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RESEARCH PAPER

DRIS, a precision system for diagnosis of nutrient deficiencies in chilli

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Abstract: The leaf nutrients content of Byagdi chilli crop was assessed by using Diagnosis and Recommendation Integrated System (DRIS). The DRIS norms, which showed higher variance and lower co-efficient of variation were found to have greater diagnostic precision. Based on the concept DRIS, the locations were bifurcated into two groups as high yielding and low yielding categories by taking cut off yield as chilli 8.50 q ha^{-1}. Accordingly, 115 locations were high yielding and remaining 60 locations were low yielding. DRIS indices were worked out for leaf samples of low yielding locations. Based on these indices the order of nutrients requirement was K>S>Mg>P. This indicated that potassium was highly limiting, followed by sulphur further followed by magnesium. Phosphorus nutrient was least limiting the yield.

Key words: Index leaf, Nutrient imbalance index, Nutrient norms, Nutrient ratios

Introduction

Byadgi chilli (*Capsicum annuum* L.) is an important spice cum vegetable crop. Nutrients are essential to enhance the chilli yield. Leaf analysis in any crop provides a useful measure of the nutrient content of the plant and can help to improve the nutrients management. The basic principle involved in DRIS approach is that, the concentration of a nutrient within the plant particularly in leaf at any particular stage is an integrated value of all the factors that have influenced the nutrient concentration upto the time of sampling. Thus, study of relationship of the nutrient content of the plant in relation to plant growth is a direct approach as it addresses the plant about its nutritional problems. Diagnosis and Recommendation Integrated System (DRIS) is a diagnostic tool which recommends nutrients application based on the relative balance between the nutrients. Most of the chilli growers in northern Karnataka are not applying the fertilizers as per the recommended doses and therefore there is imbalanced application of nutrients to meet physiological needs. Any nutrient if not applied in required quantity and proportion may lead to either deficiency or excess. The relative proportion between nutrients in index leaf at critical stage of plant significantly influences the yield of any crop rather than concentration of individual nutrients. Hence, a field survey was conducted during *kharif* 2017-18 in chilli growing areas of Dharwad, Gadag and Haveri districts in northern Karnataka to identify the nutrients responsible for low yield as well as higher yield based on the concentration of nutrients in index leaf of chilli at critical stage of plants. Ratios between nutrients can be calculated and optimum ratios may be identified that have direct relationship with yield.

Material and methods

Study site

A survey was conducted in three districts where Byadgi chilli crop was grown extensively in northern Karnataka. Totally 175 locations were selected based on soil type and extent of area under chilli crop in different talukas of Dharwad, Gadag and Haveri districts. At each location index leaf samples were collected at peak flowering stage to develop leaf nutrient norms. About 15 leaves per plant were collected from 15 to 20 plants selected randomly in each location and a total of 150 to 200 index leaves were collected to form a composite sample. Totally eight talukas spread over in three districts were selected (Fig. 1). In Dharwad district, Dharwad, Hubballi, Kundagol and Navalgund talukas, in Gadag district Gadag and Shirahatti, and in Haveri district Shiggaon and Savanur talukas were selected. Yield data was recorded from all the175 locations. Taking 8.5 q/ha as cut off yield locations were classified into low and high yielding locations. Based on the concentration of nutrients in index leaf of chilli at critical stage of plants the ratios between two nutrients can be critical. Optimum ratios were identified that have direct relationship with yield.

Generally, these soils are deep black medium black and red soils. The soils cropped to chilli in districts are classified under Vertisol, Vertic intergrades and to a little extent as Alfisols. The texture of these soils ranged from sandy loam to clay.

Nutrient analysis in leaf samples

The index leaf samples of chilli collected from different locations were processed in the laboratory and analysed for N, P, K, S, Ca, Mg, Fe and Zn as per standard procedures outlined by Jaiswal (2013). The concentration of primary and secondary nutrients was expressed in per cent while that of iron and zinc was expressed in mg/kg. Ratios between selected nutrients were calculated.

Computation of DRIS norms and indices

Nutrients data bank was established for the whole chilli population. The whole population of study area were divided into low and high yielding categories by taking the cut off chilli yield as 8.50 q/ha as a base to establish DRIS norms. Letzsch and Sumner (1984) indicated that, the actual cut-off value fixed for yield had little effect on developing norms as long as it was

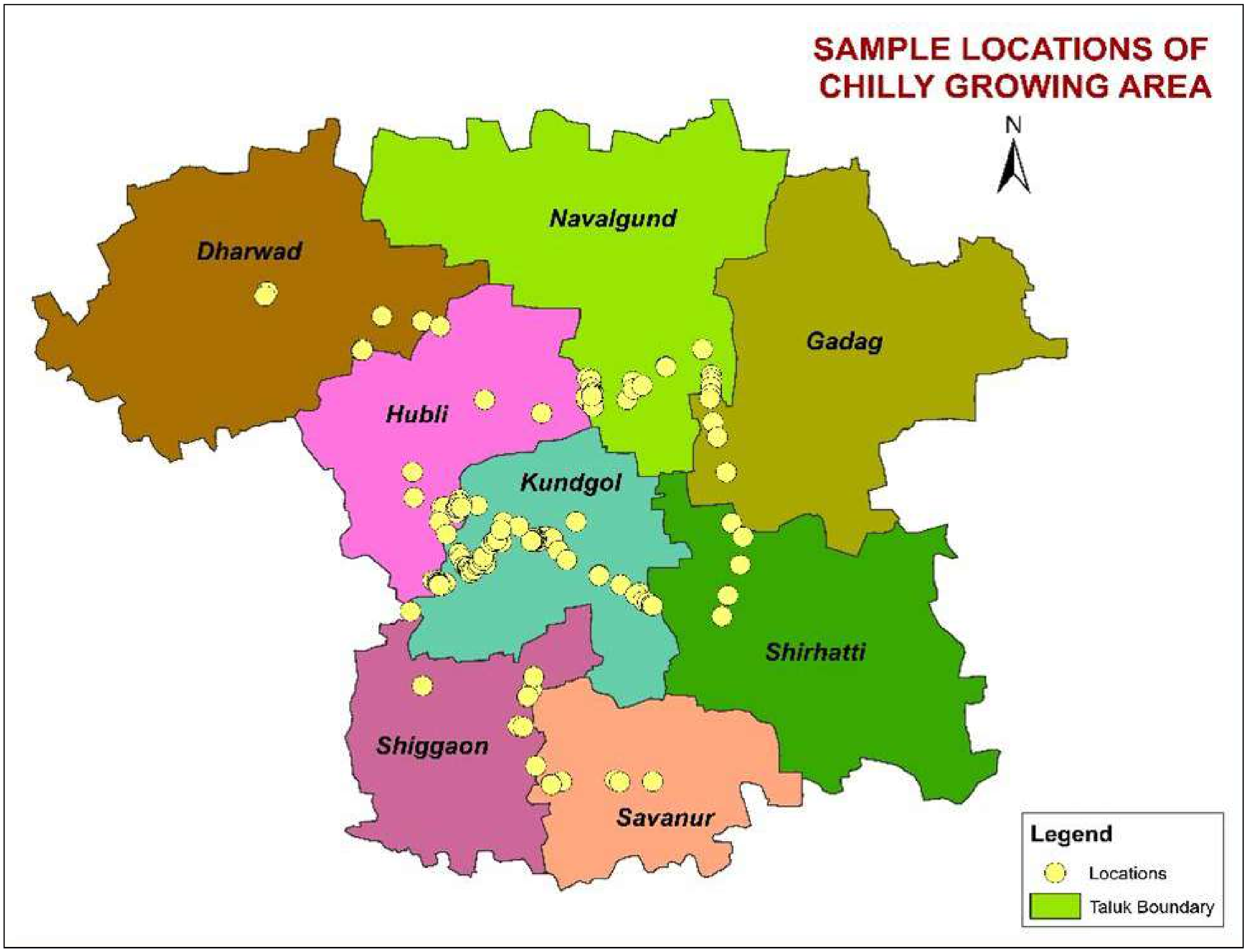

Fig. 1. Map of Dharwad, Gadag and Haveri districts showing locations of sample collection

not too low. Each parameter was expressed in as many forms as N/P, P/N, *etc.* and mean values for each nutrient-expression together with their associated CVs and variances, were then calculated for the two populations. The mean values of nutrient-expressions in high yielding plants were choosen as diagnostic norms. Among the different forms of expressions, the one showing higher variance ratio (variance of low yielding / variance of high yielding) was selected as a norm.

DRIS provides a means of arranging nutrient ratios in the form of indices. DRIS indices were calculated as described by Walworth and Sumner (1987) using the following formula, and for nitrogen it is shown below:

N index = 1/7 [-f (P/N)-f(K/N)+f(N/Ca)+f(N/Mg)-f(S/N)-f (Fe/N)+f(N/Zn)]

P index = [f(P/N)-f (K/P)-f(Ca/P)-f(Mg/P)-f(S/P)-f(Zn/P)-f (Fe/P)]

$$f\left(\frac{N}{P}\right)=\begin{cases}\left(\frac{N/P}{n/p}-1\right)x\,\frac{1000}{CV} & when\ N/P > n/p\\ 0 & when\ \frac{N}{P}=\frac{n}{p}\\ \left(1-\frac{n/p}{N/P}\right)x\,\frac{1000}{CV} & when\ N/P < n/p\end{cases}$$

where

1. N/P: The actual value of the ratio of nitrogen to phosphorus in the leaf under diagnosis
2. n/p: Value of the norm (which is mean value of the high-yielding population)
3. CV: Coefficient of variation of high yielding population

Similarly, indices for other nutrients were calculated using appropriate formulae. The absolute sum (positive and negative) values of nutrient indices generate an additional index called the nutrient imbalance index (NII) (Walworth and Sumner, 1987).

Nutrient Imbalance Index (NII) = $|I_N| + |I_P| + |I_K| + |I_S| + |I_{Ca}| + |I_{Mg}| + |I_{Zn}| + I_{Fe}|$

Where : I_N - N index

I_P - P index

$$\text{Nutritional Balance Index} = \frac{\text{Nutritional Balance Index}}{7}$$

Results and discussion

Nutrients content in leaf (Table 1)

The leaf nitrogen content in the entire population varied from 2.07 to 3.50 per cent with a mean value of 2.71 per cent. Phosphorus ranged from 0.12 to 0.93 per cent with a mean value of 0.44 per cent and potassium content ranged from 1.07 to 4.52 per cent with a mean of 3.22 per cent. Similarly, calcium content in leaf ranged from 0.72 to 3.00 per cent with a mean of 1.59 per cent while magnesium and sulphur contents ranged from 0.02 to 1.64, 0.21 to 0.69 per cent with mean values of 0.55 and 0.44 per cent respectively.

Among the major nutrients, the variations in N and P were more as compared to that of potassium. Ca and Mg also recorded wider variation in index leaf in the surveyed samples. This wider variation was due to the leaf samples collected from chilli grown area under different management systems**.** This wide variation in nutrient content of leaf samples was due to large variation in soil types, fertility status, quantity of fertilizers applied and other management practices adopted by the farmers that have contributed to wide variation in index leaf. Similarly, Srijaya (2016) for chilli crop, Dhanwinder *et al.* (2012) for cotton reported wide variations in nutrient contents in index leaf samples of different crops grown in different areas.

Table 1. Leaf nutrients contents of Byadgi chilli plants in the study area

Nutrients (%)	Mean	Max.	Min.	SD
N	2.71	3.50	2.07	0.31
P	0.44	0.93	0.12	0.17
K	3.22	4.52	1.07	0.84
Ca	1.59	3.00	0.72	0.47
Mg	0.55	1.64	0.02	0.28
S	0.44	0.69	0.21	0.08
Fe (mg/kg)	57.76	126.84	37.56	12.57
Zn (mg/kg)	25.91	28.82	21.14	1.56

SD : Standard Deviation

Range of nutrients content in index leaf in high and low yielding population.

The entire population of study area was divided into two groups as high and low yielding (Beaufils, 1973) based on the cut off yield level of 8.50 q/ha. It was observed that, in high yielding population, leaf N, P and K contents ranged from 2.09-3.50, 0.20-0.93 and 1.75-4.52 per cent, respectively where as in low yielding population they ranged from 2.07-3.36, 0.12-0.76 and 1.07-3.94 per cent, respectively. Similarly, Ca and Mg contents for high yielding population ranged from 0.72-3.00 and 0.15-1.64 per cent, respectively, whereas for low yielding plants the values for Ca and Mg ranged from 0.84 to 2.52, and 0.02-1.08 per cent, respectively. Similarly, for iron and zinc contents the values for high and low yielding plants ranged from 37.56 to 126.84, 21.14 to 28.82 and 39.90 to107.34 and 22.15 to 27.55 mg/kg, respectively. It was observed that all nutrients were in higher concentration in plants of high yielding population than in low yielding population. The higher availability of nutrients in soil along with favourable moisture and other soil properties might have increased the concentration of these nutrients in high yielding chilli plants compared to low yielding groups. This might has governed the growth and yield attributes. The presence of higher concentration of nutrients in high yielding plants was also recorded by Savitha and Anjaneyulu (2008) for sapota, Raghupathi *et al.* (2004) for pomegranate and Nagaraj (2003) for coffee.

Table 2. Range and mean of nutrients concentration in index leaves and fruit yield in high and low yielding locations

Nutrients	High yielding		Low yielding	
(%)	Range	Mean	Range	Mean
Nitrogen	2.09 - 3.50	2.73	2.07 - 3.36	2.68
Phosphorus	0.20 - 0.93	0.47	0.12 - 0.76	0.38
Potassium	1.75 - 4.52	3.51	1.07 - 3.94	2.68
Calcium	0.72 - 3.00	1.59	0.84 - 2.52	1.59
Magnesium	0.15 - 1.64	0.56	0.02 - 1.08	0.52
Sulphur	0.33 - 0.69	0.47	0.21 - 0.60	0.38
Iron (mg/kg)	37.56 - 126.84	58.22	39.90 - 107.34	56.87
Zinc (mg/kg)	21.14 - 28.82	26.40	22.15 - 27.55	24.97
Fruit yield (q/ha)	8.63 - 20.09	13.12	2.06 - 8.49	6.20

DRIS ratio norms for index leaves of Byadgi chilli

The DRIS method uses nutrient ratios instead of absolute or individual nutrient concentrations. The priority was to select those nutrient expressions for which the variance ratios (*Variance of low yielding population/ Variance of high yielding population*) were relatively large (Walworth and Sumner, 1987).

A total of twenty- eight nutrient ratios were used as diagnostic norms from high yielding population and are presented in Table 3 along with their co-efficient of variation. Ideally it has been observed that, a particular nutrient ratio to be choosen as a norm should have high variance ratio and small co-efficient of variation between high and low yielding groups for the purpose of higher diagnostic precision (Raghupathi *et al.,* 2013). The nutrient ratios which were having lower co-efficient of variation with high variance were more critically related to yield than the nutrient ratios which had a very high co-efficient of variation. These nutrient ratio norms were worked out as derived by Bhargava (2002) for grapes, Hundal and Arora (2001) for kinnow oranges and Raghupathi *et al*. (2004) for mango.

The DRIS ratios involving N, K, S, Fe and Zn nutrients in the present study reported lower co-efficient of variation (CV) compared to the ratios with P, Ca and Mg. This showed that, N, K, S, Fe and Zn nutrients had greater influence on chilli fruit yield than P, Ca and Mg. The CV varied from a lowest of 13 per cent for N/Zn to the highest of 71 per cent for P/Mg indicating larger variation in their absolute concentration in the high yielding population. Among different expressions involving N, the norm N/P ratio was 6.55. Among the sixty low yielding locations, twenty locations showed negative indices for nitrogen and thirty-three locations showed negative indices for phosphorus indicating that the balance between nitrogen and phosphorus was not close to norm value more often because of low phosphorus. Similar findings were recorded by

Table 3. DRIS norms for index leaf concentrations at peak flowering stage for high yielding locations in the study area

Sl. No.	Nutrient Ratios	DRIS norms	CV (%)
1	N/P	6.55	39
2	N/K	0.81	23
3	N/Ca	1.91	36
4	Mg/N	0.21	49
5	N/S	5.85	16
6	Fe/N	21.57	24
7	N/Zn	0.10	13
8	P/K	0.14	42
9	Ca/P	3.78	45
10	P/Mg	1.08	71
11	S/P	1.13	36
12	Fe/P	137.38	36
13	Zn/P	63.26	35
14	Ca/K	0.48	41
15	Mg/K	0.17	53
16	S/K	0.14	25
17	Fe/K	17.26	30
18	Zn/K	7.87	24
19	Ca/Mg	3.51	59
20	Ca/S	3.40	34
21	Ca/Fe	0.03	36
22	Ca/Zn	0.06	31
23	Mg/S	1.19	47
24	Fe/Mg	126.71	49
25	Zn/Mg	58.95	50
26	Fe/S	123.91	22
27	Zn/S	56.60	14
28	Fe/Zn	2.21	22

Savitha (2008) for sapota crop. She reported that, the important ratios were N/K (1.731), N/Ca (0.928), Mg/N (0.360), Fe/N (99.89), N/Cu (0.104), N/B (0.037), Mg/Ca (0.329), Ca/B (0.040), Mg/S (1.103), Fe/Mg (278.6), Mg/Zn (0.037), Mg/B (0.013), and Fe/Zn (10.39). These ratios involving macro and micronutrients showed lower co-efficient of variation compared to others and thus might have a greater physiological rationale.

The norm value for N/K was 0.81 indicating that N and K concentrations were needed almost in equal proportions in leaf. Potassium was found to be yield limiting in most of the areas, indicating that K was more imbalanced nutrient among the low yielding population. The results of the present study highlighted the need to improve the potassium status of chilli growing areas to avoid its limitation. Similarly, potassium imbalance was reported in papaya crop by Anjaneyulu, (2007) and in sapota crop by Savitha (2008).

The DRIS norm for N/Ca was 1.91 indicating that calcium concentrations was very low compared to leaf nitrogen concentration. Calcium contributes very less to the fruit yield. The mean calcium concentration was lower than nitrogen concentration in high yielding population. Similarly, DRIS norm for Mg/N was 0.21 and the mean magnesium concentration was much lower compared to that of nitrogen concentration.

DRIS ratio norms indicated that, the mean iron concentration was generally 100 times higher to that of N concentration. Fe/N ratio was 21.57 which was low in 17 low yielding areas. N/Zn ratio was 0.10, and zinc was also low in as many as 20 low yielding areas. It is often difficult to consider all the twenty-eight nutrient expressions for interpretation of leaf analysis data for diagnosis of nutrient imbalances (Ragupathi *et al.,* 2013, Savitha *et al.,* 2017). Therefore, among the different expressions, the expressions having higher physiological relevance particularly for chilli crop needs to be considered. Data indicated that, the ratios that have showed lower co-efficient of variation compared to others and were critical from the crop performance point of view (Raghupathi *et al*., 2004). The nitrogen and magnesium are vital constituents of chlorophyll and enhance the photosynthesis. Phosphorus contributes for the root growth of chilli seedlings and development, while potassium is known to play a key role in red colour synthesis in chilli fruits (Bidari, 2000). Calcium plays role in providing strength to the terminal axes which lead to reduced flower dropping and increased fruiting (Jadhav, 2017). This has resulted in increased fruit yield. Hence, maintaining an optimum ratio between these nutrients (N, P, K, Mg, Ca) is obviously important to get high yield and good quality chilli fruits. Nonetheless, these nutrients were considered as yield limiting components and they need to be maintained at an optimum balance for maximum efficiency in terms of dry matter/ yield production (Anjaneyulu, 2006). These nutrient ratio norms were worked out as derived for grapes (Bhargava, 2002), Banana (Angeles *et al*., 1990), Mango (Raghupathi *et al*., 2004), Chilli (Srijaya, 2016), Litchi (Savitha *et al.,* 2017) and Nagaraj (2003) for coffee.

Identification of yield limiting nutrients by DRIS indices calculated from the index leaves

DRIS index is a measure of the deviations of the nutrient ratios containing a given nutrient from it's respective normal or optimum value. Thus, DRIS provides a means of ordering nutrient ratios into meaningful expressions in the form of indices. Thus, the relative abundance of each nutrient is evaluated by comparing all the ratios containing that nutrient with DRIS norms (Beaufils, 1973). The DRIS indices calculated for different nutrients in chilli leaf samples at peak flowering stage are shown in Table 4. Nutrients were arranged in the order of importance in which they are limiting the yield. As the value of each ratio is added to one index, subtotalled and subtracted from another prior to averaging all indices will be balanced around zero. The yield limiting nutrients differ from locations to locations in the study area though some of the nutrients are more prominent. Thus, diagnosis of nutrients imbalances through DRIS indices indicated that phosphorus and potassium were the most yield limiting nutrients among the low yielding locations (11 locations with red soil). DRIS indices also indicated that nitrogen was limiting the yield only in certain locations. Among the secondary nutrients, sulphur followed by magnesium and calcium were the yield limiting nutrients in low yielding locations. Among micronutrients, Zn and Fe were found to be most yield-limiting nutrients in most of the locations. The low content of micronutrients in many locations might be attributed to the high pH, presence of high free lime resulting in lower availability of micronutrients particularly zinc and iron due to their

Table 4. DRIS indices for index leaves nutrients content, order of nutrients requirement and nutrients imbalance index (NII) for low yielding locations of Byadgi chilli [Cv. Dyavnur]

Sl. No.	Location Nos.	N	P	K	Ca	Mg	S	Fe	Zn	NII	Order of nutrients requirement	Fruit yield (q/ha)
				←—— Indices ——→								
1	29	3.52	-7.46	-32.45	5.28	6.06	13.25	9.85	1.94	79.82	K>P	2.06
2	131	13.69	-18.15	-15.69	21.35	-28.47	-9.72	15.64	21.35	144.06	Mg>P>K>S	2.43
3	24	2.94	-21.24	-32.80	0.58	19.94	12.83	9.45	8.30	108.07	K>P	2.45
4	16	10.89	9.70	-9.15	-4.73	-14.48	11.22	4.88	-8.34	65.05	Mg>K>Zn>Mg	2.78
5	12	-13.98	6.71	-1.89	4.92	-3.06	6.89	2.16	-1.75	41.35	N>Mg>K>Zn	2.82
6	122	5.72	-14.35	-3.21	4.33	16.47	-6.81	3.03	-5.17	59.09	P>S>Zn>K	2.91
7	22	3.29	-14.96	10.94	15.99	-39.69	13.44	8.23	2.76	109.31	Mg>P	3.06
8	96	22.43	-12.15	4.65	-8.43	6.09	-14.24	-4.66	6.31	78.96	S>P>Ca>Fe	3.39
9	13	-5.07	-17.51	-24.98	3.24	20.59	2.23	17.47	4.03	95.12	K>P>N	4.27
10	34	7.18	-24.95	0.76	17.72	-12.69	-9.47	6.92	14.52	94.21	P>Mg>S	4.28
11	21	-13.40	11.20	-6.72	11.92	-9.59	-13.50	29.34	-9.25	104.92	Mg>N>Ca>Zn>K	4.51
12	144	1.35	-23.01	1.99	3.11	15.45	-6.82	3.95	3.99	59.67	P>Mg	4.57
13	20	-4.21	-3.27	-8.21	1.50	18.69	15.42	-16.37	-3.55	71.22	Fe>K>Zn>P	4.67
14	14	18.33	-9.34	-17.54	-8.51	-9.14	17.80	9.87	-1.45	91.99	K>P>Mg>Ca>Zn	4.88
15	168	6.19	6.00	7.56	19.32	-7.03	-20.27	-7.44	-4.33	78.15	S>Fe>Mg>Zn	5.00
16	174	4.62	-22.61	8.62	15.21	23.60	-25.09	-5.43	1.08	106.26	Mg>P>Fe	5.02
17	18	-1.36	3.20	1.19	-3.26	7.65	-1.78	-1.40	-4.24	24.07	Zn>Ca>S>Fe>N	5.16
18	63	25.80	18.77	-48.78	7.17	32.17	-50.13	-10.42	25.42	218.66	S>K>Fe	5.41
19	110	0.37	4.74	1.79	7.93	-9.99	2.92	-5.66	-2.09	35.48	Mg>Fe>Zn	5.62
20	102	-1.68	-6.79	-34.55	7.25	32.14	-11.51	10.04	5.11	109.08	K>S>P	5.72
21	162	1.56	8.98	-2.67	-7.92	9.47	-24.83	7.34	8.07	70.84	S>Ca>K	5.77
22	104	19.94	-4.96	-31.79	-7.53	31.07	-14.25	1.77	5.76	117.06	K>S>Ca>P	5.89
23	17	-6.48	9.33	-18.49	-9.23	19.45	15.37	-3.33	-6.62	88.29	K>Ca>Zn>N>Fe	5.91
24	23	-2.65	16.03	-19.26	-14.05	13.25	8.89	3.28	-5.48	82.89	K>Ca>Zn>N	5.99
25	111	15.25	-63.14	-3.25	19.58	-41.11	-10.83	69.56	13.95	236.67	P>Mg>S>K	6.15
26	8	9.72	-15.87	15.74	-5.74	-17.43	-14.97	10.35	18.19	108.01	Mg>P>S	6.23
27	25	-3.33	10.05	1.68	5.28	5.51	-10.92	0.84	-9.10	46.70	S>Zn>N	6.35
28	161	-5.96	16.76	3.31	9.00	7.70	-27.44	-5.60	2.23	78.00	S>N>Fe	6.38
29	72	25.31	-15.68	-31.18	18.82	-10.59	-20.26	12.66	20.93	155.42	K>S>P>Mg	6.41
30	28	-2.34	-4.25	-4.02	-12.95	16.95	7.70	3.69	-4.78	56.67	Ca>Zn>P>K>N	6.60
31	51	12.80	-11.99	-20.60	4.12	3.42	-10.28	4.45	18.07	85.73	K>P>S	6.60
32	71	7.96	-20.45	12.18	13.58	-18.05	-13.60	5.62	12.76	104.21	P>Mg>S	6.74
33	97	28.20	9.71	-45.90	0.60	5.56	-19.79	20.82	0.79	131.36	K>S	6.77
34	30	-3.43	24.08	3.25	-26.84	-4.56	7.36	-1.97	2.11	73.60	Ca>Mg>N>Fe	6.94
35	169	36.07	25.96	21.77	-13.23	-60.82	-25.22	3.05	12.42	198.54	Mg>S>Ca	7.24
36	77	9.82	-6.16	4.85	1.67	-3.51	-9.35	1.07	1.61	38.03	S>P>Mg	7.30
37	10	-12.62	-23.22	5.09	-0.18	35.47	-24.70	7.67	12.49	121.44	S>P>N	7.31
38	54	11.16	6.71	4.52	0.22	7.38	-20.92	-5.28	-3.79	59.97	S>Fe>Zn	7.33
39	118	15.34	-56.27	10.29	23.94	8.55	-10.64	2.03	6.75	133.81	P>S	7.35
40	143	9.00	-26.70	10.63	9.88	-29.54	-4.76	18.59	12.91	122.00	Mg>P>S	7.40
41	41	1.65	9.32	-9.81	3.98	-18.66	-6.23	5.73	14.01	69.40	Mg>K>S	7.48
42	27	-1.37	-6.53	-19.42	12.00	5.05	-0.96	18.27	-7.03	70.64	K>Zn>P>N>S	7.49
43	106	8.85	10.38	2.57	-5.63	-16.17	-8.94	2.90	6.05	61.48	Mg>S>Ca	7.49
44	76	18.25	-24.81	-14.19	25.46	4.77	-25.78	7.59	8.71	129.55	S>P>K	7.50
45	108	-1.30	4.39	5.83	-8.71	18.49	-21.32	-0.57	3.19	63.81	S>Ca>N	7.58
46	101	-8.13	-3.98	-13.58	4.91	21.41	-3.62	11.58	-8.59	75.81	K>Zn>N>P>S	7.61
47	125	3.70	-14.60	-0.16	-3.64	12.89	-5.98	4.17	3.62	48.76	P>S>Ca>K	7.62
48	49	-4.11	-0.80	8.19	3.82	-3.19	-12.26	4.22	4.09	40.68	S>N>Mg	7.70
49	172	7.57	-12.67	11.86	-8.43	2.33	-14.36	6.77	6.92	70.92	S>P>Ca	7.88
50	103	8.08	-1.61	-4.50	-0.10	16.32	-8.50	-9.48	-0.24	48.82	Fe>S>K>P>Zn	7.91
51	56	6.11	26.54	-25.36	16.42	-18.57	-14.67	0.30	9.23	117.19	K>Mg>S	7.99
52	42	-1.40	4.15	-0.93	7.82	7.29	-7.88	-8.63	-0.42	38.51	Fe>S>N>K>Zn	8.01

Contd...

53	170	27.58	5.20	-28.44	17.19	-42.44	-8.35	8.70	20.55	158.45	Mg>K>S	8.07
54	15	14.07	24.74	5.78	7.26	-60.61	6.81	4.62	-2.68	126.58	Mg>Zn	8.17
55	5	-13.09	5.04	-23.39	-5.54	22.96	-15.80	22.76	7.06	115.64	K>S>N>Ca	8.23
56	132	4.88	-34.70	8.84	16.45	11.89	-12.62	-0.59	5.85	95.82	P>S	8.26
57	123	5.78	2.75	-9.73	4.97	11.42	-22.45	8.64	-1.39	67.14	S>K>Zn	8.29
58	116	17.61	8.63	-16.02	-8.20	-10.23	3.01	-4.28	9.48	77.46	K>Mg>Ca>Fe	8.38
59	107	16.91	4.59	-31.96	4.78	8.39	-20.34	4.19	13.43	104.60	K>S	8.48
60	35	-3.76	-19.35	6.96	21.97	6.85	-16.75	-2.00	6.08	77.63	P>S>N>Fe	8.49

precipitation as carbonates and hydroxides. Soil analysis of the study area and at the time of index leaves sample collection, zinc and iron deficiency symptoms were observed on chilli plants. Thus, among major nutrients phosphorus and potassium while in secondary nutrients sulphur were found to be the most common yield-limiting nutrient.

The nutrient indices near to zero indicated optimum level, negative values indicated relative deficiency and positive values as relative excess of that particular nutrient. The absolute sum values of the nutrient indices generated an additional index called the "Nutritional Imbalance Index" (NII). Higher the NII, larger is the plant nutritional imbalance and lower the yield. The sum of indices irrespective of the sign varied from 24.07 to 236.67. Among the 60 low yielding locations, locations with numbers, 111, 63, 169 and 170 recorded higher NII values as 236.67, 218.66, 198.54 and 158.45, respectively indicating that these locations were more imbalanced compared to the locations 18, 110, 77 and 42 which recorded lower NII values as 24.07, 35.48, 38.03 and 38.51, respectively. Simple correlations were worked out between Nutritional Imbalance Index (NII) and yield for the low yielding locations. The linear correlation co-efficient indicated a weak but positive correlation between yield and nutritional imbalance index ($r = 0.018$). Therefore, it is better to take into consideration sometimes the individual nutrient imbalance in each location to assess their impact on yield rather than total nutritional imbalance in the areas.

Conclusion

DRIS indices indicated potassium as the most common yield limiting nutrient among the major nutrients. Among secondary and micronutrients sulphur and zinc were most yield limiting nutrients, respectively. The results of the present investigations confirmed that the positive and negative indices of leaf nutrient developed through DRIS approach indicated that, a specific nutrient application could be recommended. The nutrient imbalance index for low yielding locations showed that most of the locations were having low NII indicating that ratios between different nutrients are coming into balance.

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