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Diagnosis and Recommendation Integrated System (DRIS) Norms for Identifying Yield Limiting Nutrients in Byadgi Chilli Fruits Grown in Northern Transitional Zone and Dry Zones of Karnataka (India)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Fruit samples collected from different part of northern Karnataka districts of Dharwad, Gadag and Haveri, when peak fruit harvesting stage were collected the samples, were processed and analysed for various nutrients and thus, the data bank was established. By using Diagnosis and

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Recommendation Integrated System (DRIS), nutrient expressions, which have shown higher variance and lower coefficient of variation, were selected as norms viz, N/P(4.98), N/K (0.73), N/Ca (1.17), N/Mg (4.65), S/N(0.10), N/Fe(0.02), N/Zn(0.08) *etc*. In addition, five nutrient ranges have been derived using mean and standard deviation as low, deficient, optimum, high and excess for each nutrient to serve as a guide for diagnostic purpose. The optimum N ranged from 2.30 to 2.84%, P from 0.48 to 0.56%, K from 3.16 to 3.44%, Ca from 2.08 to 2.74%, Mg from 0.60 to 0.88% and S from 0.24 to 0.27%. Among the micronutrients, the optimum Zn ranged from 28.71 to 29.78 ppm, Fe from 113.60 to 150.03 ppm for byadgi chilli crop.

Keywords: Diagnosis and recommendation integrated system; nutrient; micronutrients; chilli crop.

1. INTRODUCTION

Chilli (Capsicum annuum L.) is one of the important commercial vegetable crops and is widely cultivated throughout tropical and subtropical countries in the world. In Karnataka, major area under chilli is found in Northern Transition Zone followed by Southern Transition Zone. The crop is now grown in large scale. Chilli is an indispensable condiment of every Indian household. It is used in the daily diet on one form or the other. It is a rich source of vitamin A and C with good medicinal properties. Among the spices consumed per head, dry chilli fruits constitute a major share. The pungency in chilli is due to the alkaloid 'capsaicinoid'. It occurs in the cores or septa walls and placenta.

Nutrients are essential to enhance the chilli yield. 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. The over input of fertilizers is an used practice among farmers, to achieve this aim it is necessary to evaluate the nutritional state of the plant to obtain information about the relation among nutrients available in the soil, nutrients content in the plant and yield. It is known that the plant is considered an extractor of nutrients from the soil.

The most disadvantage of the sufficient range method: its diagnosis results do not show the nutritional balance; it is not feasible to know the order of nutritional requirement; the leaf nutrient contents are not correlated to the yield under field conditions; it is sensitive to the stage of plant maturation, this way the diagnosis must be done at the same stage that the sufficient range was established. With the intent to correct the problems observed into the sufficient range to developed the Diagnosis and Recommendation Integrated System (DRIS). This diagnosis system consists in dual ratios among all nutrients in diagnosis (N/P, N/K, K/N, K/Ca, etc.). But, to use DRIS is necessary to develop DRIS norms, these norms were developed from data of farmland or experimental units. The most important is that the data must be from high yield population. For each nutrient under diagnosis, the DRIS method provides one DRIS index, this index can be positive or negative, which represents the effect of each nutrient into the nutritional balance of the plant. The closer the proximity of the DRIS index to zero, the closer to the nutritional balance. The origin of theses indices is from the comparative analysis with the norms previously established being necessary to relate the nutrients in dual ratios (N/P, P/N, N/K, K/N, etc.) in the sample and in this way, it is possible to assess the sample through the DRIS system. It is necessary to interpret the DRIS index for each nutrient, this interpretation depends on the value and the sign of the index. The order of nutrient requirement by plant is the most used method to interpret the DRIS indices. In this method, the DRIS indices are arranged from the most negative to the most positive value. When the DRIS index is close to zero, it means that the nutrient is adequate for the plant. The proposed in this study was to apply the Diagnosis and Recommendation Integrated System (DRIS) to assess the nutritional state of chilli crop through the order of nutrient requirement and nutritional balance. 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 fruit nutrients in chilli crop.

2. MATERIALS AND METHODS

2.1 Data Source

This study was performed with data from commercial byadgi chilli fields, of the growing season in the year 2017-2018 in northern part of Karnataka (Dharwad, Gadag & Haveri). The soil of the study area consisted predominantly of Vertisol, Inceptisol. The yield data of the chilli were collected from the farmers and compiled in a database.

2.2 Data Base

To constitute the database, 175 samples of index leaves 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 and 2). 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. In the leaf samples, the total contents of N, P, K, Ca, Mg, S, B, Zn, Cu, Mn, and Fe were determined by the methodology described by Jaiswal 2013. The information stored in the database and used for DRIS were the total leaf contents of macronutrients (%) and micronutrients (mg kg^{-1}) and seed byadgi chilli yield (kg ha^{-1}).

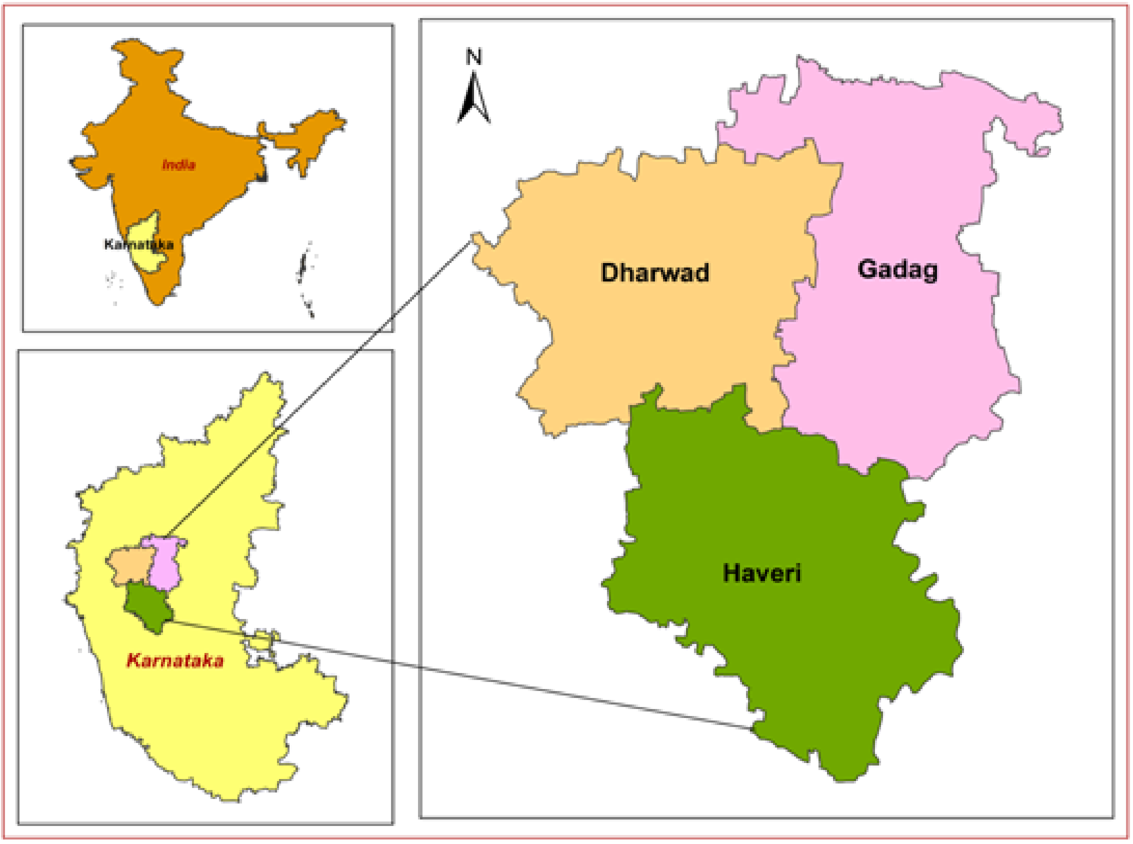

Fig. 1. Map of Dharwad, Gadag and Haveri districts in Karnataka showing study area

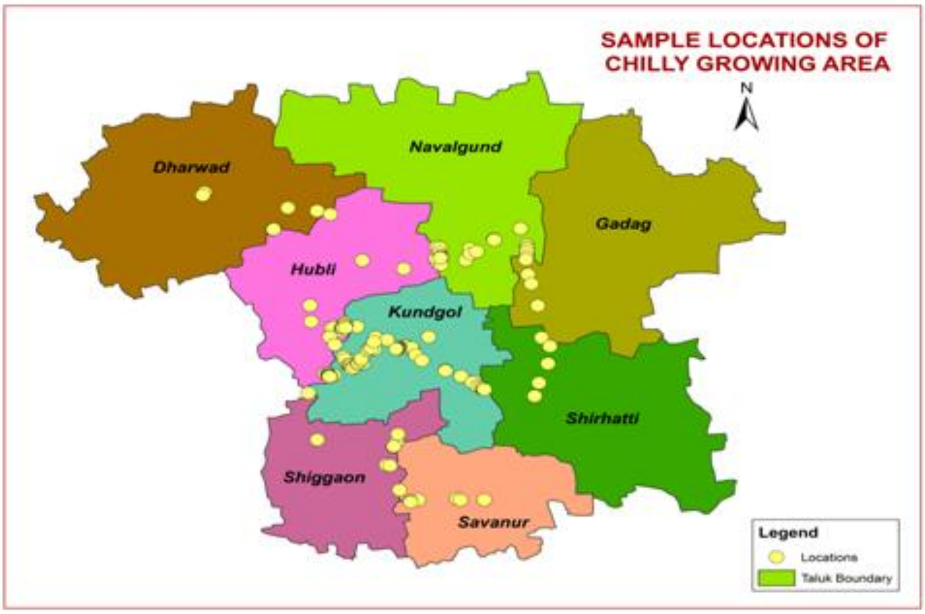

Fig. 2. Map of Dharwad, Gadag and Haveri districts showing locations of sample collection

2.3 Development of DRIS Norms

The database was divided into two subpopulations, using the 8.50 quintals/ha was taken as cut off yield for the purpose of categorizing low and high yielding groups of locations. This exercise is a foundation for the development of DRIS norms and identification of yield limiting nutrients. The high-yielding population was compound by 115 plots and 60 plots were compound the low-yielding population. The determination of the ratio (*A*/*B* or *B*/*A*) to establish the norm by the variance ratio method, the F value, was defined as the variance ratio of the low-yielding and high-yielding population and the order of the ratio with the highest value was chosen among the variance ratios.

The fruit composition data was separated for high and low yielding population using demarcating yield level of 8.50 q ha^{-1}. Means, variances and coefficient of variations (CV) of various forms of expressions for high and low yielding population were calculated separately using the standard procedure. Variance ratios for each form of expression (variance of low yielding population / high yielding population) were also calculated. The form of expression for each pair of nutrients, for eight nutrients viz., N, P, K, S, Ca, Mg, Fe, and Zn were selected. The expressions representing the norms selected for this study were: N/P, N/K, N/Ca, N/Mg, N/S, N/Zn, N/Fe, P/K, P/Fe, P/Zn, P/Ca, P/Mg, P/S, K/Fe, K/Zn, K/Ca, K/Mg, K/S, Fe/Zn, *etc.,* and their reciprocals and products for use in the DRIS indices calculation.

2.4 Calculation of DRIS Function

DRIS function values for nutrients were calculated using the original procedures proposed by Beaufils [1], which have been used in many studies. This procedure involves two formulas, depending on the ratio of the two nutrients under study is smaller or larger than their corresponding norm values. These formulas are explained below:

Formula 1: If the ratio between the two elements is greater than their corresponding norm, i.e., when A / B > a / b, then following formula is applicable:

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

Where A/B is the value of the ratio of the two elements in the tissue under diagnosis, a/b is the value of the corresponding norms, and CV is the coefficient of variation associated with each nutrient ratio norm.

Formula 2: If the ratio between the two elements is less than their corresponding norms, *i.e.,* when A / B < a / b then the following formula is applicable:

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

The function value, for example of N and P, thus will be derived from the general formula as below:

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

Where N/P is the value of the ratio of the N and P in the tissue under diagnosis, n/p is the value of the corresponding norm, and CV is the coefficient of variation. The other functions were calculated similarly using appropriate values of A/B and a/b.

2.5 Statistical Analysis

Statistical analysis was performed using the program SPSS for Windows, version. The other DRIS calculations were performed with Excel ® (2010) spreadsheets.

2.6 Fruit Nutrient Guides/Ranges Derived from Mean and Standard Deviation

Five leaf nutrient guides/ranges have been derived using mean and standard deviation as deficient, low, optimum, high and excess for each nutrient. The optimum nutrient range is the value derived from "mean -4/3SD (standard deviation) to mean + 4/3SD". The range "low" was obtained by calculating "mean - 4/3 SD to mean - 8/ 3SD" and the value below "mean - 8/3 SD" was considered as deficient. The value from "mean + 4/3 SD to mean + 8/3 SD" was taken as high and the value above "mean + 8/3 SD" was taken as excessive [2].

3. RESULTS

3.1 Fruit Nutrient Concentrations

The fruit nutrient status under different locations varied differently. For the entire population of Byadgi chilli the fruit Nitrogen content in red chilli fruits ranged from 1.47 to 3.23 with a mean of 2.28 per cent, phosphorus ranged from 0.20 to 0.64 with a mean of 0.44 per cent and potassium content ranged from 1.92 to 3.78 with a mean of 3.06 per cent. Similarly sulphur content ranged from 0.17 to 0.31 with a mean of 0.23 per cent, while calcium and magnesium contents ranged from 0.96 to 3.48 and 0.14 to 0.96 with mean values of 2.05 and 0.60 per cent, respectively. For iron and zinc contents, the values ranged from 51.20 to 192.23 and 20.51 to 30.63 mg/kg with mean values of 110.12 and 26.85 mg/kg, respectively.

3.2 DRIS Norms for Fruit Nutrient Concentrations for Byadgi Chilli Crop at Peak Picking Stage for Yield Levels

The DRIS norms were worked out for fruit nutrient concentration to know the relationship between quality parameters and nutrient ratios in Byadgi chilli. A total of twenty-eight nutrient ratios were chosen as diagnostic norms from high yielding population and are presented in Table 1 along with their co-efficient of variation (CV). The data indicated that the important nutrient ratios were N/K (0.73), S/N (0.10), N/Zn (0.08), K/P (6.80), S/P (0.49), Zn/P (60.15), S/K (0.07), Zn/K (8.86), Zn/Ca (14.28), S/Zn (0.01), Fe/Zn (4.08) *etc.,* which showed lower co-efficient of variation compared to others. The important nutrient expressions involving N were: N/P (4.98), N/K (0.73), S/N (0.10) and N/Zn (0.08), while in phosphorus the expressions were K/P (6.80) and Ca/P (4.51). In sulphur the nutrient ratios were S/P (0.49), S/Zn (0.01) and S/K (0.07), similarly in calcium the ratio was: Ca/K (0.66), in iron and zinc the ratios were Fe/Zn (4.08), Zn/P (60.15), Zn/K (8.86) and Zn/Ca (14.28). These ratios were equally important from the physiological point of view. Table 2 shows that the co-efficient of variation (CV) ranged from the lowest of 10 per cent for Zn/K to the highest of 56 per cent for N/Mg indicating wide variation in their absolute concentrations in the high yielding population. The nutrient ratios having lower co-efficient of variation with high variance ratios were more critically related to quality than the nutrient ratios which had very high co-efficient of variation.

3.3 Fruit Nutrient Guide and Classification of Byagi Chilli Crop

The optimum ranges for fruit nutrient concentrations were established based on the mean values and standard deviation (SD) parameters from high yielding population. The nutrients were classified as deficient, low, optimum, high and excessive based on the principle of DRIS [2] and presented in Table 3. The optimum fruit nitrogen content ranged from 2.30 to 2.84 per cent. The fruit nitrogen contents

Table 1. Range and mean of nutrients concentration in chilli fruit (sun dry basis) in the study area

Nutrients (%)	Range	Mean
Nitrogen	1.47 - 3.23	2.28
Phosphorus	0.20 - 0.64	0.44
Potassium	1.92 - 3.78	3.06
Calcium	0.96 - 3.48	2.05
Magnesium	0.14 - 0.96	0.60
Sulphur	0.17 - 0.31	0.23
Iron (mg/kg)	51.20 - 192.23	110.12
Zinc (mg/kg)	20.51 - 30.63	26.85

Table 2. DRIS norms for fruit nutrients concentration in high yielding locations at peak harvesting stage of Byadgi chilli

Sl. No	Nutrient ratios	DRIS norms	CV (%)	Sl. No	Nutrient ratios	DRIS norms	CV (%)
1	N/P	4.98	24	15	Mg/K	0.19	38
2	N/K	0.73	19	16	S/K	0.07	14
3	N/Ca	1.17	32	17	Fe/K	35.94	25
4	N/Mg	4.65	56	18	Zn/K	8.86	10
5	S/N	0.10	22	19	Mg/Ca	0.31	53
6	N/Fe	0.02	33	20	S/Ca	0.12	33
7	N/Zn	0.08	19	21	Ca/Fe	0.02	35
8	K/P	6.80	15	22	Zn/Ca	14.28	29
9	Ca/P	4.51	30	23	S/Mg	0.12	33
10	Mg/P	1.29	40	24	Mg/Fe	0.01	49
11	S/P	0.49	20	25	Mg/Zn	0.02	38
12	Fe/P	243.45	28	26	S/Fe	0.0022	32
13	Zn/P	60.15	17	27	S/Zn	0.01	16
14	Ca/K	0.66	25	28	Fe/Zn	4.08	26

CV: Co-efficient of variation

Table 3. Nutrients concentration standards of chilli fruits derived for high yielding locations

Nutrients (%)	Deficient	Low	Optimum	High	Excess
Nitrogen	< 1.20	1.21 - 2.29	2.30 - 2.84	2.85 - 3.39	> 3.40
Phosphorus	< 0.29	0.30 - 0.47	0.48 - 0.56	0.57 - 0.66	> 0.67
Potassium	< 2.56	2.57 - 3.15	3.16 - 3.44	3.45 - 3.73	> 3.74
Calcium	< 0.74	0.75 - 2.07	2.08 - 2.74	2.74 - 3.41	> 3.42
Magnesium	< 0.02	0.03 - 0.59	0.60 - 0.88	0.89 - 1.16	> 1.17
Sulphur	< 0.14	0.15 - 0.23	0.24 - 0.27	0.28 - 0.31	> 0.32
Iron (mg/kg)	< 37.74	38.74 - 112.60	113.60 - 150.03	151.03 - 187.46	> 188.46
Zinc (mg/kg)	< 23.56	24.56 - 27.71	28.71 - 29.78	30.78 - 31.86	> 32.86

less than 1.20 and more than 3.40 per cent were considered as deficient and excess, respectively. The optimum phosphorus content ranged from 0.48 to 0.56 per cent and fruit potassium ranged from 3.16 to 3.44 per cent. The fruit phosphorus contents less than 0.29 per cent and more than 0.67 per cent were considered as deficient and excess, respectively. The fruit potassium contents less than 2.56 per cent and more than 3.74 per cent were considered as deficient and excess, respectively. Similarly, calcium concentration ranged from 2.08 to 2.74 per cent and content less than 0.74 and more than 3.42 per cent were grouped as deficient and excess, respectively. Further, optimum magnesium content ranged from 0.60 to 0.88 per cent and sulphur content ranged from 0.24 to 0.27 per cent. The magnesium content less than 0.02 per cent and more than 1.17 per cent and fruit sulphur content less than 0.14 per cent and more than 0.32 per cent were considered as deficient and excess, respectively. Lastly optimum iron and zinc concentrations values were 112.60 to 150.03 and 27.71 to 29.78 mg kg^{-1}, respectively. Iron and zinc concentration values less than 37.74, 23.56 and more than 188.46 and 32.86 mg kg^{-1} were considered as deficient and excess, respectively.

4. DISCUSSION

These fruit samples were collected from the plants where index leaves samples were also collected in the farmers' fields**.** There existed a large variation between locations in terms of nutrient status, quantity of fertilizers applied and other management practices adopted by farmers which might have resulted in wide variation in fruit nutrient concentrations. In addition to the above factors, variation in physical and chemical properties of soils might have also influenced the uptake of nutrients as well as their assimilation in plants. Pankar and Magar [3] reported the nutrient content in red chilli fruits of different cultivars, extensively grown in India. Among the different cultivar fruits of Byadgi cultivar recorded slightly higher potassium content than other cultivars. Similar observations were made by Bidari [4] for three cultivars of Byadagi chillies. Likewise, Somimol [5] and Neelgar [6] reported that, chilli fruits accumulate highest amount of potassium followed by nitrogen, sulphur and phosphorus. This was due to the role of potassium in the synthesis of red colour in chilli fruits and role of nitrogen in capsaicin synthesis- the pungent principle. Sulphur plays role in synthesis of oil content in chilli seeds leading to oleoresins.

The fruit nitrogen content ranged from 1.47 to 3.23 per cent with a mean value of 2.28 per cent. Fruit samples of different locations vary widely with respect to concentrations of N, P, K, Ca, Mg, S, Fe and Zn. This might be due to differential uptake and translocation and assimilation of nutrients on account of variation in available nutrient status of soils along with other soil physical and chemical properties and also management practices adopted by the farmers.

4.1 DRIS Norms for Byadgi Chilli Fruit Nutrient Concentrations

The DRIS norms were worked out for fruit nutrients concentrations. A total of twenty-eight nutrient ratios were chosen as diagnostic norms from high yielding population and are presented in Table 2 along with their co-efficient of variation. The DRIS ratios involving nitrogen, potassium, sulphur, iron and zinc nutrients recorded lower co-efficient of variation (CV) than ratios with phosphorus, calcium and magnesium. The CV varied from a lowest of 10 per cent for Zn/K to the highest of 56 per cent for N/Mg which indicated larger variation in their absolute concentration in the high yielding population.

Among different expressions involving nitrogen, the N/P ratio was 4.98, which indicated that the phosphorus concentration was much lower as compared to fruit nitrogen concentration. The DRIS ratio norm for N/K was 0.73 which indicated that both nitrogen and potassium were needed in almost equal proportion. The mean N and K concentrations in fruits were nearly equal due to higher uptake and translocation by plants in the high yielding population. The norm for N/Ca was 1.17 which indicated that nitrogen and calcium were needed in almost equal proportion. The mean calcium concentration was marginally higher as compared to nitrogen concentration in the high yielding population. This was mainly attributed to the presence of high content of free calcium carbonate in the areas where the present survey was conducted. Calcium is required for the synthesis of pericarp in red chilli fruits. It gives greater stalk strength to flowers thus avoiding flower dropping in chilli. Hence high calcium content in fruits resulted in higher yield. The norm for N/Mg was 4.65 and the mean nitrogen concentration was higher than that of magnesium. Magnesium plays role in chlorophyll synthesis and its requirement is more felt in grand growth period When chilli fruits start turning red from green, magnesium concentration gradually decreases. But potassium concentration increases. The DRIS norm for K/P were 6.80 which indicated that potassium concentration was more as compared to fruit phosphorus. The ratio S/N was 0.10 indicating that the sulphur concentration in fruits was very less as compared to fruit nitrogen. Nitrogen and sulphur are the most important nutrients elements for yield of chilli. Nitrogen present in leaves gets translocated to fruits because it is highly mobile in plants. But sulphur is less mobile in plants [7] and its translocation to fruits is restricted. Since the consideration of all the twenty-eight nutrient expressions for the interpretation of the data for diagnosis of nutrient imbalance is often difficult [8], among the expressions only expressions having physiological relevance particularly to chilli are considered here. Potassium is known to play a key role in nitrogen uptake and translocation, whereas, magnesium and nitrogen are vital constituents of chlorophyll. Hence, maintaining a correct ratio of these two nutrients in plants is obviously very important for enhancing the yield of any crop [9,10]. However, maintenance of the optimum ratios of some expressions with large co-efficient of variation was less critical for the performance of chilli crop. Further, it is also not practically feasible to consider all the expressions for diagnosis of nutrient imbalance. The nutrients considered to be yield building component need to be kept in a state of relative balance for the maximum efficiency of dry matter production [11,10]. Similarly, the norms developed for other nutrients may also help in identification of the critical ratios for the normal growth and development of Byadgi chilli.

4.2 Nutrient Standards for Byadgi Chilli

The optimum fruit nutrient standards developed based on the fruit nutrient concentrations of high yielding groups at peak harvesting stage are presented in Table 3. These standards were developed based on the principle of DRIS. The present study indicated that, optimum range for nitrogen was 2.29 to 2.84 per cent, phosphorus 0.47 to 0.56 per cent and potassium 3.15 to 3.44 per cent. For secondary nutrients calcium and magnesium were 2.07 to 2.74 and 0.88 to 1.16 per cent, respectively, while for sulphur it was 0.23 to 0.27 per cent. Similarly, for micronutrients, particularly for iron and zinc the values were 150.03-187.46 and 29.78 to 31.86 mg kg^{-1}, respectively. It indicated that, accumulation of nutrients was more in fruits. This might be due to heavy application of fertilizers in these locations along with favourable soil properties that lead to increased uptake and translocation of applied nutrients and their accumulation in fruits to produce good quality chilli fruits. Similar results were reported by Savitha et al. [10] for litchi fruit in Uttarakhand and Savitha and Anjaneyulu [12] for sapota grown areas of northern part of Karnataka. However, further investigations are needed to establish nutrient standards for high yielding chilli plants.

5. CONCLUSION

It can be concluded that the fruit nutrient standards developed can be used for efficient fertilizer programming and to correct the nutrients in question for obtaining optimum flower yield and quality in chilli crop grown under transitional and dry zones. and thereby emphasizing DRIS as an important and ideal technique for evolving nutrient management strategies to realize higher fruit yields.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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