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Identifying nutrient imbalances in pomegranate (Cv. Bhagwa) at different phonological stages by the diagnosis and recommendation integrated system

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ABSTRACT

The diagnosis and recommendation integrated system (DRIS) approach was used to interpret nutrient analyses of leaf tissues from pomegranate cv. Bhagwa orchards grown in southwestern Maharashtra, India. The DRIS norms were established for three growth stages,*viz.* 50% flowering, fruit development and first harvesting of pomegranate. Various nutrient ratios were obtained from high-yielding population and were used to compute DRIS indices for diagnosing nutrient imbalances and their order of limitation to yield. Nutrient sufficiency ranges at 50% flowering derived from DRIS norms were 1.32–2.15% nitrogen (N), 0.18–0.24% phosphorus (P), 1.29–1.99% potassium (K), 0.64–1.20% calcium (Ca), 0.23–0.45% magnesium (Mg), 0.16–0.26% sulfur (S), 103.04–149.12 mg kg^{-1} iron (Fe), 39.60–72.85 mg kg^{-1} manganese (Mn), 15.99–26.10 mg kg^{-1} zinc (Zn), 6.16–9.32 mg kg^{-1} copper (Cu), 23.38–39.88 mg kg^{-1} boron (B) and 0.29–0.47 mg kg^{-1} molybdenum (Mo). Similarly, the sufficiency range at fruit development and first harvesting was developed for computing DRIS indices. The requirement of Fe, Mg, S, Zn and N by the pomegranate plant was higher at 50% flowering and fruit development stages. According to these DRIS-derived indices, 87.85, 73.83, 70.09, 69.16 and 65.42% orchards were deficient in Fe, S, Mg, Zn, and N, respectively, at 50% flowering, while 70.03, 66.36, 63.55, 61.68, and 68.22% orchards were found to be deficient in respective nutrients during the fruit development stage.

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Introduction

Pomegranate (*Punica granatum* L.) is an important horticultural crop of semi-arid and arid regions of India. This plant has wider adaptability owing to its hardy nature and ability to tolerate drought and alkaline soil conditions. In order to improve the economical profit of pomegranate cultivation in the Deccan plateau region of India, the development of technologies to increase yield productivity, especially those concerning to the mineral nutrition and fertilization, is an essential necessity. Information about the nutritional status of a plant is a basic prerequisite for maintaining the optimum nutrition and is crucial to achieve high-yield productivity. The leaf analysis is a powerful tool in the mineral nutrition research; it not only evaluates the response to various nutrients but is also used as diagnostic techniques for assessing the nutritional status of

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plants. Hence, it can eventually be employed for making fertilizer recommendations (Chapman and Brown 1950). However, the usefulness of leaf analysis depends on the correct selection of leaf and stage of the crop. Many a times, the results of leaf analysis are difficult to interpret as the critical concentration of a specific nutrient in the shoots for optimum growth may change with the age of plant and concentration of other nutrients (Walworth and Sumner 1987). The critical concentration concept assesses single-nutrient element deficiency or toxicity at a time and does not reflect nutrient balance. However, the diagnosis and recommendation integrated system (DRIS) provides a means of simultaneously identifying nutrient imbalances, deficiencies, and excessiveness, and accordingly ranks them in the order of exigency. The DRIS is the establishment of the reference standards known as "norms" developed from the nutrient status of commercially cultivated area/orchards considered high yielding. The DRIS was developed by Beaufils (1971, 1973) as an objective means of coping with difficulties inherent in the diagnostic procedure and was successfully applied in different crops like maize and sugarcane. It is being tested as an evaluation method to assess the nutritional status of several crops such as pineapple (Angeles, Sumner, and Barbour 1990), citrus (Cerda, Nieves, and Martinez 1995), grapes (Monteiro et al. 2004) and green dwarf coconut (Santos, Monnerat, and Carvalho 2004). Until the present day, very little information on optimum nutrient norms of pomegranate cv. Ganesh is available (Raghupathi and Bhargava 2008). Unfortunately, the cultivar Ganesh was replaced by cv. Bhagwa in the recent past and it is most widely grown owing to its attractive red color and superior fruit quality. Monteiro et al.(2004) evaluated the nutritional status of grapevines cv. Italia in three developmental stages using the DRIS method and verified that it reflected the nutritional status and the grapevines exhibited variability with regard to the order and degree of nutritional limitation in the productivity.

Thus, the objective of this work was to evaluate the nutritional status of pomegranate cv. Bhagwa plant in the southwestern Maharashtra, India, in different growth stages using the DRIS methodology.

Materials and methods

This work was accomplished in the southwestern region (Latitude 14°30′ to 18°12′N and Longitude 74°22′ to 75°35′E, *i.e.*, Solapur, Satara and Sangli districts) of Maharashtra State in India during 2011–2012 to establish the DRIS standards. One hundred and fifty regional representative pomegranate orchards which were four to sixyears old grown under drip irrigation were selected in Hasta bahar, with a yield productivity ranging from 4.82 to 25.98 Mg ha^{-1} and average productivity of 16.43 Mg ha^{-1}.

New matured leaves, generally the eighth pair of leaves from the non-bearing branch apex (Bhargava 2002), were collected in three different growth stages: (1) 50% flowering (November, 2010), (2) fruit development (January, 2011), and (3) fruit development and first harvesting (April, 2011). After collection, samples were conditioned in paper bags and transported to a laboratory where they were cleaned. Then, the leaves were dried in a hot air oven at 70°C, during 48 hr. After being dehydrated, samples were pulverized on a mill (Wiley-like mill) with a 20-mesh sieve and then stored in hermetically closed glass vials. The concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), chlorine (Cl), iron (Fe), zinc(Zn), manganese (Mn), and boron (B) were determined in the samples after wet digestion and dry combustion (for B) following the standard analytical procedures (Malavolta, Vitti, and Oliveira 1997).

Orchards were grouped into two classes according to the productivity: (1) orchards with productivity above 20 Mg ha^{-1} (varying from 20.02 to 25.98 Mg ha^{-1}), and (2) orchards with productivity below 20 Mg ha^{-1} (ranging from 4.82 to 19.32 Mg ha^{-1}). The mean nutrient concentration values for high-yielding orchards were used to generate DRIS standards. The mean and standard deviation of macro- and micronutrient concentrations were determined for three different growth stages and two productivity levels.

The DRIS indices were calculated for the nutrients using the following generalized equations:

$$\text{Index A} = \frac{\left[f\left(\frac{A}{B}\right)+f\left(\frac{A}{C}\right)+f\left(\frac{A}{D}\right)+\cdots+f\left(\frac{A}{N}\right)\right]}{Z}$$

$$\text{Index B} = \frac{\left[-f\left(\frac{A}{B}\right)+f\left(\frac{B}{C}\right)+f\left(\frac{B}{D}\right)+\cdots+f\left(\frac{B}{N}\right)\right]}{Z}$$

$$\text{Index N} = \frac{\left[-f\left(\frac{A}{N}\right)-f\left(\frac{B}{N}\right)-f\left(\frac{C}{N}\right)\cdots-f\left(\frac{M}{N}\right)\right]}{Z}$$

where when A/B is larger or equal to a/b,

$$f\left(\frac{A}{B}\right) = \left(\frac{\text{A/B}}{\text{a/b}} - 1\right) \times \frac{1000}{\text{CV}}$$

or, when A/B is smaller than a/b,

$$f\left(\frac{A}{B}\right) = \left(1 - \frac{\text{a/b}}{\text{A/B}}\right) \times \frac{1000}{\text{CV}}$$

In these equations, A/B is the tissue nutrient ratio of the plant to be diagnosed, a/b is the optimum value or norm for that given ratio, CV is the coefficient of variation associated with the norm, and Z is the number of functions in the nutrient index composition. Values for other functions, such as f (A/C) and f (A/D), are also calculated in the same way, using appropriate norms and CV. In other words, one nutrient index is the average function of all the ratios containing a given nutrient. The components of this average value are weighted by the reciprocal of the CVs of the high-yielding populations (reference populations).Thus, if both A/B and A/C ratios are used to generate an index for the A nutrient, the contribution of each one toward the calculation of this index will be a function of the CV values (reference ratios) associated with them, which will reflect the relative influence of these two expressions in the fruit yield.

Results and discussion

Macronutrients

The DRIS norms for the leaf concentration of nitrogen at 50% flowering, fruit development and first harvesting stages were 1.32–2.15, 1.15–1.95 and 1.19–1.98%, respectively (Tables 1–3).

Table 1. Leaf nutrient DRIS norms at the 50% flowering stage of pomegranate.

Nutrients	Very low	Low	Optimum	High	Very high
N (%)	< 0.89	0.89–1.31	1.32–2.15	2.16–2.57	>2.57
P (%)	< 0.13	0.13–0.17	0.18–0.24	0.25–0.28	>0.28
K (%)	< 0.92	0.92–1.28	1.29–1.99	2.00–2.35	>2.35
Ca (%)	< 0.34	0.34–0.63	0.64–1.20	1.21–1.48	>1.48
Mg (%)	< 0.10	0.10–0.22	0.23–0.45	0.46–0.57	>0.57
S (%)	< 0.09	0.09–0.15	0.16–0.26	0.27–0.31	>0.31
Zn (mg kg^{-1})	< 10.92	10.92–15.98	15.99–26.10	26.11–31.16	>31.16
Fe (mg kg^{-1})	< 79.99	79.99–103.03	103.04–149.12	149.13–172.16	>172.16
Mn (mg kg^{-1})	< 22.96	22.96–39.59	39.60–72.85	72.86–89.47	>89.47
Cu (mg kg^{-1})	< 4.57	4.57–6.15	6.16–9.32	9.33–10.90	>10.90
B(mg kg^{-1})	< 15.11	15.11–23.37	23.38–39.88	39.89–48.14	>48.14
Mo(mg kg^{-1})	< 0.19	0.19–0.28	0.29–0.47	0.48–0.57	>0.57

Table 2. Leaf nutrient DRIS norms at the fruit development stage of pomegranate.

Nutrients	Very low	Low	Optimum	High	Very high
N (%)	< 0.74	0.74–1.14	1.15–1.95	1.96–2.35	>2.35
P (%)	< 0.12	0.12–0.16	0.17–0.23	0.24–0.27	>0.27
K (%)	< 0.84	0.84–1.18	1.19–1.88	1.89–2.22	>2.22
Ca (%)	< 1.61	1.61–1.82	1.83–2.24	2.25–2.44	>2.44
Mg (%)	< 0.13	0.13–0.27	0.28–0.57	0.58–0.72	>0.72
S (%)	< 0.10	0.10–0.15	0.16–0.27	0.28–0.33	>0.33
Zn(mg kg^{-1})	< 13.09	13.09–19.92	19.93–33.58	33.59–40.41	>40.41
Fe (mg kg^{-1})	< 159.72	159.72–175.96	175.97–208.44	208.45–224.68	>224.68
Mn(mg kg^{-1})	< 33.62	33.62–54.02	54.03–94.82	94.83–115.22	>115.22
Cu(mg kg^{-1})	< 5.41	5.41–7.29	7.30–11.03	11.04–12.91	>12.91
B(mg kg^{-1})	< 15.66	15.66-–23.67	23.68–39.69	39.70–47.71	>47.71
Mo(mg kg^{-1})	< 0.19	0.19–0.29	0.30–0.49	0.50–0.59	>0.59

Raghupathi and Bhargava (1998b) have reported the optimum concentrations of N in the leaves of cv. Ganesh to be between 0.91 and 1.66%. Our findings were in support of the earlier report and the deviation which was observed in our results might have resulted owing to a difference in cultivar and edaphic conditions (Al-Maiman and Ahmad 2002). This trend indicates that the plant required more N during flower and fruit-setting stages. This trend was in consistence with the work of Mirdehghan and Rahemi (2007) who reported higher N demand in the sink (developing fruit) during 10–30 days after full bloom. The optimum concentration ranges of phosphorous at three growth stages were 0.18–0.24, 0.17–0.23 and 0.14–0.22%, respectively (Tables 1–3). Higher phosphorous concentration was observed at 50% flowering and fruit developmental stages implying its high requirement as P plays an important role in cell division (Mirdehghan and Rahemi 2007). Raghupathi and Bhargava (1998b) observed the optimum level of phosphorous in the leaves of cv. Ganesh which varied from 0.12 to 0.18%. Our finding closely agrees the earlier report. Some studies (Gimenez et al. 2000) reported an optimum tissue concentration of P to be from 0.10 to 0.16% which also falls within our range. DRIS norms for the leaf K concentration at three stages were worked out to be 1.29–1.99, 1.19–1.88 and 1.07–1.63%, respectively (Tables 1–3). The norms for the K concentration were lower than those earlier reported byRaghupathi and Bhargava (1998b) who could find it to vary from 0.55 to 2.27% for cultivar Ganesh. The variation might arise from the differences in cultivars and edaphic soil conditions. The lower K concentration in the leaf tissue at the first harvesting stage revealed the redistribution of nutrients from source to sink (*i.e.*, fruit) for fruit development and maturity. K is involved in the sugar translocation leading to the maturity of fruit.Hepaksoy, Aksoy, and Can (2009) also reported the optimum range of potassium at the fruit development stage to be 1.20–2.08% which was in close agreement with our findings.

Table 3. Leaf nutrient DRIS norms at the first harvesting stage of pomegranate.

Nutrients	Very low	Low	Optimum	High	Very high
N (%)	< 0.78	0.78–1.18	1.19–1.98	1.99–2.38	>2.38
P (%)	< 0.09	0.09–0.13	0.14–0.22	0.23–0.26	>0.26
K (%)	< 0.78	0.78–1.06	1.07–1.63	1.64–1.91	>1.91
Ca (%)	< 1.63	1.63–1.80	1.81–2.13	2.14–2.30	>2.30
Mg (%)	< 0.11	0.11–0.25	0.26–0.51	0.52–0.65	>0.65
S (%)	< 0.08	0.08–0.14	0.15–0.27	0.28–0.33	>0.33
Zn (mg kg^{-1})	< 13.62	13.62–20.20	20.21–33.37	33.38–39.95	>39.95
Fe (mg kg^{-1})	< 129.01	129.01–147.44	147.45–184.31	184.32–202.74	>202.74
Mn (mg kg^{-1})	< 16.91	16.91–38.12	38.13–80.53	80.54–101.73	>101.73
Cu (mg kg^{-1})	< 5.49	5.49–7.10	7.11–10.31	10.32–11.91	>11.91
B (mg kg^{-1})	< 16.24	16.24–24.04	24.05–39.65	39.66–47.45	>47.45
Mo (mg kg^{-1})	< 0.19	0.19–0.29	0.30–0.49	0.50–0.59	>0.59
Yield(Mg ha^{-1})	< 16.49	16.49–19.73	19.74–26.20	26.21–29.44	>29.44

Secondary nutrients

DRIS norms for calcium at three growth stages,*i.e.*, 50% flowering, fruit development and first harvesting, were computed to be 0.64–1.20, 1.83–2.24 and 1.81–2.13%, respectively (Tables 1–3). Since calcium is essential for the fruit development and production of good quality of fruits (Wavhal and Choudhari 1985), higher requirement of calcium was noticed during the fruit development stage. The Ca deficiency symptoms were reported in pomegranate when the leaf Ca concentration was less than 0.54% (Wavhal and Choudhari 1985). Raghupathi and Bhargava (1998b) reported the optimum calcium concentration in the leaf tissue of pomegranate cv. Ganesh to be 0.77–2.02% which was higher than cultivar Bhagwa. This difference may be due to their genetic makeup. Optimum leaf tissue concentrations of Mg at three growth stages were found to be 0.23–0.45, 0.28–0.57 and 0.26–0.51%, respectively (Tables 1–3). In cultivar Ganesh, the optimum leaf tissue concentration of Mg was reported to vary from 0.16 to 0.42% (Raghupathi and Bhargava 1998b). They observed that the Mg concentration in the leaf tissue in 53 selected orchards of Pune and Bijapur districts of Maharashtra and Karnataka, respectively, ranged from 0.16 to 0.49%. Gimenez et al. (2000) reported a very narrow range of Mg concentration in the leaf which was 0.30–0.36% for Mollar variety and 0.30–0.38% for Israel variety. Our results were in consistence with the earlier report. DRIS norms for sulfur (S) at 50% flowering, fruit development and first harvesting stages were 0.16–0.26, 0.16–0.27 and 0.15–0.27% (Tables 1–3). A similar optimum leaf S concentration range was reported in cultivar Ganesh by Raghupathi and Bhargava (1998b) who observed that the optimum sulfur in the leaf tissue of pomegranate cv. Ganesh ranged from 0.16 to 0.26%. This indicates that the requirement of S for both the cultivars,*viz.* Ganesh and Bhagwa is similar. Sulfur deficiency symptoms in pomegranate were reported when the leaf S concentration fell below 0.09% (Wahval and Choudhari 1985). In our study also, the leaf concentration of S below 0.09% was categorized under the very low group in the DRIS norms.

Micronutrients

DRIS norms derived for the zinc (Zn) concentration at 50% flowering, fruit development and first harvesting stages ranged from 15.99 to 26.10, 19.93 to 33.58 and 20.21 to 33.37 mg kg^{-1}, respectively (Tables 1–3). A wide variation in the optimum leaf Zn concentration in pomegranate was reported by various workers. Raghupathi and Bhargava (1998a) reported the optimum leaf Zn concentration in Ganesh to be 14–72 mg kg^{-1},while Gimenez et al. (2000) found the zinc concentration to be 11–15 mg kg^{-1}in the leaves optimum for pomegranate. This wide variation might arise from varying soil and agro-climatic conditions. The optimum leaf Fe concentrations at three growth stages of pomegranate were 103.04–149.12, 175.97–208.44 and 147.45–184.31 mg kg^{-1}, respectively (Tables 1–3). Our DRIS norm for Fe rightly corroborates the earlier report (Gimenez et al. 2000) who observed that the optimum leaf Fe concentration in pomegranate ranged from 100 to 152 mg kg^{-1}. They also reported a positive correlation between leaf iron concentration and yield of pomegranate. In our results, we could notice higher optimum concentration ranges of Fe during fruit development and maturity stages. However, Raghupathi and Bhargava (1998b) reported the optimum concentration of iron in the leaf tissues of pomegranate cv. Ganesh to vary from 71 to 214 mg kg^{-1}. DRIS norms for Mn were 39.60–72.85, 54.03–94.82 and 38.13–80.53 mg kg^{-1} at 50% flowering, fruit development and first harvesting stages, respectively, (Tables 1–3). Among the three phenological stages, the highest concentration range was observed at the fruit development stage. The optimum leaf Mn concentration range as derived from our study rightly corroborates the earlier report by Raghupathi and Bhargava (1998b) who reported that the optimum concentration of Mn for pomegranate cv. Ganesh ranged from 29 to 89 mg kg^{-1}. Optimum leaf concentrations of copper (Cu) at three stages,*viz.* 50% flowering, fruit development and first harvesting of pomegranate cv. Bhagwa were worked out as 6.16–9.32, 7.30–11.03 and 7.11–10.31 mg kg^{-1}, respectively (Tables 1–3). However, Gimenez et al. (2000) reported a higher range (13–18 mg kg^{-1}) of leaf tissue concentration of Cu in pomegranate which may be due to cultivar. DRIS norms for boron (B) at 50% flowering, fruit development and first harvesting of pomegranate were 23.38–39.88, 23.68–39.69 and 24.05–39.65 mg kg^{-1}, respectively (Tables 1–3). The concentration

of B in leaves was higher than many of the cationic micronutrients like Zn and Cu and no variation was observed among the three stages implying its higher requirement by the pomegranate plant than Zn and Cu. Moreover, B plays an important role in a number of physiological processes starting from cell division, pollination, and fruit or seed set and translocations of sugars. It plays an important role in fruit development (Wavhal and Choudhari 1985). This indicates that pomegranate requires B from floral initiation to maturity of fruit. DRIS norms for molybdenum at three growth stages of pomegranate were also developed and they were 0.29–0.47, 0.30–0.49 and 0.30–0.49 mg kg^{-1} at 50% flowering, fruit development and first harvesting stages, respectively (Tables 1–3). Andris (2002) conducted a survey of pomegranate orchards and reported that the optimum tissue concentration of molybdenum should be above 0.3 ppm for the optimum yield.

DRIS indices

The value of each ratio function is added to the subtotal of one index and subtracted from another (*i.e.*, the value f (A/B) is added to the A index and subtracted from the B index) before the final ponderation; all the indices are balanced around zero (Walworth and Sumner 1987). Consequently, the sum of the nutritional indices must be zero, when the results are negative; that means, deficiency and positive values indicate excessive quantities of the considered nutrient relatively to others. The more the negative index, the more deficient the nutrient and the more the imbalances of the particular nutrient. Mean DRIS indices (Table 4) for major nutrients like nitrogen, phosphorous and potassium at 50% flowering stage were −5.14, −1.51 and 17.54, respectively. It indicated that among the major nutrients, nitrogen was the most deficient. Raghupathi and Bhargava (1998b)could also identify N as the most limiting nutrient in pomegranate. Hence, proper fertilization needs to be taken care off before initiation of flower buds for restoring nutrient balance and enhancing flowering and fruit setting, whereas potassium was the most abundant. This may also limit the absorption and utilization of other nutrients by the plant and again may create nutrient imbalances. Regarding secondary nutrients, mean DRIS indices for Ca, Mg and S were 25.12, −16.78 and −9.79 at 50% flowering. Among the secondary nutrients, Mg was the most deficient followed by S. Mg deficiency might arise from the abundance of potassium which competes with Mg for the absorption by the plant. Mean DRIS indices for micronutrients,*viz.* zinc, iron, manganese, copper, boron and molybdenum at 50% flowering were −8.88, −19.29, −0.37, 0.31, 1.25 and 0.48, respectively This indicates that among the micronutrients, Fe and Zn were the most deficient in pomegranate at 50% flowering stage. Zinc as a limiting nutrient in pomegranate was also reported by Raghupathi and Bhargava (1998b). The soils in the majority of pomegranate-growing areas arecalcareous in nature which restricted the absorption and translocation of Fe. This resulted in the deficiency of Fe in the pomegranate plant (Nikolic, Romheld, and Merkt 2000).

Table 4. DRIS indices for leaf tissue nutrients at different growth stages of pomegranate.

	Crop growth stage		
Nutrient	50% flowering	Fruit development	First harvesting
N	−5.14	−2.07	−15.23
P	−1.51	−1.43	−16.34
K	17.54	22.66	22.74
Ca	25.12	0.28	−6.05
Mg	−16.78	−8.38	0.71
S	−9.79	−8.92	−7.44
Zn	−8.88	−7.22	−5.40
Fe	−19.29	−4.86	−8.01
Mn	−0.37	−1.56	−0.66
Cu	0.31	−3.81	4.13
B	1.25	1.22	−1.02
Mo	0.48	−0.12	−0.48

Table 5. Order of nutrient requirement for the leaf nutrient concentration of pomegranate at different crop growth stages.

Sr. No.	Phenological stages	Order of nutrient requirement	
		Limiting nutrients	Nutrient in excess
1	50% flowering	Fe (87.85)* > Mg (70.09) > S (73.83) > Zn (69.16) > N (65.42) > P (42.99) > Mn (51.40)	Cu, Mo, B, K, Ca
2	Fruit development	S (66.36) > Mg (63.55) > Zn (61.68) > Fe (71.03) > Cu (60.75) > N (68.22) > Mn (52.34) > P (44.86) > Mo (62.53)	Ca, B, K
3	First harvesting	P (66.36) > N (100) > Fe (70.09) > S (63.55) > Ca (71.96) > Zn (61.68) > B (53.56) > Mn (51.40) > Mo (43.26)	Mg, Cu, K

*Values in parenthesis represent the percent of orchards found deficient in particular nutrient.

The mean DRIS indices for major nutrients,*viz.* N, P and K at the fruit development stage (Table 5) were −2.07, −1.43 and 22.66, respectively. At the fruit development stage, farmers avoid applications of nitrogen in the anticipation of wrong notion that the higher N content may reduce fruit quality and invite the incidence of bacterial blight disease. As a consequence, N appeared to be the most limiting during the fruit development stage. The study also indicated that P was also deficient during the fruit development stage; this might be owing to a higher demand of P by the developing fruit as it plays an important role in the cell division and in the limited supply of soil in P due to high pH (7.8–8.2) and calcareousness. Mean DRIS indices for secondary nutrients,*viz.* Ca, Mg and S at the fruit development stage were 0.28, −8.38 and −8.92, respectively. Like at 50% flowering, Mg and S were also deficient during the fruit development stage. However, the magnitude of imbalance was lower than at the 50% flowering stage. This implies that the requirement of plant for Mg and S gets lowered as the plant proceeds from flowering to the fruit development stage. Mean DRIS indices for micronutrients,*viz.* Zn, Fe, Mn, Cu, B and Mo at the fruit development stage were −7.22, −4.86, −1.56, −3.81, 1.22 and −0.12, respectively. The indices indicated that Zn and Fe were mostly deficient followed by Cu during the fruit development stage. The order of deficiency also revealed the micronutrients' requirement pattern by the pomegranate plant at the fruit development stage (Mirdehghan and Rahemi 2007).

The nutritional status at harvesting reflects the nutritional requirement of plant for the subsequent bahar (crop). This acts as a guiding principle for undertaking proper nutrient management practices for optimizing plant nutrition and increasing fruit yield. At the first harvesting stage, the mean DRIS indices for N, P and K were −15.23, −16.34 and 22.74, respectively. Mean DRIS indices for secondary nutrients,*viz.* Ca, Mg and S at the first harvesting stage were −6.05, 0.71 and −7.44, respectively. Regarding micronutrients, the mean DRIS indices for zinc, iron, manganese, copper, boron and molybdenum were −5.40, −8.01, −0.66, 4.13, −1.02 and −0.48, respectively. The study indicated that plants became more deficient in N, P, Ca, S, Fe and Zn after the harvesting of fruit. As plants proceed from flowering–fruit development–fruit maturity stage, nutrients get redistributed from leaves (source) to fruit (sink). Nutrients in fruits get removed from the production system along with harvest. It was observed that 1.98–2.82 kg N, 0.32–0.65 kg P, 2.84–4.74 kg K, 0.69–1.54 kg Ca, 0.33–0.52 kg Mg and 0.14–0.19 kg S were lost from the production system for 1000 kg fresh pomegranate harvested. This caused the plant to appear deficient in N, P, Ca, S, Fe and Zn. So it is suggested that the pomegranate farmers of southwestern Maharashtra should undertake proper nutrient management practices for correcting the deficiencies of N, P, Ca, S, Fe and Zn before taking the subsequent bahar.

Order of nutrient requirement

Table 5 shows the order of nutrient requirement at 50% flowering fruit development and first harvesting and the values in parenthesis represent the percent of orchards which are found deficient in particular nutrient at respective stages. The study indicated that the pomegranate plant is required to be replenished with more concentrations of Fe, Mg, S, Zn and N before flowering to take place, while

during the fruit development stage, it needs to be supplemented with more concentrations of S, Mg, Zn, Fe and Cu. It was also observed that the majority of orchards in southwestern Maharashtra were deficient in N, Mg, S, Fe and Zn during 50% flowering and fruit development stages.

Conclusions

It is evident from this investigation that the leaf tissue analysis at three different stages of pomegranate fruit plant can be rightly interpreted by the DRIS approach, which will generate positive or negative indices for each nutrient. A positive index indicates sufficient or excessive amounts of the nutrient under consideration, whereas a negative index indicates insufficiency. The study indicated that N, Mg, S, Fe and Zn were the most yield-limiting nutrients in pomegranate orchards of southwestern Maharashtra. Thus, the nutrient requirements can be ordered relative to one another. Based on the indices obtained, the fertility status of the soil, the management levels of the ber fruit trees, and the type and amount of fertilizer to be applied can be formulated. With the DRIS approach, each nutrient can be efficiently applied through the single-element fertilizer rather than the application of multi-elemental compounds or mixtures.

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