of fruits, which weigh about 5 kg. In doing so, marginal adjustment in weight was also done. Based on this, average fruit weights were computed. The fruit yield for each selected tree was calculated from total number of fruits per tree computed earlier and average fruit weight. Finally, fruit yield per hectare was estimated depending on spacing and total population. The cutoff line of fruit yield levels for young and aged orchards for separating high- and low-yield populations was obtained by adopting the procedure of third quartile method (Nageshwar Rao 1983). The population was divided into high- and low-yielding groups using yield cutoffs of 7.2 t fruit ha^{-1} for young orchards (<20 years) and 9.11 t fruit ha^{-1} for aged orchards (>20 years). The general procedure described by Walworth and Sumner (1987) for calculating the DRIS indices was followed.

Scrutiny of DRIS indices developed were tested under long-term fertilization practices in the existing experiment at Fruit Research Station, Sangareddy, Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India. Out of 20 total treatment combinations consisting of different doses of N, P, and K fertilizer doses, only a few selected treatments were used for comparison. N, P, and K fertilizer doses were 0, 405, 1000, 1595, and 2000 g $tree^{-1}$, respectively. N, P, and K nutrients were applied through urea, single super phosphate, and muriate of potash, respectively.

At different selected locations at random, the first two yield-limiting nutrients identified through DRIS at that locations were applied through their respective fertilizer sources, and yield responses were calculated to test the effectiveness and validity of DRIS indices developed. The fertilizer sources used for N, P, K, magnesium (Mg), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn) were urea, single super phosphate, muriate of potash, magnesium sulphate, zinc sulphate, copper sulphate, ferrous sulphate, and manganese sulphate, respectively. Gypsum was the source for calcium (Ca) and sulphur (S). Leaf samplings were collected from these selected trees, and DRIS indices were calculated to see any change in priority after application of first two limiting nutrients. The percentage of cases where there is change in priority of the limiting nutrients was calculated. DRIS indices developed from leaf composition values obtained at two different stages were compared to see the effect of age of sampling tissue on final diagnosis of yield-limiting nutrients by DRIS.

RESULTS AND DISCUSSION

Forms of Nutrient Expressions and DRIS Indices

DRIS norms were selected separately for young and aged mango orchards (Table 1). DRIS indices, incorporating the forms of expressions (DRIS norms) selected as per Walworth and Sumner (1987), are presented in Table 2. It should be noted from those equations that the content of individual nutrient as such does not express the full variability of nutrient content in the index leaves and that the ratio between the nutrients is more important in governing the fruit yield rather than the individual nutrient content as such. This trend emphasizes the theoretical soundness of the DRIS indices. The ideal form of expressions selected for inclusion in DRIS indices depend on the age of the tree and the ratios were getting reciprocated for young and aged orchards, the reasons for which need to be explored.

Relative Merits of Diagnosis of Yield-Limiting Nutrients by DRIS Indices over Conventional Critical Nutrient Concentration (CNC) Method

Comparison of diagnosis of yield-limiting nutrients by the conventional CNC method and DRIS indices showed wide variability (Table 3). The number of nutrients identified as yield limiting by DRIS indices is much higher than those identified by the conventional CNC method. It should be observed from the data that the majority of the nutrients indicated as yield limiting by the CNC method also find a place in the nutrients diagnosed by DRIS to maximize the yield. The inadequacy of yield-limiting nutrients identified by the CNC method was clearly established by nonsignificant or low correlation coefficient between the concentration of individual nutrients in the index leaves with the fruit yield. The coefficient of correlations (R) among N, P, K, Ca, Mg, S, Zn, Cu, Fe, and Mn contents in the index leaves with the fruit yield were only 0.033, 0.055, −0.130, −0.035, −0.110, −0.134, −0.063, −0.152, 0.025, and −0.217, respectively. Further, the variance ratio between the low- and high- yielding population for the forms of expression involving the individual nutrient concentration was never the highest, and hence none of them were used in the formulae computed for DRIS indices (Table 2). Walworth and Sumner (1987), in their extensive review, and subsequently Elwali and Gascho (1984), Angeles, Sumner, and Barbour (1990), Needham, Burger, and Oderwald (1990), Caron, Parent, and Gosselin (1991), Sanchez, Snyder, and Burdin (1991), Jamadagni (1993) and Parent et al. (1994), concluded the superiority of DRIS indices over CNC or the sufficiency method in diagnosing the yield-limiting nutrients. Soltanpour, Malakouti, and Ronaghi (1995), however, contradicted this conclusion. They noted that a very high level of one

Table 1. DRIS norms developed for young and aged orchards of mango

Young orchards			Aged orchards		
Forms of expression/ DRIS norm	Mean	CV (%)	Forms of expression/ DRIS norm	Mean	CV (%)
N/P	15.97	77.3	P/N	0.08	59.3
K/N	0.59	58.8	N × K	1.60	41.1
Ca/N	1.95	64.3	N × Ca	4.64	51.1
Mg/N	0.33	70.4	N/Mg	4.87	83.1
S/N	0.20	80.5	N × S	0.31	55.2
Zn/N	13.50	51.9	N/Zn	0.13	82.2
N/Cu	0.21	100.4	Cu/N	8.15	58.0
N/Fe	0.012	116.0	Fe/Mn	109.47	82.2
Mn/N	235.2	112.6	N/Mn	0.024	91.7
K/P	6.6	52.0	P/K	0.17	60.4
Ca/P	21.69	53.1	P/Ca	0.06	39.8
Mg/P	3.59	59.8	P/Mg	0.30	58.8
S/P	1.97	60.9	P × S	0.02	58.9
Zn/P	158.11	68.9	P/Zn	0.01	70.6
Cu/P	95.97	54.2	P × Cu	1.61	55.2
Fe/P	2384.5	125.7	P × Fe	23.52	70.6
Mn/P	2096.3	90.9	P/Mn	0.0006	82.6
K × Ca	1.48	46.1	Ca/K	3.19	51.0
K/Mg	2.03	39.7	Mg/K	0.69	74.2
K/S	3.97	57.5	S/K	0.20	28.7
K/Zn	0.04	34.2	K/Zn	0.051	29.4
K/Cu	0.08	61.3	Cu/K	15.17	50.1
K/Fe	0.01	115.7	Fe/K	241.67	62.0
K × Mn	158.3	107.0	Mn/K	262.38	99.9
Ca/Mg	6.39	26.1	Ca/Mg	5.18	32.4
Ca × S	0.47	66.8	S/Ca	0.07	37.3
Ca × Zn	33.43	35.0	Ca/Zn	0.16	52.8
Ca × Cu	21.05	46.0	Ca/Cu	0.23	43.4
Ca/Fe	0.02	92.2	Ca × Fe	464.59	65.1
Ca × Mn	539.5	105.6	Ca/Mn	0.03	80.9
S/Mg	0.60	42.0	S/Mg	0.37	46.3
Mg × Zn	5.61	46.9	Mg/Zn	0.03	79.6
Cu/Mg	30.32	47.0	Cu/Mg	26.34	53.0
Mg/Fe	0.0003	103.9	Fe/Mg	399.14	66.2
Mn/Mg	644.1	75.5	Mn/Mg	506.21	101.7
S × Zn	3.17	56.3	S/Zn	0.0112	39.7
S × Cu	2.12	73.0	S × Cu	2.01	44.5
S/Fe	0.002	119.1	S × Fe	27.23	57.3
Mn/S	1085.1	65.3	S × Mn	37.58	96.0

(*continued*)

Table 1. Continued

Young orchards			Aged orchards		
Forms of expression/ DRIS norm	Mean	CV (%)	Forms of expression/ DRIS norm	Mean	CV (%)
Zn × Cu	153.68	47.6	Cu/Zn	0.70	41.5
Zn/Fe	0.14	132.3	Fe/Zn	11.37	62.3
Zn × Mn	3547.2	97.4	Mn/Zn	12.45	92.4
Cu/Fe	0.08	116.2	Cu × Fe	2450.10	77.9
Mn/Cu	24.36	73.1	Cu/Mn	0.14	96.2
Mn/Fe	1.76	121.1	Fe/Mn	2.16	89.0

nutrient can result in erroneous diagnosis of yield-limiting nutrients and that the optimum ratio between the nutrients produces maximum yield only when all the nutrients are in their respective sufficiency ranges. This occurs very rarely in mango. Therefore, the present trends indicate the superior nature of the diagnosis of yield-limiting nutrients by the DRIS method over that the CNC method.

Sensitivity of DRIS Indices to Long-Term Fertilization

The sensitivity of DRIS indices developed were tested under long-term fertilization practices in an experiment already in progress at the Fruit Research Station, Sangareddy, Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India. Results are presented in Table 4. It can be noticed from the data that in the treatment T_7, with highest fruit yield of 694 kg plant^{-1} after continuous fertilization for 15 years, no deficiencies of N, P, and K were indicated, but deficiencies of Ca, Fe, Mg, Zn, S, and Cu were indicated. In the next highest yield treatment, T_3, N, and P were deemed adequate, but K was shown as limiting nutrient in the fourth place and Mg was indicated as the most limiting nutrient, followed by Ca and Zn, thereby showing that the dose of K applied (405 g tree^{-1} K_2O) was not adequate to fully overcome the limitation at the level of N and P applied. In all the treatments involving application of K at 405 g K_2O tree^{-1} (treatment level 1), K was indicated to be yield limiting, though not necessarily the most limiting, thereby inciting the sensitiveness of DRIS indices to the long-term fertilization practices. In none of the treatments studied were N or P found to be yield-limiting nutrients, indicating adequacy of N and P levels applied even at the minimum level and the order of limiting nutrients showing the sensitiveness of the DRIS indices.

Table 2. Formulae selected for calculating indices in young and aged orchards Young orchards

Orchard	Parameter	Formula
Young orchards[a]	N index	$\frac{f(N/P) - f(K/N) - f(Ca/N) - f(Mg/N) - f(S/N) - f(Zn/N) + f(N/Cu) + f(N/Fe) - f(Mn/N)}{9}$
	P index	$\frac{-f(N/P) - f(K/P) - f(Ca/P) - f(Mg/P) - f(S/P) - f(Zn/P) + f(Cu/P) - f(Fe/P) - f(Mn/P)}{9}$
	K index	$\frac{f(K/N) + f(K/P) + f(K \times Ca) + f(K/Mg) + f(K/S) + f(K/Zn) + f(K/Cu) + f(K/Fe) + f(K \times Mn)}{9}$
	Ca index	$\frac{f(Ca/N) + f(Ca/P) + f(K \times Ca) + f(Ca/Mg) + f(Ca \times S) + f(Ca \times Zn) + f(Ca/Cu) + f(Ca/Fe) + f(Ca \times Mn)}{9}$
	Mg index	$\frac{f(Mg/N) + f(Mg/P) - f(K/Mg) - f(Ca/Mg) - f(S/Mg) + f(Mg \times Zn) - f(Cu/Mg) + f(Mg/Fe) - f(Mn/Mg)}{9}$
	S index	$\frac{f(S/N) + f(S/P) - f(K/S) - f(Ca \times S) + f(S/Mg) + f(S \times Zn) + f(S \times Cu) + f(S/Fe) - f(Mn/S)}{9}$
	Zn index	$\frac{f(Zn/N) + f(Zn/P) - f(K/Zn) + f(Ca \times Zn) + f(Mg \times Zn) + f(S \times Zn) + f(Zn \times Cu) + f(Zn/Fe) + f(Zn \times Mn)}{9}$
	Cu index	$\frac{-f(N/Cu) + f(Cu/P) - f(K/Cu) + f(Ca \times Cu) + f(Cu/Mg) + f(S \times Cu) + f(Zn \times Cu) + f(Cu/Fe) - f(Mn/Cu)}{9}$
	Fe index	$\frac{-f(N/Fe) + f(Fe/P) - f(K/Fe) - f(Ca/Fe) - f(Mg/Fe) - f(S \times Fe) - f(Zn/Fe) - f(Cu/Fe) - f(Mn/Fe)}{9}$
	Mn index	$\frac{f(Mn/N) + f(Mn/P) + f(K \times Mn) + f(Ca \times Mn) + f(Mn/Mg) + f(Mn/S) + f(Zn \times Mn) + f(Mn/Cu) + f(Mn/Fe)}{9}$
Aged orchards[b]	N index	$\frac{-f(P/N) + f(N/K) + f(N \times Ca) + f(N \times Mg) + f(N \times S) + f(N/Zn) - f(Cu/N) - f(Fe/N) + f(N/Mn)}{9}$

(*continued*)

Table 2. Continued

Orchard	Parameter	Formula
	P index	$\frac{f(P/N) + f(P/K) + f(P/Ca) + f(P/Mg) + f(P \times S) + f(P/Zn) + f(P \times Cu) + f(P \times Fe) + f(P/Mn)}{9}$
	K index	$\frac{f(N \times K) - f(P/K) - f(Ca/K) - f(Mg/K) - f(S/K) + f(K/Zn) - f(Cu/K) - f(Fe/K) - f(Mn/K)}{9}$
	Ca index	$\frac{f(N \times Ca) - f(P/Ca) + f(Ca/K) + f(Ca/Mg) - f(S/Ca) + f(Ca/Zn) + f(Ca/Cu) + f(Ca \times Fe) + f(Ca/Mn)}{9}$
	Mg index	$\frac{-f(N/Mg) - f(P/Mg) + f(Mg/K) - f(Ca/Mg) - f(S/Mg) + f(Mg/Zn) - f(Cu/Mg) - f(Fe/Mg) - f(Mn/Mg)}{9}$
	S index	$\frac{f(N \times S) + f(P \times S) + f(S/K) + f(S/Ca) + f(S/Mg) + f(S/Zn) + f(S \times Cu) + f(S \times Fe) + f(S \times Mn)}{9}$
	Zn index	$\frac{-f(N/Zn) - f(P/Zn) - f(K/Zn) - f(Ca/Zn) - f(Mg/Zn) - f(S/Zn) - f(Cu/Zn) - f(Fe/Zn) - f(Mn/Zn)}{13}$
	Cu index	$\frac{f(Cu/N) + f(P \times Cu) + f(Cu/K) - f(Ca/Cu) + f(Cu/Mg) + f(S \times Cu) + f(Cu/Zn) + f(Cu \times Fe) + f(Cu/Mn)}{9}$
	Fe index	$\frac{f(Fe/N) + f(P \times Fe) + f(Fe/K) + f(Ca \times Fe) + f(Fe/Mg) + f(S \times Fe) + f(Fe/Zn) + f(Cu \times Fe) + f(Fe/Mn)}{9}$
	Mn index	$\frac{-f(N/Mn) - f(P/Mn) + f(Mn/K) - f(Ca/Mn) + f(Mn/Mg) + f(S \times Mn) + f(Mn/Zn) - f(Cu/Mn) - f(Fe/Mn)}{9}$

[a]In the formulae given, f (N/P); $-$f (K/N) $+ \cdots +$f (Mn/Fe) were calculated as follows. When calculated N/P for the test sample $\geq$n/p (norms for the expression, i.e., the mean value for the high-yielding population), then f (N/P) = [(N/P)/(n/p) – 1] 1000/CV. When calculated N/P value for the test sample $<$n/p, then f (N/P) = [(1 $-$ n/p) / (N/P)] 1000/CV where n/p is the value of norm selected from the high-yielding population, which is taken as the standard.

[b]In the formulae given, $-$f (P/N), f (N/K) $- \cdots -$f (Fe/Mn) were calculated in the same manner as indicated in mango orchards.

Table 3. Comparison of diagnosis of limiting nutrient by the conventional critical nutrients concentrations (CNC) method and DRIS indices

Orchard no.	Tree no.	Limiting nutrients by conventional CNC method	Order of limiting nutrients requirement as indicated by DRIS indices
Young trees			
1	2	Zn	Mn > K > Zn
2	3	N, Zn	Mn > N > K > S
5	4	N, Ca	S > Ca > K > N > Mg > Mn
14	6	N, Ca, Zn	Cu > Zn > S > Mg > Fe
15	2	Zn	N > Zn > S
17	10	Zn, Cu, Fe	S > Cu > Zn > Fe > Ca > Mn
20	4	Ca, Zn	Zn > Cu > Ca > Mg > K > S > Mn
Aged trees			
27	2	Ca, Cu, Fe	Fe > Cu > Ca > S > K > N > Mg > P
29	2	Zn	Zn > Mn > K > N > S
30	7	N, Zn	N > K > Mn > Zn > Ca > Mg

[a]As per Bhargava and Chadha (1988).

Sensitivity of DRIS Indices to Short-Term Application of Limiting Nutrients

Sensitivity of DRIS indices to the short-term application of the first two most yield-limiting nutrients was also tested through their application in July 1995

Table 4. Sensitivity of DRIS indices to long-term fertilizer application of N, P, and K

Treatment no.[a]	Treatments[b] N	P	K	Order of nutrient deficiencies	Fruit yield (kg plant^{-1})
1	1	1	1	K > Fe > Ca > Mg > S	280.0
2	3	1	1	K > Ca > Mg > Mn > S	163.0
3	1	3	1	Mg > Ca > Zn > K > S > Fe	490.0
7	1	3	3	Ca > Fe > Mg > Zn > S > Cu	694.0
8	3	3	3	Fe > Ca > S > Mg > Zn > Cu	302.2
10	4	2	2	Mg > Zn > Ca > K > Cu > Mn > Fe	270.2
12	2	4	2	Zn > Ca > Mg > S > K > Mn	212.5
13	2	2	0	K > Ca > Mg > Zn > S	247.5

[a]Selective treatmental combinations were taken for comparison.
[b]N: 1, 2, 3, and 4 doses are 405, 1000, 1595 and 2000 g N tree^{-1}. P: 1, 2, 3, and 4 doses are 405, 1000, 1595 and 2000 g P_2O_5 tree^{-1}. K: 1, 2, 3, and 4 doses are 405, 1000, 1595 and 2000 g K_2O tree^{-1}.

at the recommended dose. Eighty-eight trees from young orchards and 46 trees from aged orchards were used in the study. The sensitivity of the DRIS indices were tested by diagnosing the limiting nutrients based on nutrient composition in the leaf samples collected about 3 months after the application of limiting nutrients (in October and November 1995). The data are summarized in Table 5. These data indicate that the application of yield-limiting nutrients either totally corrected the limitation or changed the order of limitation to a lower level in 96.6 and 93.5% of the cases in young and aged trees, respectively, and indicated the sensitiveness of DRIS indices to short-term fertilization changes also. The limitation of both nutrients applied was corrected in 20.5 and 17.4% of young and aged orchards, respectively, thereby suggesting that the doses and the methodology adopted in these cases were able to fully overcome the limitation. Only one of the limiting nutrients was either corrected or shifted to lower limitation in 46.6 and 50.5% of the samples tested in young and aged trees, respectively. In all such cases, the dose of only one of the nutrients applied was adequate and simultaneously the dose of the second limiting nutrient applied was not adequate to fully overcome its limitation. In as many as 31.3 and 27.2% of young and aged trees, the limitation was not totally overcome though there was a shift in their order to the lower rank. In these cases, either the dose of limiting nutrient applied was not adequate to overcome the limitation or the method of application may need to be changed to improve the efficiency of applied nutrient, or both.

Effect of Age on Final Diagnosis of Yield-Limiting Nutrients by DRIS Indices

One of the advantages claimed for DRIS indices over the conventional CNC method in identifying the yield-limiting nutrients is that the final

Table 5. Summary of the changes in DRIS indices due to application of two of the most limiting nutrients

Sl. no.	Particulars	Young trees	Aged trees
1	Number of trees tested	88	46
2	Percentage of cases where there is change in priority of the limiting nutrients	96.6	93.5
3	Percentage of cases in which limitations of both the nutrients are corrected	20.5	17.4
4	Percentage of cases in which only one limiting nutrient was corrected and another nutrient was shifted to lower priority	46.6	50.0
5	Percentage of cases in which limitations of both the nutrients were not totally corrected but where there was a shift in priority	31.3	27.2

diagnosis by the former method is less dependent on the age of the sampled tissue (Walworth and Sumner 1987). To test this hypothesis, samples of index tissue were collected a second time, in the month of January 1994 (after a gap of about 3 months) from 178 trees, and the yield-limiting nutrients were computed by the DRIS indices.

From the results summarized in Table 6, it can be seen that the percentage of nutrients repeated as most limiting after 3 months gap was 22.8, whereas the percentage of nutrients shown as limiting in one of the first two places was 52.2. Similarly, the percentage of the same nutrient shown as limiting in the two samplings was 59.8. These trends do not fully support the claim of diagnosis being independent of age of sampling tissue (Walworth and Sumner 1987). However, if the probability of all possible combinations of 10 nutrients studied were taken into consideration (100 possible combinations with each combination having a probability of 0.01%), a repetition of the same nutrient as the most limiting (first place) in 24.2% of cases and repetition of the same nutrient being limiting in one of the first two places to an extent of 52.2% out of a total of 178 observations is quite significant, and there appears to be a rationale in the claim that was made, though it was not fully confirmed in the present study.

Effect of Application of Limiting Nutrients on the Fruit Yield

The effect of application of yield-limiting nutrients, as indicated by DRIS indices, on fruit yield was studied to test the effectiveness of DRIS indices developed in promoting higher productivity. The data are presented in Table 7. Positive response to application of the yield-limiting nutrients on fruit yield was noticed in all the cases. The mean percentage response over

Table 6. Effect of age of sampling tissue on final diagnosis of yield-limiting nutrients by DRIS indices

Sl. no.	Particulars	
1	Total number of observations	178
2	Percentage of nutrients repeated as most limiting (first place) after three months gap	22.8
3	Percentage of nutrients showing as limiting in one of the first two places after 3-month gap	52.2
4	Percentage of the same nutrients shown as limiting even after 3-month gap	59.8
5	Percentage of nutrients shown as limiting in the first sampling but not as such after 3-month gap	40.9
6	Percent of new nutrients shown as limiting after 3-month gap	42.0

Table 7. Effect of application of limiting nutrients on fruit yield in mango

Limiting nutrient applied	Age of tree	Number of trees applied	Control yield (t ha^{-1})[a] Range	Mean	Increase in yield (mean)	Increase over control (%)
N	Young	20	5.03–15.00	6.77	1.42	21
	Aged	18	5.84–6.20	5.72	1.88	32.9
P	Young	4	6.20–15.00	12.8	3.3	25.8
	Aged	6	6.10–21.00	9.82	1.76	17.9
K	Young	17	4.50–15.00	6.61	1.05	15.9
	Aged	12	5.84–6.20	6.08	1.46	24
Ca	Young	9	4.50–7.00	6.56	2.07	31.6
	Aged	8	5.84–21.00	13.6	4.63	34
Mg	Young	17	4.50–7.76	6.02	0.69	11.5
	Aged	—	—	—	—	—
S	Young	26	4.00–15.00	7.83	1.74	22.2
	Aged	9	5.84–13.90	8.9	1.86	20.9
Zn	Young	12	4.00–7.76	4.71	2.16	45.9
	Aged	3	5.84–6.10	5.9	1.2	20.3
Cu	Young	19	4.50–7.99	6.85	1.23	17.9
	Aged	7	6.10–21.00	9.88	1.5	15.2
Fe	Young	25	4.00–15.00	6.35	0.81	12.8
	Aged	9	5.84–21.00	12.68	2.31	18.2
Mn	Young	27	4.00–15.00	6.88	1.47	21.4
	Aged	14	5.84–13.90	8.65	2.36	27.3

[a]Yield in t ha^{-1} was calculated based on spacing adopted in orchard.

control, however, varied depending on the kind of nutrient and on the age of the tree. The mean response for Zn (45.9%) and Ca (31.6%) were higher in young trees compared to other nutrients. In cases of P, S, Mn, and N, the responses were greater than 20.0% in the young trees. In case of aged trees, the response was relatively higher in case of Ca (34%), followed by that of N (32.9%). In cases of Mn, K, S, and Zn, the responses varied between 20.3 and 27.3%.

CONCLUSIONS

DRIS norms were developed separately for young and aged mango orchards. The results indicated that the forms of expressions and DRIS indices varied for young and aged trees. The DRIS indices were observed to indicate more limiting nutrients as compared to the conventional CNC method and to be sensitive to both long- and short-term fertilization practices in mango. Application of two of the most yield-limiting nutrients, as indicated by DRIS indices, resulted in higher fruit yield.

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