STANDARDIZATION OF DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM OF MANGO (*Mangifera indica* L.) CV. DASHEHARI UNDER JAMMU SUB TROPICS

BY

Jyoti Devi

(J-15-D-249-A)

Thesis submitted to Faculty of Postgraduate studies

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IN

(HORTICULTURE) FRUIT SCIENCE

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Ph.D

STANDARDIZATION OF DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM OF MANGO (*Mangifera indica* L.) CV. DASHEHARI UNDER JAMMU SUB TROPICS

Jyoti Devi

2021

CERTIFICATE-I

This is to certify that the thesis entitled **"Standardization of Diagnosis and Recommendation Integrated System of mango (*Mangifera indica* L.) cv. Dashehari under Jammu Sub tropics"** submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Horticulture (Fruit Science)** to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is a record of bonafide research, carried out by **Mrs Jyoti Devi**, Registration No. **J-15-D-249-A,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.

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We, the members of advisory committee of **Mrs Jyoti Devi,** Registration No. **J-15-D-249-A,** a candidate for the degree of**, Doctor of Philosophy in Horticulture (Fruit Science)** have gone through the manuscript of the thesis entitled **"Standardization of Diagnosis and Recommendation Integrated System of mango (*Mangifera indica* L.) cv. Dashehari under Jammu Sub tropics"** and recommend that it may be submitted by the student in partial fulfillment of requirements for the degree.

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ABSTRACT

Title of the Thesis	**:**	**"Standardization of Diagnosis and Recommendation Integrated System of mango (*Mangifera indica* L.) cv. Dashehari under Jammu Sub tropics"**
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ABSTRACT

The present investigation entitled "Standardization of Diagnosis and Recommendation Integrated system of Mango (*Mangifera indica* L.) cv. Dashehari under Jammu sub tropics" was carried out in Jammu division including two locations at Akhnoor and Samba.Total fifty orchards were selected, among these orchards twenty eight were selected from Akhnoor area and twenty two were selected from Samba area. Soil samples were collected from three soil depths 0-30 cm, 30-60 cm and 60-90 cm. The soil samples were analyzed for various physico- chemical properties and nutrient status. Leaf and fruit samples were also collected from the same orchards and analyzed for nutrient content, quality parameters and yield. In the surface and sub-surfaces depth, pH varied from 6.24 to 7.8, 6.30 to 7.82 and 6.33 to 7.83 with mean values of 6.97, 7.02, and 7.05. The EC ranged from 0.05 to 0.27, 0.04 to 0.25 and 0.03 to 0.24 dS m^{-1} with mean values 0.15, 0.13 and 0.12 dS m^{-1} in the surface and sub-surface depths. The respective contents of organic carbon in surface and sub- surfaces depth ranged from 0.21 to 2.30, 0.18 to 2.25 and 0.15 to 0.28 per cent with mean values of 0.99, 0.93 and 0.89 per cent. The soil pH was nearly neutral in reaction and showed an increasing trend with depth, while electrical and organic contents decreased with the increase in soil depth. From the surface and sub-surface soil layers the available macro nutrient nitrogen ranged from (107.10-298.26), (75.60-282.63) and (57.80-280.15) kg ha^{-1}, available phosphorus ranged from (7.60-22.90), (6.90-20.00) and (6.20-18.42) kg ha^{-1} and available potassium ranged from (95.10-224.23), (90.00-217.19) and (79.34-210.00) kg ha^{-1} available sulphur ranged from (12.60-19.74), (10.40-17.90) and (9.80-16.95) kg ha^{-1} available calcium ranged from (4.02-6.35), (4.00-6.32) (4.00-6.29) [c mol (p+) kg] $^{-1}$available magnesium ranged from (2.18-3.32), (2.16-3.28) (2.14-3.28) [c mol (p+) kg]$^{-1}$
From the surface and sub-surface layers of soild available micro-nutrient zinc ranged from (0.52-1.04 ppm), (90.50-0.97 ppm) and (0.48-0.95 ppm), available iron ranged from (11.48-21.75 ppm), (11.10-20.94 ppm) and (10.99-20.75 ppm), available copper ranged from (0.90-1,65 ppm), and (0.80-1.63 ppm) and available manganese ranged from (4.15- 22.25 ppm), (4.00- 20.98 ppm) and (3.92- 20.89 ppm) respectively.
The leaf nutrient content ranged for nitrogen 1.10-2.25 %, 0.09-0.25% for phosphorus, 0.19- 0.45 % for leaf potassium, 0.04-0.29 % for sulphur, 1.8-2.45 % for calcium, 0.42-1.01 % for leaf magnesium, 10.6-28.5 ppm for zinc, 101.2-310.5 ppm leaf iron, (10.5-24.7 ppm copper and 69.9-193.9 ppm leaf manganese. The fruit weight ranged from 139.98-171.03 g, fruit length 9.05-10.45 g,

fruit diameter 5.00-6.17 cm, fruit volume 138.90-170.00 cm^3, specific gravity 1.006-1.008, pulp weight 87.05-109.80 g, stone weight 26.32-31.1 g, pulp: stone ratio 3.23-3.55, and fruit yield 30.50-84.69 kg/ plant, Whereas, the chemical characteristics of fruits such as total soluble solids ranged from 17.11-20.17 ^{0}Brix, titrable acidity 0.21-0.28 %, total soluble solids : acid ratio 66.55-82.19, ascorbic acid 35.59-41.82 mg/100g, total sugars 12.58-15.27%, reducing sugar 2.95-3.98 % and non-reducing sugar 9.63-11.29 %, respectively. The relationship of soil pH of the surface layer 0-30 cm was significantly and positively correlated with available magnesium and available copper. For the sub- surface layer 30-60 cm the soil pH was found to be positively and significantly correlated with available copper. A positive and significant correlation of electrical conductivity with available soil calcium, magnesium, and copper was recorded from the different soil depths (0-30, 30-60 and 60-90 cm). The organic carbon content in the surface soil 0-30 cm was found to be significantly and positively correlated with available soil nitrogen, phosphorus, calcium, magnesium, zinc, copper and manganese. For the sub- surface layers 30-60 and 60-90 cm it was found to be positively and significantly correlated with available nitrogen, phosphorus, calcium, magnesium and copper. Soil pH in the sub- surface layer 60-90 cm exhibited positive and significant correlation with leaf nitrogen, phosphorus, sulphur, zinc and manganese. The correlation of soil electrical conductivity and organic carbon with leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn were found non- significant from the surface and sub- surfaces soil depths. The correlation studies between available nutrient elements in soil with their respective contents in leaves from the three layers of soil depth. The correlation of available phosphorus with leaf nitrogen exhibited negative but significant from sub- surface layers, 30-60 and 60-90cm, whereas, it was non significant at soil surface layer 0-30 cm. A positive and highly significant correlation of fruit weight, fruit length, fruit diameter, fruit volume, specific gravity, pulp weight, pulp: stone ratio and yield was observed with all leaf nutrients (N, P, K, S, Ca, Mg, Zn, Fe, and Mn). The relationship of total soluble solids, titrable acidity and ascorbic acid, total sugars, reducing sugar and non- reducing sugar with leaf nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, zinc, iron, copper and manganese were found to be highly significant and having positive correlation at Akhnoor.

DRIS approach diagnosed 10, 18, 8, 30, 14, 2, 2, 12, 2,0 per cent orchards as having major relative deficiency for N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn, respectively while as sufficiency range approach identified 16, 2, 0,18,12,0, 8, 20, 12 and 14 per cent of the orchards deficient for N, P, K, Ca, Mg, Zn, Fe, Cu and Mn, respectively.

The DRIS approach diagnosed 2, 6, 4, 16, 18, 0, 6, 4, 40 and 4 per cent as the major relative excess for N,P, K, S, Ca, Mg, Zn, Fe, Cu and Mn whereas sufficiency range approach diagnose none of the orchard is in excess. DRIS approach diagnosed sulphur as most deficient nutrient followed by phosphorus calcium, iron, nitrogen, potassium, magnesium, zinc, copper and manganese.
Keywords: *Mango, soil nutrients, leaf nutrients, DRIS norms and sufficiency range.*

Signature of Major Advisor **Signature of Student**

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LIST OF ABBREVIATIONS

%	:	Per cent
Ca	:	Calcium
cc	:	cubic centimeter
cm	:	Centimeter
cm^2	:	Square centimeter
cv	:	Cultivar
EC	:	Electrical conductivity
Fe	:	Iron
g	:	Gram
ha	:	Hectare
K	:	Potassium
kg	:	kilogram
L	:	Litre
M	:	Meter
m^2	:	Square meter
Mg	:	Magnesium
Mn	:	Manganese
N	:	Nitrogen
P	:	Phosphorus
S	:	Sulphur
Zn	:	Zinc
Fe	:	Iron
Cu	:	Copper
r	:	Correlation coefficient
Ha	:	Hectare
ml	:	Mililiter
mm	:	Millimeter
t ha^{-1}	:	Tonnes per hectare
^0C	:	Degree centigrade
ppm	:	Parts per million
<	:	Lesser than
>	:	Greater than

^{0}Brix	:	Degree Brix
NII	:	Nutrient imbalance index
SD	:	Standard deviation
CV	:	Co- variance
FYM	:	Farmyard manure
KCI	:	Potassium chloride
DTPA	:	Diethylene Triamine Penta Acetic Acid
cmol (P^{+}) kg^{-1}	:	Centi mole per kilogram
dS m^{-1}	:	Deci Siemens per meter
viz.	:	Videlicet
AOAC	**:**	Association of official analytical chemists
et al.	**:**	**A**nd other

Chapter-1

Introduction

CHAPTER I

INTRODUCTION

Mango (*Mangifera indica* L.) belonging to family Anacardiaceae is the most important commercially grown fruit crop of Indian sub-continent. Mango is one of the delicious tropical seasonal fruits and believed to be originated in the sub-Himalayan plains of Indian subcontinent. Mango is cultivated in India since time immemorial, is regarded as the national fruit of the country. The genus *Mangifera* contains several species that bear edible fruit. *Mangifera indica* L. is the most commercial important species in the genus for commercial fruit production in tropical and sub- tropical region of the world. Indian mangoes come in various shapes, sizes and colours with a wide variety of flavor, aroma and taste. The Indian mango is the special product that substantiates the high standards of quality and bountiful of nutrients packed in it. The cultivation of mango in India is as old as 4,000 to 6000 years (Yadav and Singh, 2017). India is largest producer of mangoes in the world contributing about 50% of total production worldwide (Barman *et al*. 2015). In India, mangoes are mainly grown in tropical and sub-tropical regions from sea level to an altitude of 1,500 m. In India, it is grown in Uttar Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Haryana, Andhra Pradesh, West Bengal, Karnataka, Bihar Uttarakhand and Jammu and Kashmir. In Jammu and Kashmir mango is grown in sub-tropical areas of Jammu, Samba, Kathua, Udhampur, Reasi and Rajouri districts of Jammu province. The current area and production of mango in India is 2288 thousand hectares and production 21253 thousand million tons (Anonymous, 2018) whereas, in Jammu province of J&K union territory, the total area under mango cultivation is 13037 ha with the total production of 30478 metric tons, respectively. (Anonymous, 2019).

The Mango fruit is very nutritious and has great health benefits both, when eaten raw and as a ripe fruit. The fruit (ripe and unripe), bark, leaves, seed, root and even the smoke of burning mango leaves have healing properties. It is known to be a very good source of vitamins such as vitamin C, thiamine, riboflavin, niacin and ß-carotene. Mango contains numerous polyphenolic and phyto-nutrient compounds that have been shown to exhibit antioxidant properties. Mangoes can be considered as a good source of dietary antioxidants, such as ascorbic acid, carotenoid and phenolic compounds (Ribeiro *et al.* 2007).

Growth and productiveness of fruit trees is governed by a number of factors such as proper moisture, air supply, suitable temperature and light conditions etc. But nutrition plays an important role in determining the quality and yield of fruit. The deficiency or an excess of an essential element may cause disturbance in plant metabolism and its vital functioning may fail, leading to a sub-normal performance. A considerable amount of various nutrients has been reported to drain off every year in the form of yield, pruning wood and fallen leaves from the plant and leaching, run off, erosion etc from soil system. Therefore, determination and assessment of the nutritional status and nutritional requirements of an orchard assumes significance for successful fruit culture. For this purpose, various diagnostic methodologies viz., soil analysis, plant analysis and tissue analysis are being used worldwide. Leaf analysis for nutrient concentration provides an indication of the nutrient status of a crop and can help to guide fertilizer recommendations. Ever since the inception of various diagnostic methodologies, different concepts of interpretation based on the use of either critical or standard values (Kenworthy, 1961), sufficiency ranges (Chapman, 1966) and Diagnosis and Recommendation Integrated System i.e. DRIS (Beaufils, 1973) have been propounded to find out optimum nutritional levels necessary for the growth and production.

Sufficiency range approach has been used extensively as interpretation method, in which values above or below defined norms are correlated with decreases in quality and yield in these crops (Baldock and Schulte, 1996). But, this approach diagnoses only deficiency, adequacy or toxicity of single element at a time and does not reflect nutritional balances and is also affected by changes in the type of tissues sampled or time of sampling. These constraints impose a severe limitation in the acceptability of critical value approach as a standard approach for interpretation of foliar diagnosis. Although the importance of nutrient balance in determining the yield and quality of fruit crops has been well established, yet no means of readily quantifying it was available until the introduction of Diagnosis and Recommendation Integrated System (Beaufils, 1973). The DRIS uses nutrient concentration ratios, rather than the concentration themselves to interpret tissue analysis (Sumner, 1979). It has been found to overcome some of the constraints being faced with critical value approach (Walworth and Sumner, 1987). The DRIS approach is essentially based on the principle that the absorption of any nutrient depends on the presence of other nutrients in the root medium and the tissue. This premise leads to the use of ratios between the nutrient contents rather than concentrations themselves. It also takes care of the dilution effect due to increased growth on the nutrient concentration which is a major impediment in the critical value approach. The major advantage of this approach lies in its ability to minimize the effects of the tissue age on diagnosis, thus enabling one to sample over a wider range of tissue age than permissible under the conventional critical value approach. It also determines the efficiency of each nutrient in relation to others in the plant, calculating a nutrient index simultaneously for each nutrient. It also identifies not only the nutrient most likely to be limiting, but also the order in which other nutrients are likely to become limiting and nutrient imbalance index is calculated which indicates the overall nutrient balance in the plant. Thus, DRIS approach provides a complete logical agreement with requirement of balanced nutrition concept of the mango trees.

Very little attention is given to nutritional program of mango trees by the orchardists and this could be a major factor contributing to lower fruit yield and quality in India. Actually, fruit nutrition is complex, and detection of nutritional limitation to yield among a host of other factors is also a major constraint. Environmental or other biological factors are often particularly limiting and fluctuating yield are observed even when there is no nutritional problem. Sometimes yield responses in nutritional orchard trials are also inconsistent. For these reasons, determining nutritional status of fruit trees is usually difficult, expensive and time-consuming. The most common standard technique for interpreting leaf tissues mineral status is to compare observed concentrations with critical concentration or ranges (reference values). Nutritional concentrations substantially lower or higher than reference values are associated with decline in tree growth or its yield and quality. The DRIS technique deals with nutrient concentration ratios, rather than individual nutrient levels to interpret leaf tissues analysis. It also provides a mean of simultaneously identification of imbalances, deficiencies, and excesses of nutrients and ranking them in the order of importance (Walworth and Sumner, 1986). Previously, DRIS was found reliable in diagnosing nutrient requirement for sugarcane (Beaufils and Sumner, 1976), brinjal (Raghhupathi and Bhargava, 1999a), litchi

(Hundal and Arora, 1995; Hundal and Arora 1996), and for kinnow (Hundal and Arora, 2001) and other crops. DRIS norms could be established from a large number of independent leaf tissues mineral compositions and their corresponded yield for a particular fruit trees rather than conducting the time consuming and expensive orchard trials traditionally.

The DRIS was developed by Beaufils (1973), he used the nutrient ratio a stable criteria with respect to the age of plants and position of leaf tissues, has been proved useful in the interpretation of leaf tissue analysis. The DRIS has been applied successfully to many annual and perennial crops using both survey and fertilizer calibration data (Walworth and Sumner, 1987). The DRIS has helped to diagnose nutrient imbalance in fruits and nuts crops as related to yield (Beverly *et al.* 1984; Sumner, 1986) and fruit quality (Fallahi and Righetti, 1984).

In addition, DRIS is based on nutrient balance and indicates not only the nutrient most likely to be limiting, but also the order in which other nutrients are likely to become limiting and was able to diagnose plant nutrient needs early in the life of crops than sufficiency range method. DRIS is a method to evaluate plant nutritional status that uses a comparison of the leaf tissue nutrient concentration ratios (norms) of nutrient pairs with norms from a high-yielding group (Soltanpur *et al*. 1995). DRIS is a perfect combination of soil test and plant analysis. Leaf analysis can be a very useful tool for plant nutritional diagnosis, since adequate procedures available for data analysis. Because of the dynamic nature of the leaf tissue composition, strongly influenced by leaf age, maturation stage, and the interactions involving nutrient absorption and translocation, the tissue diagnosis may be a practice of difficult understanding and utilization (Walworth and Sumner, 1987). This system is claimed to have certain advantages over other conventional interpretation tools (Li *et al*. 1999). The merits impart DRIS the ability to identify nutrient constraints early in the crop growth and allow sufficient time for remediation of identified problem right in the same season of crop (Walworth and Sumner, 1987).

In Jammu region, Akhnoor and Samba are the major mango growing areas, mainly for Dashehari cultivar. Most of the mango growers in Jammu region are not applying the fertilizers as per recommended doses and therefore, the crop rarely gets adequate nutrition to meet its physiological needs. Further, nutrients, if not applied in required quantity and proportion, may either lead to their deficiency or wastage due to excess application. In addition, the excess or low application of one nutrient may sometimes limit the availability of the other leading to nutrient imbalances. DRIS norms assess the nutrient status, their imbalances and rationalize fertilization for optimum growth and yield. So keeping all the above factors in view, present study entitled "Standardization of Diagnosis and Recommendation of Integrated System (DRIS) of Mango (*Mangifera indica* L.) cv. Dashehari under Jammu sub tropics" was conducted with the following objectives:

i. To evaluate the physico-chemical properties of mango orchard soils.

ii. To analyze the leaf nutrient content of high and low productivity of mango trees.

iii. To establish DRIS norms for mango orchards of Jammu division.

Chapter-2

Review of Literature

CHAPTER-2

REVIEW OF LITERATURE

Mineral nutrition plays an important role in determining the quality and yield of fruit. One of the main plant mineral nutrition objectives is increasing net incomes through efficient fertilization management. To attain this goal, it is initially necessary to correctly determine the yield – limiting impact of a given nutrient. The search for an effective method to determine plant nutritional status has been the target of many researches in plant nutrition. The current methods include both soil and tissue analysis. According to Chapman (1960), soil analysis has been not only as an aid for interpreting the results of research and confirming the visual symptoms and nutritional deficiencies but also to study the excess and imbalances of nutrients in plants so as to enable us to guide soil fertility and management practices. Among the different methods of analysis, leaf analysis is a very useful tool for plant nutritional diagnosis. Because of the dynamic nature of the leaf tissue composition, strongly influenced by leaf age maturation stage and the interaction of involving nutrient absorption and translocation (Walworth and Sumner, 1987). Soil analysis and leaf analysis together give more reliable information than either of them alone.

The literature pertaining to the objectives specified under the research problem has been reviewed and presented under the following heads and sub-heads:

2.1 Soil reaction, electrical conductivity and organic carbon

2.2 Soil nutrient status

2.3 Leaf nutrient status

2.4 Fruit characteristics

2.5 Relationship of soil nutrients with soil properties, leaf nutrients and fruit Characteristics

2.6 Relationship of leaf nutrients with fruit characteristics

2.7 Derivation of Diagnosis and Recommendation Integrated System (DRIS) norms for fruit crops

2.1 Soil pH and electrical conductivity and organic carbon

2.1.1 Soil pH and electrical conductivity

Datta *et al.* (1990) found that the pH values of upland soils were comparatively lower than that of lowland soils due to surface run off inland soils.

Dongale and Kadrekar (1992) studied the lateritic soils of Konkan (M.S) and observed that pH value varied from 5.10 to 7.20 while, Dongale (1993) observed that the soils of Ratnagiri district were acidic in reaction and pH values ranged from 5.70 to 6.90.

Gupta *et al*. (1995) observed that the pH value of soils of Pir Panjal Himalayan region of Jammu and Kashmir ranged from 5.2 to 6.2. While, Raghupati and Bhargava (1997) found that the soil status of Alphonso mango orchards of Ratnagiri district in respect of pH was 4.3 to 5.8 and electrical conductivity 0.10 to 0.20 dSm^{-1}, respectively.

Jiang *et al*. (1999) observed that soil pH ranged from 4.1 to 5.0 among different fruit orchards established in Changtal district of Fuji. While, Das *et al.* (2000) noted the pH of red lateritic soil of West Bengal within range of 5.02 to 5.80 that shown acidic nature of the soil and noted that the pH increased with soil depth. Similar pattern of observation reported in the lateritic soils of Maharashtra by Todmal *et al.* (2008) and Varma *et al.* (2005) also observed similar pattern with soil depth.

Dhopavkar (2001) observed that the pH and electrical conductivity of mango orchards of Konkan region had respective mean values of 5.08 and 0.43dSm^{-1} before harvest of crop and 5.22 and 0.043 dSm^{-1} after the harvest of crop.

Singh *et al.* (2002) conducted the soil survey experiment in five different agro climatic zones of Punjab and reported that all regions were non-saline and ranged from slightly acidic to alkaline.

Gupta (2003) reported that the availability of iron status in the soil of Nagaur tehsil (Rajasthan) ranged between 0.52 to 6.17 mg/Kg and also reported that pH and EC of soil ranged between 7.7 to 9.7 and 0.50 to 1.50 dSm^{-1}, respectively.

Sharma *et al.* (2009) studied assessment of fertility status of erosion prone soils of Jammu Shivaliks and reported that the soil reaction of kandi soils were neutral with pH of most soils between 6.76 and 7.67 and the electrical conductivity of the soils ranged from 0.27 to 1.18 dSm^{-1} Somasundaram *et al.* (2009) studied the soils under perennial cultivation and observed low pH values than that of regularly cultivated soils. It may be attributed to higher leaf litter addition to soil which helps in acceleration of mineralization process. Patil *et al.* (2010) reported pH of 5.90 and EC of 0.10 dSm^{-1} in soils of Alphonso mango orchard of Sindhudurga district. However Suryavanshi (2010) reported that the lateritic soils from mango orchards of Sindhudurg district showed that the value of physico-chemical properties viz. pH and EC to be in the range of 4.68 to 5.33 with a mean of 4.98 and 0.027 to 0.049 with a mean of 0.037 dSm^{-1}, respectively .

Joshi (2012) from her study on micronutrient status of soil from mango orchards of Ratnagiri district and their relationship with soil properties showed that the values of pH and electrical conductivity as 4.10 to 5.46 with an average value of 4.72 and 0.027 to 0.098 with an average value of 0.052 dSm^{-1}, respectively.

Kumar *et al.* (2012) collected the soil samples from mango orchard of Uttar Pradesh after harvest and observed that pH ranged from 6.1 to 7.4. In same year Pawar (2012) from his study on lateritic soils from mango orchards of Sindhudurga district revealed that the respective values of pH and EC to be 4.78 to 5.41 with an average value of 5.10 and 0.030 to 0.067 with an average value of 0.04 dSm^{-1}, respectively. The soil sample collection was done after harvest of the crop.

Sonawane (2013) observed that physico-chemical properties pH and EC after harvest of Alphonso mango from soils of Ratnagiri district in the range of 4.97 to 6.05 and 0.032 to 0.161 dSm^{-1}, respectively. Adak *et al*. (2014) collected the soil samples in the month of September from the mango orchard of Lucknow and found that pH was 7.02 and EC 0.04 to 0.13 dSm^{-1}.

Dar *et al*. (2015) found the pH of soil was slightly acidic to slightly alkaline and ranged from 6.10 to 7.76 with a mean value of 6.75. Joshi (2015) from her study on periodical changes in soil and leaf nutrient and its effect on time of fruit maturity and yield of Alphonso mango under Konkan condition at different stages and at different locations showed the values of pH and electrical conductivity as 5.19 to 6.09 with an average value of 0.114 dSm^{-1}, respectively. While, Puranik (2015) from his study on periodical nutrient content in soil and leaf of Alphonso mango orchards from

Ratnagiri and Devgad and their effect on yield and quality showed the value of pH from 5.48 to 6.28 with an average value of 5.88 and electrical conductivity 0.05to 0.27 with average value of 0.16 dSm^{-1}, respectively.

Singh *et al*. (2015) studied comparative soil nutrients status and fruit characteristics of Litchi (*Litchi chinensis.* Sonn) orchard under sub-mountain zone of Punjab and reported that soil pH ranged from 6.7 to 8.6 and EC 0. 15 to 0.44 dSm^{-1}

Sharma and Pathak (2018) studied the forms of potassium in mango, citrus, and guava orchard soils under rainfed foothills region of Jammu and found that pH range between 6.12 to 7.40 and noticed mild variation in pH of the soils.

2.1.2 Organic Carbon

Organic carbon content in soil is an important parameter of the soil and was significantly responsible for the fertility and productivity of the soil (Bandopadhayay *et al.* 2008).

Grewal *et al*. (1969) conducted study on the available micronutrient status of Punjab, Haryana and Himachal soils and reported that organic carbon in the soils of Nagrota Bagwan and Palampur ranged from 0.60 to 1.31 per cent .

Bhandari and Tripathi (1979) recommended that optimum organic carbon in orchard soils should range between 0.5 to 1.0 per cent and above 0.1 per cent organic carbon was considered as high.

Singh and Raman (1982) studied pine forest soils of North east Himalayans region and reported organic carbon status to range from 2.18 to 2.33 per cent. While, Brar *et al*. (1983) analyzing the soils of Majha tract of Punjab found that the soils were either low (<0.40 per cent) or medium (0.40 to 0.75 per cent) in organic carbon.

Pereira *et al.* (1986) observed that the organic carbon content of lateritic soils in mango orchards of Ratnagiri district at lower slopes varied from 02.40 to 25.90 g kg^{-1} with a mean value of 12.90 g kg^{-1} while at higher slopes the organic carbon showed variation between 7.30 to 28.80 g kg^{-1} with a mean value of 16.80 g kg^{-1}.

Many researchers had studied organic carbon in the lateritic soils of Konkan (M.S.) Revandkar (1990) and Shah (1992) reported that the organic carbon in the surface and profile soils showed variation between 3.00 to 18.90 g $kg-^{1}$. They observed a decreasing trend of organic carbon content with the soil depth which may be due to lack of vegetation and highly percolative nature of the lateritic soil.

Diwale (1994) studied organic carbon content at various depths in the lateritic soils of Konkan (M.S.) and observed the organic carbon in the range of 13.70 to18.90, 8.00 to 16.20, 7.80 to 13.60 and 3.00 to 10.70 g kg^{-1} at 0 to 15, 15 to 30, 30 to 45 and 45 to 60 cm depth of soil, respectively. The organic carbon content decreased with soil depth. Sahoo *et al.* (1995) observed that the organic carbon content of hilly terrain was highest, while the plateau had medium and the plain land had lowest values of organic carbon content.

Pharande *et al.* (1996) opinioned that the variation of organic carbon content in the soil was attributed to high temperature responsible for hastening the rate of oxidation as well as addition of organic matter and crop residues in the soil. However Pednekar (1998) reported no specific trend of organic carbon content with soil depth.

Bhat (2001) observed that content of organic carbon in surface soils varied from 1.30 to 1.62 per cent with a mean value of 1.49 per cent while in sub-surface layers it ranged from 0.34 to 1.20 per cent with a mean value of 0.65 per cent and it decreased with increase in depth. While, Mahajan (2001) from his study revealed that the surface soil organic carbon had a range of 01.25 to 3.32 per cent with mean value of 2.48 per cent. While, for profile soil the values ranged from 0.38 to 3.15 per cent with a mean value of 1.60 per cent.

Sarkar *et al.* (2002) also reported a decreasing trend of organic carbon with soil depth. Similar trend of organic carbon was also reported by Varma *et al.* (2005) and Patil *et al.* (2008). The higher value of organic carbon at surface soils may be due to the addition of manure and plant residue at surface than subsurface (Rajeswar *et al.* 2009). Suryavanshi (2010) reported that the organic carbon content of lateritic surface soils of Konkan (M.S.) was found to be 7.80 to 18.30 g kg^{-1} and that for profile soil from 04.20 to 15.70 g kg^{-1}. Organic carbon content exhibited decreasing trend with the soil depth. Shrinivas *et al.* (2011) related the low values of organic carbon content in the soil with higher rate of oxidation in the soil at higher temperature and good aeration.

Sonawane (2013) observed 14.82 to 20.28 g/kg organic carbon after harvest of Alphonso mango from soils of Ratnagiri district.

Joshi (2015) studied periodical changes in soil and leaf nutrient and its effect on time of fruit maturity and yield of Alphonso mango under Konkan conditions at different stages and at different locations and observed organic carbon content as 9.13 to18.66 g/kg with an average value of 13.99 g/kg. However, Puranik (2015) from his study on periodical nutrient content in leaf and soil of Alphonso mango orchards from Ratnagiri and Devgad and their effect on yield and quality showed the values of organic carbon content range as 13.64 to 48.25 g/kg with an average value of 30.94g/kg.

Singh *et al.* (2015) made comparative studies of soil nutrients status and fruit characteristics of Litchi (*Litchi chinensis*. Sonn.) orchard under sub- mountain zone of Punjab and reported that soil organic carbon ranged from 0.22 to 0.39 per cent.

Sharma *et al.* (2018) studied the forms of potassium in mango, citrus and guava orchard soils under rainfed foothills region of Jammu and found that organic carbon content ranged for mango soil from 3.9 to 9.2 g/kg. Whereas, for citrus growing soils it was 3.6 to 13.1 g/kg and for guava soils it ranged from 3.2 to 13.5 g/kg.

2.2 Soil nutrient status

As per the physico-chemical compositions of mango orchards are concerned the soil of mango orchards vary from location to location. The objective of soil testing of mango orchards is to evaluate the soil productivity status and to determine specific conditions of soil which can be corrected by addition of requisite quantity of fertilizer. Thus soil analysis can be a useful guide for judicious application of fertilizers with profitable response.

Soil nutrient status directly affects the growth, quality and yield of the particular orchard. Soil macro and micro nutrients are the important source of nutrition to the plant. Deficiency or excess of the nutrients directly affects the growth and yield of the fruit crops. The synergetic and antagonistic effect of macro and micro nutrients also plays a key role in the production of fruit crops.

Nitrogen is one of the most important nutrients for the growth of mango and it has a relevant role in the production and quality of the fruits. Its effects are seen in the vegetative phase of growth and considering the relationship that exists between vegetative and reproductive flushes. Nitrogen deficiency may adversely affect yield.

Mangoes adequately nourished with nitrogen regularly develops shoots, which when they reach maturity have panicles able to bear fruit (Silva *et al*. 1997). Lack of Nitrogen causes retarded development, less vegetative growth and reduced production of fruit (Jacob and Uexkull, 1958; Geus,1964). Excess of nitrogen causes excessive vegetative growth, difficulty at floral differentiation, loss of yield and fruit quality and increase susceptibility to disease.

Phosphorus favours root system development, production of a strong stem/trunk and retention and maturation of fruits (Samra and Arora, 1997). Deficiency of phosphorus may result in a weaker root system, restricting the uptake of water and nutrients, slowing the maturation of fruits, slowing growth, premature falling of leaves, drying and death of leaves branches and substantial decrease in yield are other symptoms of the P deficiency (Childers, 1966).

Potassium plays key regulatory role in many physiological process of plant growth. Marschner (1986) reported that the potassium is an essential element that helps in fruit enlargement and cell turgidity by reducing carbohydrate contents. Potassium deficiency occurs in their older leaves as small red spots irregularly distributed. The leaves fall only when they are completely dead (Childers, 1966; Koo, 1968). An excess of potassium may cause an imbalance in the levels of calcium and magnesium.

Calcium is important in the assimilation of nitrogen and transport of carbohydrates and amino acids. Calcium plays important role in the structural functions in the cellular membranes and walls throughout the entire plant. Calcium is taken up more efficiently by the roots than it is from foliar applications. Pinto *et al*. (1994) reported that one of more serious problems related to quality is collapse of the internal pulp, attributed to an imbalance between low calcium and high nitrogen.

Magnesium occurs in chlorophyll molecule and in enzymes that induce the formation of acid protein for protein synthesis. It also participates in phosphorus transport within the plant. Deficiency of magnesium reduces development, causes premature shedding of leaves and decrease yield. Application of excess amounts of calcium and potassium decrease the uptake of magnesium.

Sulphur is the principal component of amino acids and vegetable proteins. It is an enzyme activator and participates in chlorophyll synthesis. When deficient, mango growth is slowed and leaf loss is provoked. Its availability is reduced by the continues use of fertilizers that do not contain sulphur (Silva, 1997).

Zinc is responsible for strengthening cell wall and reducing the formation of abscission zone (Mengel *et al*. 2001).The beneficial effect of zinc on controlling water absorption and nutrient uptake as well as enhancing the biosynthesis of the natural hormone namely indole acetic acid. The promoting effect of zinc on the biosynthesis of organic foods especially carbohydrates could result in promoting quality of the fruits. Deficiency of zinc may be more serious in calcareous soil or in those that receive large amounts of lime and phosphorus fertilizers (Ruhele and Ledin, 1955 and Geus, 1964).

Iron is essential for the activity of several enzymatic systems and plant components such as catalase, cytochrome, ferrodoxine, frichrome, hematine, hem and cytochromoe oxidase. In addition, it seems iron be involved in nucleic acid metabolism in the chloroplast. (Bopaiah and Srivastava, 1982). Iron deficiency is associated with soils derived from calcareous material or acidic soils with very high levels of manganese (Mn). Associated with an excess of manganese applying large amounts of phosphorus fertilizer may also due to iron deficiency in mango.

Copper functions as a catalyst in photosynthesis and respiration. It is a constituent of several enzyme systems involved in building and converting amino acids to proteins. Copper also affects the flavor, the storage ability and the sugar content of fruits. Symptoms of copper deficiency are seen frequently in young plants getting large amounts of nitrogen, or in young shoots of adult plants.

Manganese is involved in the oxygen –evolving step of photosynthesis and membrane function, as well as serving as an important activator of enzymes in the cell (Widenhoeft, 2006). Manganese deficiency reduced tree growth. Liming and the application of large amounts of phosphorus decrease the availability of manganese in the soil.

Bopaiah *et al.* (1988) collected the soil samples from the mango orchard cv. Dashehari and noticed that available nitrogen, phosphorus and potassium were 79.4 ppm, 9.7 ppm and 71 ppm, respectively.

Bobade *et al.* (1991) observed that the available phosphorus in soils of Alphonso mango orchards in Dapoli and Pangari locations ranged from 0.83 to 17.81 ppm at fruit inflorescence stage.

Raghupathi and Bhargava (1997) while conducting a survey in Ratnagiri district of Maharashtra to study the fertility status of the soils growing Alphonso mango reported that optimum soil pH ranged from 4.3 to 5.8, available nitrogen from 58 to 134 mg kg^{-1}, phosphorus 10 to 15 mg, potassium 122 to 426 mg kg^{-1}, calcium 249 to 551 mg kg^{-1}, magnesium 125 to 204 mg kg^{-1}, sulphur 66 to 177 mg kg^{-1}, iron 51 to 63 mg kg^{-1}, manganese 7.8 to 51.4 mg kg^{-1}, zinc 2.6 to 3.5 mg kg^{-1} and copper 0.24 to 7.8 mg kg^{-1}.

Rodriguez and Rajas (1997) reported that foliar nutritional status of Valencia orange orchards in Venezuela for nitrogen, calcium and magnesium fall within the optimum sufficiency range for subtropical conditions while phosphorus and potassium fall in their high range.

Raghupathi and Bhargava (1998) reported that nitrogen concentration in pomegranate leaf ranged from 0.40-2.20 per cent. Nearly 68 per cent of orchards surveyed had nitrogen in the optimum range while it was low in 28 per cent of the orchards. Phosphorus concentration in leaf showed wide variation ranging within 0.08-0.33 per cent. The potassium concentration was generally low, varying from 0.20-2.05 per cent. Leaf calcium concentration ranged from 0.60- 2.40 per cent and magnesium concentration ranged from 0.16-0.49 per cent. Both calcium and magnesium were optimum in nearly all the orchards. The sulphur concentration ranged from 0.04-0.70 per cent. Sulphur concentration was very low in 36 per cent and low in 51 per cent of the orchards. The Fe concentration showed wide variation from 25 to 297 mg kg^{-1}. Nearly 90 per cent of the orchards had iron in the optimum range. Leaf manganese, zinc and copper concentration ranged from 14 to 99, 7 to 44 and 21 to 86 mg kg^{-1}, respectively.

Zhang and Chen (1999) while studying the different soil nutrients in different orchards observed that almost all the orchards had lower soil nitrogen concentrations, however, approximately 36 per cent orchards were deficient in available soil phosphorus content and 93 per cent had shown nutrient deficiency of potassium, calcium and magnesium nutrients.

Bhatnagar *et al*. (2000) conducted a nutritional survey of orchards in Bikaner district and reported that all the orchards soils were found to be poor in organic matter, electrical conductivity was found to be in normal range and soil pH was in the high ranging from 7.49 to 9.11. All the orchards soils were found low in available nitrogen content. Besides the deficiencies of nitrogen, phosphorus, potassium, sulphur, copper, and zinc were observed, the soils were founds medium to high in exchangeable calcium and magnesium.

Dhopavkar (2001) reported that the soil pH electrical conductivity, organic carbon content, available nitrogen, available phosphorus, and available potassium content from mango orchards of Konkan region had respective mean values of 5.08, 0.043, dSm^{-1}, 12.6 g/kg, 250 kg/ha, 7.7 kg/ha, 164 kg/ha all before harvest of crop and 5.22, 0.043 dSm^{-1} 13.5g/kg, 198kg/ha, 5.2kg/ha, 130kg/ha all after harvest of crop.

Mahajan (2001) observed that the iron content in surface and profile soils of mango orchards of lateritic soils of Konkan (M.S.) was in the range of 10.31 to 44.75 mg $kg^{-1}$with mean value of 21.63 mg kg^{-1} and 5.11 to 47.60 mg kg-^{1} with mean value of 15.17 mg kg^{-1}, respectively.

Reddy *et al.* (2003) showed that nitrogen, phosphorus, potassium contents in soil were higher in high yielding trees than low yielding trees in Alphonso mango. Karle (2004) reported the values of available nitrogen (342 kg ha^{-1}), available phosphorus (6.67 kg ha^{-1}) and available potassium (199 kg ha^{-1}) for the soil samples of Alphonso mango from Agricultural farm (Dapoli) after harvest stage.

Azhar *et al.* (2007) observed that the mean contents of available copper, zinc, manganese and ferrous were 4.99 μg g^{-1}, 0.52 μg g^{-1}, 14.15 μg g^{-1} and 10.63 99 μg g^{-1} respectively from soils of mango orchards of Hyderabad. Patil *et al.* (2010) reported the values of pH, electrical conductivity, organic carbon, phosphorus, potassium, zinc, copper in soils of Alphonso mango orchards of Sindhudurg district after harvest as 5.903, 0.100 dS m^{-1}, 2.763 per cent, 63.84 kg ha^{-1}, 436.8 kg ha^{-1}, 8.977 ppm and 7.420 ppm, respectively.

Dabke *et al.* (2013) found that soil samples of post-harvest stage of Alphonso mango from Wakavali orchard had values of pH (5.62), EC (0.052 dS m^{-1}), available nitrogen (282.88 kg ha^{-1}), available phosphorus (5.19 kg ha^{-1}) and available potassium (223.10 kg ha^{-1}).

Lobo (2013) from his studies on micronutrient status of soil from mango in Sindhudurg district and their relationship with soil properties revealed that the available content of nitrogen, phosphorus, potassium, iron, manganese, copper and zinc at after harvest stage were 326.68 kg ha^{-1}, 7.19 kg ha-^{1}, 292.37 kg ha^{-1}, 28.81 mg kg^{-1}, 54.34 mg kg^{-1}, 2.13 mg kg^{-1}, 1.47 mg kg^{-1}, respectively.

Sonawane (2013) studied soil texture and soil nutrient status after harvest of Alphonso mango from soils of Ratnagiri district. He observed soil pH in range of 4.97 to 6.05, electrical conductivity in the range of 0.032 to 0.161 dS m^{-1}, and organic carbon as 14.82 to 20.28 g kg^{-1}. Available nitrogen, phosphorus, potassium, iron, manganese, copper, and zinc were 385.72 to 460.09 kg ha^{-1}, 6.15 to 8.18 kg ha^{-1}, 259.39 to 314.49 kg ha^{-1}, 19.79 to 86.82 mg kg^{-1}, 36.41 to 68.23 mg kg^{-1}, 1.96 to 5.32 mg kg^{-1}, 0.20 to 2.77 mg kg^{-1}, respectively.

Soil is the primary source of nutrients, which are essentials for proper growth and development in plants, animals and human nutrition. Kumar and Hundal (2002) noted that soils of agricultural lands of mid hill soil zone were medium to high in available nitrogen, low to medium in available phosphorus and low to high in available potassium content.

Similarly, Kumar and Hundal (2002) observed that soils of Gurdaspur, Jalandhar and Hoshiarpur had low potassium concentration. However, available soil potassium content was higher in the other districts of Punjab. The relatively lower content of available potassium in the soils of northern districts is due to less biotite content in the heavy mineral fraction of sand as compared to the sands of South-western alluvial plain agro-eco sub region. Availability of soil nitrogen, phosphorus and potassium contents under different tree species was recorded by Kumar and Hundal (2002) and noted that surface soil layers had more nutrients concentrations than sub soil horizons and their values were decreased gradually with the increase in soil depth.

Bhatnagar and Chandra (2003) surveyed the orchards of Bikaner districts and reported that the available iron ranged between 2.01 to 6.36 mg/kg, available copper between 0.08to 0.51 mg/kg and available zinc between 0.08 to 0.01 mg/kg. The available iron and manganese were found low to medium whereas available copper and zinc were found to be low range.

Kumar (2003) reported that the content of available iron in soil of Merta tehsil of Nagaur district varied between 1.32 to 6.40 mg/kg with an average 3.81 mg/kg.

Pimplaskar and Bhargava (2003) collected the soil samples from mango orchard of Gujrat and reported the available nitrogen (19-335 µg/g), available phosphorus (0.21-10.55 µg/g), available potassium (66-836 µg/g), available iron (11-102 µg/g), available zinc (0.40-3.60 µg/g) and available copper (2.54-5.4 µg/g).

Reddy *et al*. (2003) found available nitrogen of soil after, before flowering, at flowering and pea size of fruits as 149.70 kg/ha, 192.60 kg/ha, 231.60 kg/ha and 254.2kg/ha, respectively in the soils from Alphonso variety of mango of Andhra Pradesh. Also Reddy *et al.* (2003) have studied soil samples before flowering and at harvest stage of Alphonso mango from Srinivasapur and found that nitrogen, phosphorus, and potassium values were 141.6 Kg ha^{-1}, 9.5 Kg ha^{-1}, 387.4 Kg ha^{-1} and 207.9 Kg ha^{-1}, 10.1 Kg ha^{-1} and 363.3 Kg ha^{-1}, respectively.

Tandon (2004) reported that about 63, 44, 21 and 37 per cent Indian soils were low in available nitrogen, phosphorus, potassium and sulphur, respectively. However Gathala *et al*. (2004) conducted a nutritional survey of pomegranate orchards in Jaipur district. They reported low to medium content of nitrogen, phosphorus, potassium, sulphur, iron, zinc, manganese, copper and manganese and medium to high in potassium, calcium and magnesium in orchards soil.

Kumar (2004) conducted a nutritional survey of ber and pomegranate orchards in Bikaner district and reported that the range of zinc and NPK varied from 0.177 to 0.533 ppm, 52.50 to 111.00, 8.84 to 16.64, 156.00 to 108.00kg ha^{-1}, respectively in ber orchards and 0.180 to 0.513 ppm, 1.98 to 4.38 per cent, 0.10 to 0.21 per cent and 68.85 to 102.60, 10.39 to 25.37, to 142.27 kg/ha, respectively in pomegranate orchards.

Raghupathi *et al.* (2004) showed that in low and high yielding varieties, available nitrogen content in soil varied before flowering and available phosphorus and available potassium content in soil did not vary with growth stages.

Kumawat (2005) conducted a nutritional survey of ber orchards in Jaipur district and observed that soil nitrogen, phosphorus, potassium, sulphur, manganese, zinc, copper and boron contents decreased with the increasing depth of soils. Whereas, calcium and magnesium increased with the increasing depth of orchards soils.

Rajan *et al*. (2005) conducted a field experiment for four consecutive years at Jhargram in West Bengal on grafted aonla plants They observed that soil of orchards was laterite having surface soil pH 5.5, EC 0.12 dS m^{-1} and available nitrogen, phosphorus and potassium were 164.9, 87.7 and 168.0 kg/ha, respectively.

Azhar *et al*. (2007) observed that the mean contents of available copper, zinc, manganese and iron as 4.99, 0.52, 14.15 and 10.6 µg/g, respectively from soils of mango orchards of Pakistan after harvest of crop.

Rohitash (2007) reported that the available nitrogen 88.38 to 131.69 kg/ha, available phosphorus 19.66 to 32.72 kg/ha, available potassium 116.95 to 149.05 kg/ha, exchangeable calcium 2.75 to 4.53 c mole kg^{-1}, exchangeable magnesium1.78 to 2.23 c mole kg^{-1}, available iron 2.34 to 6.20 mg/kg, available zinc 0.20 to 0.91 mg/kg, available manganese 2.05 to 3.87 at Bikaner district of Rajasthan.

Jibhakate *et al*. (2009) studied the micronutrient states of eleven major soil series of Katol tehsil in Nagpur district and reported that considering the critical limits of available iron, manganese, copper and zinc as 5.0, 7.5, 1.0 and 0.5 mg/kg, it could be conducted that in all eleven soil series available iron, manganese, copper and zinc were marginal, adequate, high and low to marginal, respectively. The availability of micronutrients between available iron and available copper were significantly and positively correlated among themselves. Available manganese and other micronutrients do not show any significant relationship between themselves.

Sharma *et al*. (2009) studied assessment of fertility status of erosion prone soils of Jammu Shivaliks and reported that the soils were low in available nitrogen (169 to 265 kg/ha), low to medium in available phosphorus content (9.0 to 14.3 kg/ha) and available potassium (77 to 144 kg/ha).

Bali *et al*. (2010) concluded that about 45 per cent area of state had higher values for available phosphorus content and these areas were situated in districts of Hoshiarpur, Jalandhar and Kapurthala. Whereas, Suryavanshi (2010) reported that available nitrogen, phosphorus and potassium content to be in the range of 338.94 to 527.62 with a mean of 409.94 kg/ha, 3.42 to 15.31 with a mean of 7.96 kg/ha and 219.32 to 275.73 with a mean of 248.75 kg/ha, respectively. In addition, he also found that the ranges of available iron manganese, zinc, and copper were 12.88 to 50.44

mg/kg, 18.18 to 55.64 mg/kg, 0.625 to 1.641 mg/kg and 1.147 to 2.680 mg/kg, respectively.

Joshi (2012) studied micronutrient status of soil from mango orchards of Ratnagiri district and their relationship with soil properties showed the values of available nitrogen, phosphorus and potassium was found as 322.67 to 568.34 with an average value of 465.83 kg/ha, 3.19 to 6.42 with an average value of 4.80 kg/ha and 200.66 to 311.87 with an average value of 249.86 kg/ha, respectively. The respective values for available iron, manganese, zinc and copper were 30.65 to 51.30 with a mean value of 40.62 mg/kg, 41.34 to 60.89 with a mean value of 52.76 mg/kg, 0.41 to 3.60 with a mean value of 1.50 mg/kg and 0.95 to 4.67 with a mean value of 2.21 mg/kg.

Kumar and Sohan (2012) studied the major nutrients status in soils of Raya orchard under rainfed conditions of Jammu. They reported that the available nitrogen ranged between (125-260 kg/ha, available phosphorus (10.80-18.10 kg/ha) and available potassium (126-158 kg/ha) Kumar *et al*. (2012) collected soil samples from mango orchards of Uttar Pradesh after harvesting of mango. The available nitrogen, phosphorus, potassium, Zinc, copper, manganese, iron, and boron, contents were 79.2-242.0 kg/ha, 10.1-80.9 kg/ha, 38.4-456.9 kg/ha, 0.26-1.96 mg/kg, 0.22-2.0 mg/kg, 2.4-29.8 mg/kg, 8.5-195.2 mg/kg and 0.03-0.55 mg/kg, respectively. They also noticed that the soil samples were deficient in available zinc, copper, manganese, and boron contents.

Dabke *et al.* (2013) found that the soil samples of post- harvest stage of Alphonso mango from Wakavali orchard had values of available nitrogen (282.88 kg/ha) available phosphorus (5.19 kg/ha and available potassium (223.10 kg/ha). In the same year, Lobo (2013) studied micronutrient status of soil from mango (Alphonso) orchards of Sindhudurga district and their relationship with soil properties reported that the available content of nitrogen, phosphorus, potassium, iron, manganese, copper and zinc after harvest of crop were 326.68 kg/ha, 7.19 kg/ha, 28.81 mg/kg, 54.34 mg/kg, 1.47 mg/kg, respectively.

Adak *et al*. (2014) collected the soil samples in the month of September from mango orchards of Lucknow and reported that the available phosphorus was 4.5mg/kg, available potassium 30.5mg/kg, available iron (2.232 ppm), available manganese (1.961 ppm), available zinc (0.176 ppm) and available copper (0.163 ppm).

Singh *et al*. (2015) studied the soil nutrient status and fruit characteristics of Litchi (*Litchi chinensis*. Sonn) orchard under sub-mountain zone of Punjab and reported that available nitrogen in soil range from (302.4-436.8 kg/ha), phosphorus (11.9 to 24.3 kg/ha) and potassium (70.0 to 373.0 kg/ha), whereas soil micronutrients ranged from zinc (0.3-10.6 mg/ha), iron (2.25-105.6 mg/ha), manganese (0.18-18.8 mg/ha) and copper (4.8-8.8) at 0-30 cm depth of soil in both litchi cultivars.

Sharma *et al*. (2018) studied the forms of potassium in mango, citrus and guava orchard soils under rainfed foothill region of Jammu and found that the mean values for available potassium content in mango, citrus and guava orchards were 61.1, 64.8 and 66.2 mg/kg, respectively of soil.

2.3 Leaf nutrient status

Leaf nutrient composition varies considerably from region to region under different agro-climatic conditions. As a result of nutrient supply, sampling techniques, analytical methods and cultural and management practices rather than any change in physiological requirements of plant system, there occurs a lot of variation in leaf nutrient composition (Kenworthy, 1961).

Due to difference in nutrient supply, sampling technique, analytical methods and cultural and management practices rather than any change in physiological requirement of plant system in mango leaf nutrient composition varies considerably from region to region under different agro climatic conditions.

Rao and Mukherjee (1988) indicated that the nitrogen, phosphorus and potassium content in leaves decreased gradually from January to September in case of Fazli and Langra varieties. They also observed that before harvest, after harvest and after rainy season, the leaf nitrogen, phosphorus and potassium contents were (1.317, 0.163 and 0.943 per cent), (0.794, 0.111 and 0.822 per cent) and (0.605, 0.096 and 0.740 per cent), respectively in high yielding trees. In low yielding trees, the respective contents were (0.876, 0.128 and 0.850 per cent), (0.587, 0.093 and 0.711 per cent) and (0.482, 0.075 and 0.650 per cent).

Bobade *et al.* (1991) observed that the total phosphorus content in leaves of Alphonso mango orchards at Dapoli and Pangari locations ranged between 0.030 and 0.065 per cent at fruit harvest and between 0.036 and 0.172 per cent at inflorescence stage. The increase of total phosphorous content in leaves at inflorescence stage was reasoned with higher content of available phosphorus in soil at this stage.

Kunwar and Singh (1993) conducted a nutritional survey in litchi orchards in Doon valley of Garwal hills of Uttranchal and reported that leaf nutrient content in Rose Scented cultivar of litchi ranged between 0.93-2.11 per cent nitrogen, 0.03 to 0.22 per cent for phosphorus, 0.55- 1.30 per cent for potassium, 0.40 -0.95 per cent for calcium and 0.24- 0.60 per cent for magnesium. Whereas Joon *et al*. (1997) conducted a nutritional survey in litchi orchards of the North-Eastern Haryana and observed that macro nutrient elements ranged 1.36-2.38 per cent for nitrogen, 0.180-0.310 per cent for phosphorus, 0.595- 0.965 for potassium, 0.20-2.85 for calcium and 0.070-0.40 per cent for magnesium.

Ather and Kumar (1999) studied that the effect of cultar on leaf nutrient content of litchi cv. Rose Scented and reported that average nutrient content varied from 1.85 to 1.41 per cent for nitrogen, 0.32 per cent for phosphorus, 0.88 to 0.78 per cent for potassium, 0.57 to 0.74 per cent for calcium, 0.25 to 0.35 per cent for magnesium and 0.13 to 0.12 per cent for sulphur.

Raghupathi and Bhargava (1999b) collected the leaf samples from mango orchards of Ratnagiri district in the month of May and reported nutrient contents as nitrogen (0.67 - 2.6 per cent), phosphorus (17 - 49 mg per cent) and potassium (0.36 - 1.89 per cent for trees having yields of 3.6 to 7.8 t ha^{-1}. Sukthumrong *et al.* (2000) from their study observed the total leaf nutrient contents before flowering as nitrogen (1.1-1.5 per cent), phosphorus (0.1 - 0.2 per cent) and potassium (0.5 - 0.8 per cent) in leaves. A study on Alphonso mango from lateritic soils of Ratnagiri district by Dhopavkar (2001) showed the values of total nitrogen, potassium and phosphorous content of mango leaves as 1.178, 0.415 and 0.083 per cent before harvest of the crop and 0.934, 0.411 and 0.069 per cent after crop harvest, respectively.

Pharmar (2002) conducted a diagnostic survey for cultivation practices followed by farmers with emphasis on nutrition of sapota [*Manilkara achras* (Mill.) Fosberg] in south Gujarat during 1997 and 1998 to understand the status of the industry, its weakness and strengths, to develop leaf nutrient guide and to identify the future needs of research in sapota for South Gujarat. The results brought out that farmers are highly receptive and they follow standard package of practices in terms of planting density (10 × 10 m), variety (Kalipatti), nutrition (nitrogen upto 1250 g, phosphorus 250-600 g, potassium 250-700 g and 25-70 kg fym per tree per annum), irrigation in terms of frequency and method and weed management. The leaf nutrient guideline developed from the study are indicative of the fact that plant leaf nutrient status for optimum performance should be nitrogen 1.76 %, phosphorus 0.18 %, potassium 0.82 %, iron 122.15 ppm, zinc 26.56 ppm, manganese 31.18 ppm and copper 12.87 ppm.

Pimplaskar and Bhargava (2003) collected leaf samples of Rajapuri variety of mango in Gujrat in the month of November and observed the values of leaf nitrogen as 0.99 - 4.07 g per 100 g, phosphorous as 50 - 120 mg per 100 g and potassium as 0.14 - 3.00 g per 100 g.

Reddy *et al.* (2003) indicated that leaf nitrogen increased steadily after harvest of the crop till flowering and then decreased at flowering followed by another increase from flowering to pea size of fruits of Alphonso variety from Andhra Pradesh. The nitrogen content in leaf of high yielding trees after harvest of the crop, before flowering, at flowering and at pea size of fruits was 1.84, 1.76, 1.79 and 1.99 per cent, respectively. The phosphorous content in leaf at respective stages was 0.25, 0.04, 0.05 and 0.06 per cent.

Rao *et al*. (2006) studied the sixty leaf samples of sapota (cv. Kalipatti) in existing orchards of Gujarat to develop DRIS norms and reported that the critical nitrogen concentration in the index leaf ranged from 1.25-2.38 %, where as phosphorous, potassium, calcium, magnesium, sulphur, iron, manganese, zinc and copper ranged from 0.05-0.17%, 0.36-0.77%, 1.01-2.04%, 0.48-0.92%, 0.38-0.82% and 18.9-147.43 ppm, 18.12-36.97 ppm, 7.89-16.57 ppm and 3.92-5.66 ppm, respectively.

Anjaneyulu (2007) identified forty-five nutrient expressions for sapota cv. Cricket Ball as diagnostic norms from data collected by surveying seventy-four sapota gardens in Karnataka during the year 2005-06. Hartz and Johnstone (2007) showed that Diagnosis and Recommendation Integrated System (DRIS) leaf concentration norms were calculated for nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, boron, zinc, manganese, iron, and copper. Iceberg and romaine lettuce had sufficiently similar leaf nutrient concentrations that the data were combined in the

DRIS calculations. Optimum leaf nutrient ranges were developed using data from high-yield fields in which all nutrients were in balance according to the DRIS approach. The DRIS- derived optimum ranges for potassium and calcium were substantially lower than previously published leaf sufficiency ranges, whereas for the other nutrients, the DRIS optimum ranges were in close agreement. Copper was the nutrient most frequently below the optimum range in low-yield fields. Comparison of leaf nutrient concentrations with soil nutrient availability and grower fertilization practices suggested that significant improvement in fertilizer management was possible.

Nachtigall and Dechen (2007) evaluated testing and validation of DRIS for apple tree and evaluated three procedures of the calculation of DRIS indices, as well as the efficiency of DRIS as a method for the interpretation of apple tree leaf analyses. The DRIS indices were calculated using two criteria for the choice of the ratio order of nutrients (F value – ratio of variance of the relationships among nutrients between the reference group and the low productivity group, and R value - correlation coefficients between the productivity and the relationship between pairs of nutrients) and three forms of calculation of nutrient functions (Beaufils 1973, Jones 1981, and Elwali and Gascho 1983.). The Nutritional Balance Index (NBI) presented negative correlation with the productivity in all combinations. The DRIS method described by Elwali and Gascho (1984) using the F value, presented a performance similar to the criterion of sufficiency range, and it can be used for the interpretation of foliar analysis of apple trees, because it presents values of the nutritional balance index that indicates the nutritional status of the plants, and for the efficiency in the nutritional diagnosis of the crop.

Pandey and Pandey (2007) from their study on Amrapali variety of mango observed that the values for leaf iron, manganese, copper and zinc as 337.95 ppm, 44.70 ppm, 60.15 ppm and 80.75 ppm, respectively for the samples collected in the month of October. The respective nutrient content of the samples collected in the month of February was 307.05 ppm, 47.90 ppm, 7.90 ppm and 42.45 ppm.

Savita and Anjaneyulu (2008) reported that the critical leaf nitrogen ranged from 1.51-2.09%, phosphorus from 0.06-0.15% and potassium from 0.83-1.44%. The critical concentration ranged from 1.36-2.34% for calcium, 0.54-0.68% for magnesium and 0.48-0.80% for sulphur. Among the micronutrients, critical iron, manganese, zinc, copper and B concentrations ranged from 109-206 mg/ kg, 49-99 mg/ kg, 13.3-21.9 mg/ kg, 3.76-9.10 mg/ kg and 34.8-66.8 mg/ kg, respectively for sapota cv. Kalipatti.

Dabke *et al.* (2013) had studied leaf samples before flowering and after harvest of Alphonso mango from Wakavali orchard and found that the nitrogen, phosphorus and potassium contents in leaves were 1.46, 0.087, 0.57, per cent before flowering and 0.90,0.068 and 0.35 per cent after harvest of the fruits, respectively.

2.4 Fruit quality characteristics

2.4.1 Physical characteristics

Rani and Brahmachari (2001) reported that the size and fruit weight of fruit and pulp weight increased greatly with borax 0.4 per cent and 1 per cent zinc sulphate. Ruby and Brahmachari (2001) conducted a study on twenty five years old litchi trees in Bihar and spraying of nutrients was performed before panicle emergence (early February) after completion of fruit set (early april) and on immature fruits just before colour break (early May). They observed that higher pulp weight per fruit (16.99 g) was recorded that 0.5 per cent zinc sulphate solution.

Bhatnagar and Chandra (2003) surveyed on ten year old orchard of Ber cv. Gola in Bikaner district and reported that physical and chemical attributes such as fruit weight, length and breadth, stone weight, pulp to stone ratio varied significantly among the different orchards.

Gamal and Ragab (2003) obtained best results in terms of fruit weight in Balady mandarin trees when farm yard manure and fruit number in Balandy mandarin trees when farm yard manure at the rate of 52 kg per tree +inorganic nitrogen at the rate of 1.82 kg per tree were applied. Whereas Prasad and Bankar (2003) reported that the average fruit weight of pomegranate cv. Ganesh was 200-250 g.

Sheikh and Rao (2005) observed that, the application nitrogen at the rate of 400 g per plant and potassium at the rate of 200 g per plant in four splits at monthly interval recorded the highest fruit weight (333.25 g) that resulted in improved fruit quality parameters.

Dayal *et al*. (2010) study the effect of nitrogen (250, 500 and 750 g) phosphorus (200, 350 and 500 g) on growth and yield of ber cv. Gola. The maximum diameter of fruit (3.22cm) was recorded under (500 g nitrogen+ 500 g phosphorus + 0.6 per cent zinc sulphate per tree) treatment combination and the minimum diameter of (2.85 cm) was observed under control.

Lal *et al*. (2010) reported that trees sprayed with potassium nitrate at the rate of 1.5 per cent and calcium nitrate 2 per cent significantly improved fruit weight to the tune of 20.4 and 20.37 g, respectively.

Patil (2010) reported that highest weight of fruit, size of fruit, volume of fruit, weight of stone, weight of pulp, weight peel, and pulp: stone ratio was 217.2 g, 62.3cm^2, 205 ml, 45.1 g, 125.9 g, 41 g and 3.20, respectively in fruits of well managed mango orchards.

Singh and Chadha (2012) concluded that the mean maximum fruit length and diameter was recorded by cultivar Kasba 3.78 and 3.37 cm respectively while the minimum was recorded for cv. Dehradun 2.82 and 2.41 cm, respectively.

Singh *et al*. (2010) reported that average fruit weight varied from 18.19 to 23.10 g and 17.35 to 19.85 g for Shahi and China litchi cultivars, respectively.

While investigating the response of pre-harvest foliar application of zinc and boron on mango cv. Amrapali under new alluvial zone of West Bengal, Bhowmick *et al*. (2012) revealed that the maximum number of fruits per plant (170) with maximum yield per tree (36 kg) was obtained by foliar spray of borax at the rate of 0.5 per cent. Sarrwy *et al*. (2012) studied the effect of calcium nitrate and boric acid sprays on date palm revealed that highest yield (bunch weight) (22.3 Kg), was obtained in boric acid at 500 ppm in combination with calcium nitrate at 2 per cent. Singh *et al*. (2012) studied the effect of pre-harvest chemical treatments along with mulching of mango and revealed that the treatment of 1.0 per cent borax with mulching was found more effective for increasing the fruit weight (161.66 g) and yield (37.20 kg per tree).

Dabke *et al.* (2013) reported that the nitrogen, phosphorus and potassium contents in fruit pulp were 0.96, 0.068 and 0.56 per cent, respectively. Whereas Pandey *et al*. (2013) conducted physico-chemical analysis of wood apple (Kaith) and revealed that the average fruit weight ranged from140.08 to 256.65 g, fruit length and width from 6.50-8.40 cm and 6.16 to 1.74 and pulp weight from 60.33 to 176.00 g.

Yadav *et al*. (2013) while investigating the effect of foliar application of boron, zinc and iron on low-chilled peach cv. Sharbati, revealed that foliar spraying of peach trees with 0.1 per cent boric acid + 0.5 per cent zinc sulphate.$7H_2O$ + 0.5 per cent ferrous sulphate $7H_2O$ was the promising treatment for improvement of fruit growth, fruit length, fruit diameter, fruit volume, firmness, average fruit weight and fruit yield. Similarly, Sankar *et al*. (2013) studied the influence of pre-harvest foliar application of micronutrients and sorbitol on mango tree and revealed that maximum fruit weight (268.29 g), number of fruit per tree (166.00) and yield per tree (44.60 kg) were obtained under the foliar spray of boric acid (0.02%). While, studying the effect of foliar application of potassium nitrate and urea on mango plants. Sarker and Rahim (2013) reported that plants treated with potassium nitrate at the rate of 4 per cent noted the biggest fruit (202.83g) with highest number of fruits per plant (136.67) and maximum yield (23.14 kg per plant).

Taha *et al*. (2014) studied the effect of potassium on mango tree and revealed that potassium citrate at the rate of 18.95 gram per tree recorded the highest fruit length (12.17 and 13.33 cm) in the first season and (12.67 and 12.33) in the second season with maximum number of fruits per tree (420.00 and 649.00) and yield (130.65 and 218.84 kg per tree). While studying the effect of micronutrient on acid lime cultivar Kagzi lime. Venu *et al*. (2014) revealed that the combination of zinc, boron, and iron exhibited highest number of fruits per shoot (8.53) with maximum number of fruits per plant (925.00), fruit yield per plant (27.07 kg) and yield per hectare (74.97qt).

Mhm *et al*. (2015) studied the effect of potassium, zinc and boron on growth, yield and fruit quality of Keitt mango trees and revealed that the highest number of fruits/tree (21.60 and 29.20), fruit weight (437.9 gm, 506.5 gm) and fruit yield per tree (9.46 kg , 14.79 kg) was obtained with potassium nitrate at the rate of 2 per combined with boric acid at 200 ppm during the first and second seasons, respectively. While investigating the effect of foliar spray of nutrients on yield attributing characters of mango, Singh *et al*. (2015) reported that maximum yield (51.00 kg/tree) and fruit weight (338.33 g) was obtained with the foliar application of ZnSO4 at the rate of 0.4

tree. On the other hand, Karemera and Habimana, (2014) investigated the effect of calcium chloride sprays on mango fruits and revealed that maximum weight of fruit (347.89 g) was obtained on spraying of 1.50 per cent per cent calcium chloride. Similarly, Meena *et al*. (2014) studied the effect of nutrient spray on growth, fruit yield and quality of aonla and revealed that fruit weight (45.20 g) and yield per tree (42.70 kg) were recorded with the combined spray of 0.6 per cent calcium nitrate + 0.4 per cent borax + 0.8 per cent zinc sulphate.

Hamouda *et al*. (2015) reported that yield, fruit quality and nutrients content of pomegranate leaves and fruit as influenced by iron, manganese and zinc foliar spray and found that iron, manganese or zinc sprays had positive significant effects on fruit fresh and dry weights, fruit dimension and fruit yield as well as juice volume /fruit, and fruit juice quality in both seasons as compared with the control treatment.

Nimse and More (2018) studied of physical and nutritional properties of aonla and found that physical properties such as length, diameter, whole fruit, pulp weight, per cent pulp and per cent seed of aonla fruit were 3.434 cm, 3.567 cm, 28.391 gm, 92.3 per cent and 7.60 per cent, respectively.

2.4.2 Chemical characterstics

Nijjar *et al.* (1981) studied the effect of graded doses of N, P and K on fruit yield and quality in Dashehari mango and reported that the fruit quality was not affected much by the fertilizer doses.

Malhi (1982) and Malhi *et al.* (1988) conducted studies on continuous use of nitrogen, phosphorus and potassium in Dashehari mango and found that the fertilizer application did not affect the quality of fruits. They also reported that the higher level of nitrogen and phosphorus (300g and 87.4g) significantly increased the total soluble solids in comparison with the other levels of nitrogen and phosphorus.

Singh *et al.* (1983) showed that the foliar application of nitrogen, phosphorus, and potassium at the rate of 3 per cent each resulted in significant increase in total soluble solids (17.9 ^{0}Brix) as compared to control (16.5 ^{0}Brix) and in significant increase in acidity (0.180 per cent) as compared to control (0.126 per cent) in Dashehari mango under Uttar Pradesh conditions.

Rajput and Singh (1983) reported that the foliar application of urea 3 and 6 per cent increased non-reducing sugars. The maximum non-reducing sugar 10.17 per cent and 9.91 per cent was noted with 55 application of 6 per cent and 3 per cent urea spray, respectively than control (9.26 per cent) in Dashehari mango.

Singh *et al.* (1984) observed that the application of horse manure, cow manure and artificial (N, P and K) fertilizers in Dashehari mango resulted in total soluble solids 18.0, 17.6 and 17.8 per cent, respectively as compared with 17.0 per cent in control treatment.

Syamal and Mishra (1988) reported that when nitrogen, phosphorus and potassium were applied in combination to Langra mango through soil at the rate of 1 Kg nitrogen + 2 Kg phosphorus + 1 Kg potassium, fruit quality was improved. Maximum total soluble solids of 22.82 per cent, reducing sugar (5.75 per cent), non-reducing sugar (13.20 per cent) ascorbic acid content (138.74 mg) and acidity (0.186 per cent) of pulp was recorded which was superior to other treatments.

Sharma *et al.* (1990) reported that the foliar application of 2 and 4 per cent urea showed significant differences in reducing sugars. The highest reducing sugar (4.26%) was noted with application of 4 per cent urea as compared to 2 per cent spray (4.18%) and control (3.84%). In case of non-reducing sugar, foliar application of 4.0 per cent urea showed significant increase per cent (13.51 per cent) as compared to control (12.65 per cent) in Langra variety of mango.

Singh *et al.* (1991) reported that the foliar application of 5 per cent urea resulted in increase in ascorbic acid (29.12 mg $100g^{-1}$) and reducing sugars (6.05 per cent) as compared to control (25.07 mg $100g^{-1}$) and (5.24 per cent) in Amrapali mango.

There were significant differences in total soluble solids. of mango pulp in half RDF among the treatments such as no manure, full RDF (1.5 Kg nitrogen, 0.5 Kg phosphorus and 0.5 Kg potassium), half RDF and Glyricidia at the rate of 75 Kg per tree. All treatments exhibited non-significant results in respect of acidity, reducing sugar and non-reducing sugars (Anonymous, 1998).

Magdum *et al.* (1999) reported that the potassium increased sugar content, size, shape, colour and firmness of fruits and also resulted in increased shelf life and control of some physiological ripening disorders. They also found that the application of low potassium along with higher nitrogen levels produced fruits with higher total soluble solids content. Number of fruits increased as a result of potassium application but the increase was not significant.

Manjrekar (2000) noted that there was significant effect of different fertilizers on total soluble solids content of Alphonso mango during ripening. Fifty six trees were supplied with higher potash along with recommended dose of nitrogen and phosphorus recorded highest total soluble solids. (18.73 ^{0}Brix), which was significantly superior over control. The data on acidity revealed that there was significant effect of fertilizers on acidity at harvest and at ripe stage. The trees supplied with higher phosphorous along with recommended dose of nitrogen and phosphorus recorded highest acidity (3.78 per cent) which was at par with the control. There was significant difference among different doses of fertilizers with respect to reducing sugar of fruit at harvest. The trees supplied with higher nitrogen along with recommended dose of nitrogen and phosphorus showed highest content of reducing sugar (2.41 per cent).

Bhatia *et al*. (2001) recorded that an application of 600 g nitrogen per plant was the best treatment for guava cv. Lucknow- 49 as it give higher fruit weight (125 g).

Bhatnagar and Chandra (2003) surveyed on 10 year old orchard of ber cv. Gola in Bikaner district and reported that physical and chemical attributes such as total soluble solids, ascorbic acid content, total sugars and reducing sugars varied significantly among the different orchards.

Daisy and Singh (2007) found, total soluble solids, total sugars, reducing sugars, acidity, ascorbic acid, pectin, tannin, crude fiber, pH and browning were recorded as 86.50 per cent, 10.10 per cent, 8.53 per cent, 5.14 per cent, 1.85 per cent 662 mg/100g, 1.93 per cent, 2.93 per cent, 3.07 per cent 2.90 and 0.063, respectively.

Rohitash (2007) reported the average total soluble solids, acidity and ascorbic acid of aonla varied between 8.85 to 9.50 ^{0}Brix, 1.40 to 1.90 per cent and 393.4 to 574.72 mg/pulp, respectively at Bikaner district of Rajasthan.

Burondkar *et al.* (2009) reported that the application of 1 per cent potassium nitrate significantly increased total soluble solids in Alphonso mango (19.9 ^{0}Brix) as compared to control (16.8 ^{0}Brix).

Anees *et al.* (2011) studied the effect of foliar application of micronutrients (iron, copper, boron and zinc) on the quality of mango cv. Dashehari and revealed that trees sprayed with 0.4 per cent ferrous sulphate + 0.8 per cent borax + 0.8 per cent zinc sulphate had the maximum pulp weight (169.2 g), total soluble solids (27.9°B), ascorbic acid (150.3 mg/100 ml) and non–reducing sugars (8.83 per cent)content with less stone weight (28.13 g) along with low acidity (0.178 per cent) in comparison to rest of treatments.

Bhowmick and Banik, (2011) studied the influence of pre-harvest foliar application of growth regulators and micronutrients on mango cv. Himsagar and revealed that maximum total soluble solids (19.68 °B), total sugars content (16.43 per cent) and non reducing sugar content (11.96 per cent) was highest in the plants treated with zinc sulphate at the rate of 1.5 per cent while maximum reducing sugar content (5.03per cent) was recorded with borax at the rate of 0.25 per cent treated plants. Nehete *et al*. (2011) investigated the influence of micronutrient spray on flowering, yield, quality and nutrient content of mango cv. Kesar and found that treatment consist of zinc sulphate 1 per cent + ferrous sulphate 1 per cent + borax 0.5 per cent exhibited the higher percentage of total sugars (16.67 per cent), reducing sugar (6.03 per cent) and ascorbic acid (32.80 mg/100 g pulp) content.

Bhatt *et al.* (2012) studied the effect of potassium, calcium, zinc and boron on mango cv. Dashehari and reported that the trees sprayed with 0.5 per cent borax had maximum fruit volume (164.52 per cent), total soluble solids (17.80^{0}B), reducing sugar (6.42 per cent), non reducing sugar (9.29 per cent) and ascorbic acid content (34.05 mg/100 gram pulp). While investigating the response of pre-harvest foliar application of zinc and boron on mango cv. Amrapali under new alluvial zone of West Bengal, Bhowmick *et al*. (2012) revealed that the maximum average fruit length (10.33 cm), breadth (6.33 cm), were recorded with borax 0.25 per cent . Whereas, maximum pulp content (73.57 per cent) was obtained from the treatment with borax 0.75 per cent. However, regarding quality parameters, maximum TSS (20.75°brix), total sugars (17.08 per cent), non reducing sugar (12.32 per cent), ascorbic acid (41.62

mg/100 g of fruit pulp), TSS/acid ratio (115.11) and lowest acidity (0.18 per cent) were recorded with 1.0 percent zinc sulphate application.

Sajid *et al.* (2012) reported that maximum fruit juice content (46.61 per cent), total soluble solids (10.26 per cent) and least ascorbic acid were observed when the fruit was treated with high zinc (1 per cent). However, they recorded maximum reducing sugar (10.24 per cent) in the fruits of the plants treated with boron at the rate of 0.02 per cent.

Sankar *et al*. (2013) studied the influence of pre-harvest foliar application of micronutrients and sorbitol on mango and revealed that maximum fruit length (9.98 cm), breadth (7.86 cm) and fruit volume (258.24 cc) were obtained under the foliar spray of boric acid (0.02 per cent). However, Sarker and Rahim (2013) studied the influence of foliar application of potassium nitrate and urea and reported that plants treated with potassium nitrate at the rate of 4 per cent noted the highest total soluble solids (25.15 per cent), vitamin C (32.23 mg/100g pulp), thickness (5.82 cm) while potassium nitrate at the rate of 6 per cent recorded highest reducing sugar (5.22 per cent).

2.5 Relationship of soil nutrients with soil properties, leaf nutrients and fruit characteristics

2.5.1 Correlation of soil nutrients with soil properties of mango orchards.

According to Patil and Malewar (1998), the available zinc, iron, manganese and copper had negative correlation with pH, electrical conductivity and calcium carbonate contents while the same had positive correlation with organic carbon content in the soils of Mandarin orchards. With regard to correlation between soil physico-chemical characteristics and available soil nutrients, soil pH was significantly and negatively correlated with soil phosphorus, copper, iron and manganese, Whereas it was significantly and positively correlated with calcium and magnesium (Sailaja, 1999). The EC of the soil at three depths were positively and significantly associated with available copper, iron and manganese (Reddy *et al.* 2002).

Mediratta *et al*. (1985) reported that calcium carbonate had significant and positive correlation with pH (r = 0.612**). On the other hand, the calcium carbonate had significant and negative correlation with organic carbon (r =- 0.708**). They reported that organic carbon content of soils deceased significantly with calcium carbonate (r = 0.708**) and pH (r = -0.717**). The pH of soils showed an irregular trend with depth and varied from 7.60 to 8.65.

Kanthalia and Bhatt (1991) determined relationship between organic carbon and available nutrients in some soils of sub-humid zone of Rajasthan and found that in these soils the value of organic carbon was positively related (significant) with available nitrogen while, it had non significant relationship with available phosphorus and potassium. Singh *et al*. (1997) found that the pH of soils increased significantly with increase of calcium carbonate (r = 0.612**) and decreased significantly with decrease in organic carbon (r = -0.717**).

Nayak *et al*. (2000) found that the availability of zinc reduced significantly with increase in soil pH, while its content increased with increase in organic carbon, clay, cation exchange capacity. They further reported that the available iron is negatively and significantly correlated with pH and sand, while, it has inverse and significant relationship with organic carbon and silt.

Gathala *et al*. (2004) reported that available sulphur had significant positive correlations with organic carbon (r = 0.676**), nitrogen (r =0.521**), phosphorus (r = 0.628**) and potassium (r =0.774), while it had significant negative correlation with calcium carbonate (r = -0.632**), pH (r = -0.547**), calcium (r = 0.569**) and magnesium (r = -0.252).

Jat *et al*. (2012) who observed that available nitrogen had significant and positive correlations with organic carbon, phosphorus, calcium, magnesium and sulphur, while it had significant and negative correlation with calcium carbonate and pH.

2.5.2 Relationship of soil nutrients with leaf nutrients

Samra *et al*. (1978) and Malhi (1982) observed that the application of nitrogen (1.0 kg/tree/year), phosphorus (1.0 kg/tree/year) and potassium (1.5 kg/tree/year) increased the leaf nitrogen, phosphorus, potassium level in Dashehari at the end of two years.

Samra *et al*. (1978) reported a significant positive correlation between K content in soil and leaf content of mango. Thakur *et al*. (1979) found a positive and significant correlation (r = 0.64 **) between the available phosphorus content of soil and total phosphorus content of leaf in Dashehari variety of mango.

Thakur *et al*. (1983) reported that application of potassium at the rate of 2 kg per tree per year for four successive years increased leaf potassium content significantly over control at the end of fourth year in Dashehari variety of mango.

Bopaiah and Srivastava (1984) observed no correlation between soil and leaf nitrogen and potassium contents, however a positive correlation was observed between leaf phosphorus and available phosphorus in deeper soil layers.

Chaudhary *et al.* (1985) observed an increase from 1.54 to 1.90 per cent in nitrogen, 0.05 to 0.22 per cent in phosphorus and 0.31 to 0.70 per cent in potassium contents of leaves of Langra variety of mango due to application of manures and fertilizers.

Biswas *et al.* (1987) studied the critical leaf nutrient concentration of Dashehari mango based on soil test and found that leaf nitrogen was significantly correlated only with organic carbon content of the surface soil, whereas leaf phosphorus and potassium were significantly correlated with phosphorus and potassium content of surface and sub-surface soil.

Rao and Mukherjee (1987) surveyed the nutrient status in leaf and soil of some cultivars of mango in relation to yield and reported that leaf nitrogen before flowering and after harvest and phosphorus content before flowering were positively and significantly correlated to yield of mango. A similar beneficial association of soil nitrogen and phosphorus before flowering with yield was evident.

Bopaiah *et al*. (1988) from their study on Dashehari variety of mango noticed a positive and significant correlation between phosphorus content of soil and phosphorus content of leaf from fruiting (r = 0.60*) and non –fruiting (r = 0.70*) terminals when the samples were collected in the month of February.

Biswas *et al.* (1989) found positive correlation of soil phosphorous with leaf phosphorus and soil potassium with leaf potassium in Dashehari variety of mango.

Sharma *et al*. (1990) found that available phosphorus had significant positive correlations with organic carbon (r = 0.760 **), nitrogen (r = 0.692**) and sulphur (r =

0.628**), while it had significant negative correlation with calcium carbonate (r = -0.764**), pH (r =-0.791**). Singh and Khan (1990) conducted field experiment of major (nitrogen, phosphorus and potassium) and trace (copper, zinc and boron) elements applied through soil or as a foliar spray to Dashehari mango from 1988 to 1990 and found that the fruit quality was improved by higher trace element application than the major nutrients.

Arora *et al*. (1992) found that calcium, magnesium and sulphur content in pear leaves were significantly and positively correlated with nitrogen and potassium.

Singh *et al*. (1997) reported that the nitrogen content in ber plant leaves was significantly and positively correlated with phosphorus (r =0.778**), calcium (r= 0.794 **), magnesium (r = 0.594**), sulphur (r = 0.651**). Phosphorus content in leaves was significantly and positively correlated with potassium (r = 0.608**), calcium (r = 0.702**).

Lal *et al*. (2000) reported that there is antagonistic relationship between applied manganese, phosphorus, potassium and zinc content of guava leaf. Whereas, a synergistic relationship was observed between applied manganese and nitrogen content of soil.

A study on Alphonso mango from Ratnagiri district by Dhopavkar (2001) reported an increase in the contents of total nitrogen, phosphorus and potassium of leaf due to application of manures and fertilizers.

Gathala *et al*. (2004) reported that available potassium content of orchards soils had significant positive correlations with organic carbon (r = 0.712 **), sulphur (r = 0.774**), while it had significant and negative correlation with calcium carbonate (r = -0.650**), pH (r =-0.432**), calcium (r = -0.739**) and magnesium (r = -0.365**). Available potassium content showed content showed non – significant relationship with nitrogen and phosphorus.

Jat *et al*. (2012) reported that available nitrogen had significant and positive correlations with organic carbon, phosphorus, calcium magnesium and sulphur while it had significant and negative correlation with calcium carbonate and pH.

Dabke *et al*. (2013) observed that the application of different levels of potassium fertilizers along with recommended dosages of N and P_2O_5 increased N, P and K content of leaf in Alphonso mango before flowering and post harvest stages.

Li *et al*. (2017) revealed that the contents of boron, zinc, and iron in leaves were significantly correlated with soil nutrients. However, the contents of nitrogen, phosphorus, potassium and magnesium were no significant correlations with soil nutrient contents. There was a significant negative correlation between boron content in Pummelo leaf and pH value in soil, and positively correlated with available boron organic matter, total nitrogen, total phosphorus, available nitrogen, available phosphorus, available potassium, available copper, available zinc, and available iron in soil. The Mg content in leaves was positively correlated with available nitrogen and available iron and negatively correlated with other indexes, especially with available copper, available zinc and pH while the iron content of leaves was negatively correlated with pH value and exchangeable calcium. It was positively correlated with other indexes and had a significant positive correlation with total potassium, available potassium, available phosphorus, available boron, and available copper and available zinc. It shows that leaf nutrient and soil nutrient were closely related.

2.6 Relationship of soil and leaf nutrients with fruit characteristics.

Sahay and Ram (1970) observed a positive correlation of yield of mango with leaf N level and none with other elements. Samra *et al.* (1978) observed no correlation between leaf nutrient status and yield of mango. However Rameshwar *et al.* (1981) and Rao and Mukherjee (1987) reported a direct correlation between leaf nutrient contents and yield of mango.

Bhandari (1973) in his studies on apple orchard soils of Shimla district found non significant but positive correlation of available Cu and Fe in both surface and sub-surfaces oils with their contents in leaves. Singh (1987) found significant and positive correlation of soil N and leaf N and the coefficient values were found to be 0.49 to 0.97, respectively. Verma (1987) found the leaf and soil Ca relationship decreased with the increase in soil depth.

Ray and Mukherjee (1982) observed that yield of Himsagar, Fazli and Langra mango had positive correlation with nitrogen content of leaf before flowering, after harvest and after rainy season as 0.542**, 0.616**, 0.538**, respectively. They also reported a positive correlation of phosphorous content of leaf after harvest (0.417**) and after rainy season (0.521**) with fruit yield.

Nitrogen in leaves showed positive but non-significant relation with yield of mango at flowering and post-harvest stages. Phosphorous and potassium content in leaves at harvesting stage were negatively but non-significantly correlated with yield. At flowering stage, phosphorus and potassium showed positive but non-significant relationship with yield (Anonymous, 1983). Bopaiah and Srivastava (1984) noted that the leaf nutrients did not reveal significant relationship with fruit yield except negative relationship with leaf nitrogen.

A survey of litchi orchards situated at different locations in West Bengal was undertaken by Rao *et al*. (1985) and they observed that there was a wide variation in leaf, soil nutrients status and yield of the orchards. The concentration of nitrogen, phosphorus and potassium in leaves gradually deceased from the flowering stage (January) to harvest of fruits at the end of rainy season (September). Significant variation between leaf nitrogen and potassium selected from high and low yielding plants was also observed. The correlation studies between leaf nutrient concentration and yield indicated that leaf nitrogen content at three stages of sampling and leaf potassium after harvest was positively and significantly correlated with fruit yield. It is concluded that fruit yield is directly correlated with the nutrient status of leaf as well as soil. In six years old litchi cultivar Bombay. Ghosh *et al*. (1988) observed the highest fruit yield with the soil application of nitrogen at the rate of 600 g per plant.

Rao and Mukherjee (1987) surveyed the nutrient status in leaf and soil of some cultivars of mango in relation to yield and reported that leaf nitrogen before flowering and after harvest and phosphorus content before flowering were positively and significantly correlated to yield of mango. A similar beneficial association of soil nitrogen and phosphorus before flowering with yield was evident.

Rao and Mukherjee (1988) showed that the yield had positive correlation with nitrogen and phosphorus content of leaf and available nitrogen and phosphorus of soil before flowering, after harvest and after rainy season in Fazli and Langra varieties of mango.

Sharma (1994) also observed that available N and Mn in both the surface and sub- surface soils had a positive and highly significant relationship with their respective contents in leaves. However, for P and K, the relationship was found to be positive but statistically non-significant.

Reddy *et al.* (2003) found that the yield of Alphonso had positive correlation with leaf nitrogen before (0.063**) and during flowering (0.54**), with leaf phosphorus after harvest (0.46**) and with leaf potassium before flowering (0.43**). They also observed a positive correlation of yield with available soil nitrogen at pea size stage of fruits and available soil potassium before flowering, at flowering and at pea size of fruits.

Kumar and Chandel (2004) studied the effect of different levels of nitrogen, phosphorus and potassium on growth and yield of pear cv. Red Barlett and found that nitrogen content in leaves was positively and significantly correlated with tree height, annual shoot extension growth, trunk girth, fruit length, fruit weight and fruit yield.

Raghupathi *et al.* (2004) found that the fruit yield of mango trees from peninsular India had positive correlation with nitrogen content in leaf before and during flowering. Phosphorous content in leaf had positive correlation with yield after harvest. Potassium content of leaf also had positive correlation with yield before flowering.

Khayyat *et al*. (2007) reported that boron, iron, zinc content and titratable acid were significantly negatively correlated, it indicated that it could increase sugar and reduce acid content with increasing boron, iron and zinc content. Asadi *et al*. (2007) found that the content of available potassium, boron iron, and zinc in soil increased the content of mineral elements in leaves, which increased fruit peel thickness, fruit weight, total sugar and vitamin C content etc.

Yang (2008) observed that the content of vitamin C in fruit was positively correlated with soil pH and available K, and negatively correlated with soil organic matter and other nutrient contents.

Zhang *et al*. (2010) found that the available phosphorus in soil had the greatest effects on fruit quality of mandarin, followed by potassium, nitrogen and phosphorus in leaf could significantly increase the content of vitamin C and sugar, but reduce acidity, while magnesium and boron increase the acidity of fruit. In addition, researchers have suggested that the content of soluble solids in fruit was negatively correlated with soil pH value, and there was a significant positive correlation with soil organic matter, available, iron, manganese, and zinc**.** However Aular *et al*. (2010) found that available potassium, boron and iron in soil increased the content of mineral elements in leaves which increased fruit peel thickness fruit weight total sugar and vitamin C content.

Xu *et al*. (2012) reported that most of the nutrients in citrus leaves were negatively correlated with the soluble solids of fruit quality, and positively correlated with vitamin C content.

Kumar *et al*. (2013) reported that leaf nitrogen, phosphorus, potassium, zinc, copper, manganese and iron content were positively and significantly correlated with yield in case of mango trees. However, Zhao *et al*. (2013) found that nutrient contents in soil increased with the increase of organic manure application which indicated that the increase of organic fertilizers was beneficial to improve soil available nutrient, and organic fertilizers with chemical fertilizers. It indicates that most of the nutrients in the tree came from the soil, and the leaf nutrient was closely related to the soil nutrient.

Afzal *et al*. (2015) observed that potassium content of leaf was positive but non-significant with tree height, annual shoot extension growth, trunk girth, fruit length, fruit diameter, fruit weight and fruit yield.

Singh *et al*. (2015) showed that soil potassium was positive and statistically significant with fruit yield, fruit length, fruit breadth, fruit weight, pulp, total soluble solids and pulp stone ratio in litchi cultivars. Likewise, soil nitrogen concentration had shown positive but statistically significant nitrogen, phosphorus and zinc content showed positive but non-significant correlations with fruit. Likewise, leaf nitrogen concentration had shown positive but statistically significant correlations with fruit yield ($r = 0.81$) and pulp stone ratio ($r = 0.38$) , however leaf nitrogen, phosphorus, calcium and zinc content showed positive but non significant correlations with fruit size except leaf nitrogen content with fruit breadth . On the contrary, leaf magnesium and manganese showed negative non –significant with fruit length and breadth.

Dar *et al*. (2015) revealed that nitrogen, phosphorus, potassium and sulphur content in pear foliage found significant and positive relationship with fruit length, diameter, weight, volume, total soluble solids, total sugar and yield.

Hamouda *et al*. (2016) found the highly significant positive correlation was found between the content of leaves from calcium and iron and fruit yield, juice volume, fruit diameter, total sugars, anthocyanin and vitamin C, as well as highly significant positive correlation was found between the content of leaves from phosphorus and fruit yield, juice volume, fruit diameter, total sugars and vitamin C.

Li *et al*. (2017) observed that the pH value was negatively correlated with the fruit yield and quality index but only the correlation between pH value and yield per plant reached significant level. There was a significant positive correlation between total potassium and fruit weight, and the other indexes did not reach significant level. There was a significant positive correlation with fruit weight, fruit thickness, total sugar, solid acid ratio, sugar and acid ratio, vitamin C content and fruit yield. There was a significant positive correlation between available boron content, fruit weight, fruit thickness, total sugar, sugar and acid ratio and vitamin C content and negatively correlated with juice yield, edible rate and titrable acid. The effective iron and zinc content was negatively correlated with the juice yield, edible rate and titrable acid which were significantly correlated with fruit yield and quality indexes.

Nabi *et al*. (2018) showed that the correlation between leaf nutrient content with growth parameters and revealed that nitrogen, magnesium, sulphur, copper and iron content in leaves was positively and significantly correlated with tree height, annual shoot extension growth, trunk girth, yield, fruit weight and fruit size.

2.7 Derivation of Diagnosis and Recommendation Integrated System (DRIS) norms for fruit crops.

2.7.1 Establishing DRIS norms

The general procedure for the selection of the DRIS norms was elaborated by Walworth and Sumner (1987). Jayalakshmi (1989) in ground nut; Angeles *et al.* (1990) in pineapple; Kopp and Burger (1990) and Rathfon and Burger (1991) in Fraser Fir Christmas trees; Payne *et al*. (1990) in Bahiagrass; Hallmark *et al*. (1991) in Soyabean; Sanchez *et al.* (1991) in Crishead lettuce and in pecan have followed the same procedure for selecting norms under computing DRIS indices. Beverly and Worley (1992).

Jiang *et al*. (1995) conducted the mineral analysis on the leaves of Starking Delicious apple cultivar using DRIS norms. Foliar nutrient DRIS norms were developed for mango and cause of low yield was identified to get yield from 10.50-13.70 t/ha (Bhargava, 1995). Hundal and Arora (1995) developed DRIS norms from a data bank of 675 observations for nitrogen, phosphorus and potassium status for litchi trees by dividing the observations into high and low yield sub populations using mean yield as 60 kg per plant. Mean, standard deviation and variance (S_2) for the two sub-populations were calculated for each nutrient concentration and larger variance ratio was selected. The norm expression N/P, N/K, K/P, P/N, and K/N with corresponding mean value of 7.76, 1.94, 4.21, 0.14, and 0.57 respectively were used to calculate diagnostic norms. Preliminary DRIS norms for N, P and K have been found to be useful in diagnosing and ranking the most limiting and excessive element.

Raghupathi and Bhargava (1997) developed diagnosis norms using DRIS from a survey conducted in Maharashtra to study the fertility status of soils growing Alphonso mango. The soil samples were analyzed for pH, electrical conductivity, available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and DTPA extractable iron, manganese, copper and zinc. Among different forms of expression were taken for developing formulae for calculating norms. Among different forms of expression, the one showing higher variance ratio was selected. Rodriguez and Rajas (1997) evaluated the levels of nitrogen, phosphorus, potassium, calcium and magnesium in Valencia sweet orange leaves for developing DRIS norms from the data of 1019 healthy trees from the most productive Valencia orange orchards in Venezuela. After recording the yields, they selected 214 most productive and healthy looking individual trees yielding greater than 92 kg of fruit per tree for norm development. DRIS norm expression viz. N/DM, P/DM, K/DM, Ca/DM, Mg/DM, N/P, K/N, K/P, Ca/Mg, N×Ca, N×Mg, P×Ca, P×Mg, K×Ca and K×Mg with norm values 2.75, 0.18, 1.32, 3.37, 0.30, 16.27, 0.49, 7.96, 12.85, 9.12, 0.83, 0.63, 0.05, 4.34, 0.40 respectively were selected.

Hundal and Arora (2001) computed DRIS norms from 471 sets of data on leaf mineral composition and corresponding fruit yield collected from 87 kinnow orchards of Punjab. The mean value of 2.38, 0.107, 0.901, 3.747, 0.444 per cent and 20.6, 8.40, and 28.6 mg per kg for nitrogen, phosphorus, potassium, calcium, magnesium, zinc, copper iron and manganese, respectively in leaf tissues of high yield compositions of kinnow fruit trees were taken as the DRIS norms.

Raghupathi *et al.* (2004) carried out an experiment on diagnosis of nutrient imbalance in mango by DRIS and PCA approaches and reported that DRIS indices showed no signs of improvement nor there was a trend with application of nitrogen, phosphorus, or potassium at different levels. Some measures of total imbalance of nutrients in plant were reflected through sum of DRIS indices irrespective of sign. The greater imbalance of nutrients resulted in lower fruit yield. They also reported that Principal Component Analysis (PCA) was applied to extract the correlation structure among the nutrient in low and high yielding plants and for DRIS indices. The first PC derived by PCA performed both on absolute nutrient concentration and DRIS indices were designated as (N-P + Mg-S + Fe + Cu). Involvement of several nutrients in a single PC indicated that, it was not possible to diagnose nutrient imbalance of any particular nutrient in isolation in fruit crops like mango. The nutrient concentration variation in mango leaf appears to be an overall orchard phenomenon rather than individual tree phenomenon. These norms were developed with data from only one cropping region, so they should be considered as preliminary, probably requiring some modification as more data become available. The norms were significantly different from those presented in the literature, except for N/K whose value is similar to the existing norm.

Hundal *et al*. (2005) studied diagnosis and recommendation integrated system for monitoring nutrient status of mango trees in sub-mountainous area of Punjab and established standard norms from the nutrient survey of mango fruit trees were 1.144, 0.126, 0.327, 2.587, 0.263, 0.141% for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S), and 15, 3.5, 145, 155, and 30 mg/kg, respectively, for zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), and boron (B) in dry matter. On the basis of DRIS indices, 16, 15, 12, 17, and 16% of total samples collected during nutrients survey of mango trees were low in N, P, K, Ca, and Mg, respectively. For micronutrients, 19, 18, 12, 20, and 6% samples were inadequate in Zn, Cu, Fe, Mn, and B, respectively. DRIS-derived sufficiency ranges from nutrient indexing survey were 0.92–1.37, 0.08–0.16, 0.21–0.44, 1.71–3.47, 0.15–0.37, and 0.09–0.19% for N, P, K, Ca, Mg, and S and 11–19,1–6, 63–227, 87–223, and 16–44mg/kg for Zn, Cu, Fe, Mn, and B, respectively

Seema *et al*. (2010) computed the DRIS norms from the data bank of 324 subplots on leaf mineral composition, soil available nutrients, and corresponding mean yield representing three diverse pineapple belts for 3 seasons during 2002-2004. DRIS norms derived primarily from basal portion of 'D' leaves sampled at 4th to 5^{th} month suggested critical leaf nutrient concentration *viz.*, 1.21-1.85% nitrogen (N), 0.13-0.18% phosphorus (P), 1.19-1.62% potassium (K), 0.27-0.35% calcium (Ca), 0.43-0.56% magnesium (Mg) and 78.4-102.5 iron (Fe), 41.5-58.3 manganese (Mn), 7.4-10.2 copper (Cu) and 12.2-15.8 zinc (Zn) ppm in relation to fruit yield of 55-72 tons/ ha .

Singh *et al*. (2010) studied nutrient status of ber (*Zizyphus mauritiana*) fruit trees in semi-arid and arid regions of northwest India through diagnostic recommendation and integrated system approach and established DRIS norms for various nutrient ratios obtained from the high-yield population and were used to compute DRIS indices, which assessed nutrient balance and their orders of limitation to yield. Nutrient sufficiency ranges derived from DRIS norms were 0.688-1.648%, 0.184-0.339%, 1.178-1.855%, 1.064-1.768%, 0.234-0.391%, and 0.124-0.180% for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) and were 55-205, 26-80, 17-33, and 5-11 mg/ kg for iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu), respectively. According to these DRIS-derived sufficiency ranges, 79%, 76%, 76%, 75%, 84%, and 72% of samples were sufficient, whereas 13%, 15%, 21%, 14%, 7%, and 18% of total samples were low in N, P, K, Ca, Mg, and S, respectively. For micronutrients, 84%, 85%, 77%, and 86% of samples were sufficient, whereas 6%, 3%, 8%, and 2% of samples were low in Fe, Mn, Zn, and Cu, respectively.

Agbangba *et al*. (2011) studied preliminary diagnosis and recommendation integrated system (DRIS) norms for 'Perola' pineapple. DRIS norms established from a data bank of leaf nutrient concentration (N, P, K, Ca, Mg and Zn) and fruit yield with 60 samples gathered from farmers' plantations. The data divided into high-yielding (>66.7 t/ha) and low-yielding (<66.7 t/ha) sub-populations and norms computed using standard DRIS procedures

Nayak *et al*. (2011) established preliminary diagnosis and recommendation integrated system (DRIS) norms for different nutrient ratios and used to compute the

DRIS indices, which assessed the nutrient balance and order of limitations to yield. Maximum fruit yield of 40.2 kg/plant was recorded for the plants at the age group of 10–15 years and lowest yield was recorded 28.3 kg/plant in the age of above 20 years. Nutrient sufficiency ranges for aonla derived from DRIS norms were 1.30–1.64, 0.054–0.092, 0.40–0.64%, and 32.4–45.9 ppm for nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn), respectively. On the basis of these sufficiency ranges 33, 51, 47, and 46% of samples were found sufficient whereas 34, 22, 18 and 27% of samples were low and 26, 8, 1 and 17% deficient in N, P, K, and Zn, respectively. When compared age wise, a relative deficiency for N, P, and K corresponding to relative sufficiency for Zn was detected by DRIS technique for the plants above the age group of 15 onwards. For the younger orchards (5yrs old) a relative deficiency of N, Zn, and K corresponding to the relative sufficiency of P was detected. Nitrogen was found most limiting elements in all age group of plant. When the DRIS indices were compared on basis of soil pH, Zn and K was found to be relatively lesser in order of requirement than N and P.

More (2013) from his study on mango orchards from lateritic soils of Ratnagiri district revealed that the total N, P and K content at flowering, at egg and at harvest stage in leaf was 0.93, 0.77 and 0.88 per cent for, 0.052, 0.052 and 0.044 per cent for and 0.58, 0.48 and 0.53 per cent for, respectively after application of recommended doses of fertilizers.

Adak *et al.* (2014) collected the leaf samples from mango orchards of Lucknow in the month of September. The mean leaf nutrient content of N (1.10 per cent), P (0.10 per cent) and K (0.23 per cent).

Kar *et al*. (2015) developed diagnostic norms using DRIS to ascertain optimum foliar concentrations of cationic micronutrients for mulberry growing under plains of West Bengal are 10.55 mg/kg for Zn, 2.85mg/kg for Cu, 68.97 mg/kg for Fe and 40.73 mg/kg for Mn, respectively. DRIS norms are useful to correct nutritional imbalances and to increase mulberry yield.

Xu *et al*. (2015) studied preliminary the diagnosis and recommendation integrated system (DRIS) norms for evaluating the nutrient status of apple and establish norms for apple, to compare mean yield, leaf nutrient contents and variance of nutrient ratios of low- and high-yielding subpopulations. DRIS model for apple, developed in this study, is a diagnostic tool that may be used to predict if insufficiencies or imbalances in nitrogen, phosphorus, potassium calcium, magnesium, iron, manganese and zinc supplies are occurring in apple production area.

Joshi (2015), from her study on mango orchards of Ratnagiri district revealed that total N, P, and K content at different stages in leaf were 0.806 to 1.195 per cent, 0.022 to 0.156 per cent, 0.33 to 1.194 per cent, respectively. While, Puranik (2015), from his study on Alphonso mango of Devghad and Ratnagiri observed that total N, P, K, Ca, Mg and S content at different stages in leaf were 0.82 to 1.65 with a mean value of 1.23 %, 0.10 to 0.52 with a mean value of 0.31 %, 0.29 to 0.52 with mean value of 0.40 %, 1.22 to 2.04 with a mean value of 1.63%, 0.39 to 1.62 with a mean value of 1.005% and 0.43 to 0.75 with a mean value of 0.59% respectively.

2.7.2 Calculation of DRIS Index

Standard DRIS technique proposed by Beaufils (1973) for calculation of DRIS indices is the use of two equation system. However Jones (1981) observed that the two equation system of calculating DRIS indices and intermediate DRIS functions overestimates f(A/B) when sample value is less than the norm value. Further he suggested the use of equation of (A/B) = (A/B- a/b) S.D. to calculate the function (A/B), regardless of the relative values of (A/B) and (a/b). These observations were confirmed by Beverly (1987). He concluded that these changes in the traditional DRIS approach remove systematic errors and simplify the diagnostic method and extend its applicability. The two equation system was strongly advocated by Sumner (1986), Walworth and Sumner (1987) and Sumner (1990) for calculating DRIS indices and functions. Righetti *et al. (*1988) while studying diagnosis basis in DRIS evaluation on sweet cherry and hazelnut evaluated both one equation system and two equation system and observed that one equation system had several disadvantages such as there were limits in minimum and maximum values than an index can obtain for some elements, but not for others. The range of index values obtainable varies considerably among elements and if the sum of DRIS indices, regardless of sign is used as a criterion to identify imbalances, relative deficiencies or excesses for some elements are marked. They concluded that the two – equation system lessened these difficulties to a greater extent.

Ramachander and Sikhamany (1989) adopted a new approach to developed DRIS norms for grape and considered yield as a power function of ratio of nutrient contents instead of linear function and also recommended the use of population mean and standard deviation instead of arbitrary categorization of high and low yielding sub- population. In addition, the discriminate function was employed to maximize the differences between two groups. Singh *et al.* (2000) and Sharma and Bhargava (2002) used two equation system, as directed by Sumner, (1986) and Walworth and Sumner, (1987) to calculate the DRIS indices for apple and peach, respectively.

2.7.3 Diagnosis of nutrient status of orchards in relation to yield and quality using DRIS approach

Chelvan *et al*. (1984) identified nutrient limitations associated with poor yield in Thompson Seedless grape. They observed that low potassium and high phosphorus indices were associated with low yield in grape. Negative effect of phosphorus and the synergism of magnesium and nitrogen with potassium on fruit yield were also found. Fallahi and Righetti (1984) used DRIS approach in evaluating nutritional imbalances in apple in relation to fruit quality. Schaller and Lohnertz (1984) concluded that DRIS approach successful diagnosed the nutrients limiting yield and quality in grape. Beverly *et al*. (1984) assessed nutritional status of citrus by DRIS approach. They concluded that mineral composition of Valencia orange diagnosed by DRIS was influenced by crop load and alternate bearing as it influences the nutrient concentrations.

Davee *et al*. (1986), Righetti *et al.* (1988) and Alkoshab *et al.* (1988) evaluated the nutrient status of cherry and hazelnut trees and found that DRIS nutrient imbalance indices are influenced by crop load, through it does not detect all deficiencies or excesses. Schaller (1988) used DRIS approach in assessing the nutritional status of grape vines in phosphorus fertilization studies and reported that phosphorus was in excess of plant requirements while as Mg was the most limiting factor upon yield and quality. Khan *et al*. (1988) concluded that nutrient application could be suggested for a targeted yield in coconut based on the DRIS indices.

Parent and Granger (1989) while developing DRIS norms for apple observed that DRIS norms defined yearly were preferably to general DRIS norms as a result of year to year variation of DRIS norm during the earlier period of orchard establishment.

DRIS norms can be further computed be from their relationship with annual yields. Angeles *et al*. (1990) while using DRIS approach to diagnose nutritional status of pineapple observed that potassium was the main limiting factor followed by nitrogen upon yield. Sumner (1990) used previously established DRIS norms to calculate nutrient balance index for pine apple and while comparing it with total soluble solids (TSS), titrable acidity (TA) and their products and ratio, he observed that under proper nutrient balance conditions, fruit weight was between 1 and 2 kg with TSS greater than 12^0 Brix, titrable acidity greater than 0.45 per cent. TSS/TA less than 25 and TSS × TA greater than 4.5. Szucs *et al*. (1990) while assessing nutritional values and yield data observed that lower yields were associated with over supply of potassium and under supply of phosphorus while as nitrogen status was neutral. Gou and Malakouti (1992) while developing DRIS norms for apple trees in New Zealand observed that high N and low Ca were major nutrient problems associated with fruit storage disorders. However Bhargava (1995) while using DRIS approach for mango, indicated deficiency of N ad Zn upon yield. Hundal and Arora (1996) while using DRIS norms for foliar diagnosis of micro nutrients for litchi in Punjab observed that irrespective of variety and position of leaf, DRIS indices diagnose that total orchard were suffering from inadequacy of Zn, Cu, Fe, and Mn, respectively. Bhargava and Raghupati (1997) observed that in most limiting nutrients in Anab-e-Shahi grapes while as N, P, K ad Ca were the yield limiting nutrients for Thompson Seedless grapes. Raghupati and Bhargava (1998) developed diagnostic norms while evaluating yield–limiting nutrients in low yield orchards of pomegranate. They observed that nitrogen and zinc were the most common yield limiting nutrients.

Singh *et al*. (2000) used DRIS approach for apple which indicated the superiority of nitrogen, phosphorus and potassium in combination to maintain balanced nutritional conditions in plant system for higher yield. Awasthi *et al*. (2000) while using DRIS approach for peach orchards of Himachal Pradesh observed that magnesium followed by nitrogen discriminated low and high yield.

Bhatnagar *et al*. (2001) studied nutritional survey of aonla orchards in Bikaner district of Rajasthan and reported that the analysis of leaf samples of aonla indicated deficiency of nitrogen, potassium, manganese, and zinc in the orchards, the phosphorus iron and copper status of leaf was found adequate for the growth of the plants.

Sharma and Bhargava (2002) while using DRIS approach in peach reported that nitrogen and potassium were the major limiting nutrients while as magnesium was the major relatively excess nutrients by DRIS approach. Whereas calcium was the major excess nutrient by sufficiency range approach.

Sharma *et al*. (2005) used DRIS approach for grapes during bud differentiation and flowering stage and observed that sodium as a major limiting factor was accompanied by increased levels of potassium.

Srivastava and Singh (2008) also reported that significant lowering of NII due to correction of yield limiting nutrients in Nagpur mandarin.

Savita and Anjaneyulu (2008) development of leaf nutrients norms and identification of yield limiting nutrients using DRIS in sapota cv. Kalipatti and indicated that zinc and boron were the common deficient nutrient elements.

Bangroo *et al*. (2010) showed that the Importance of nutrient balance in determining yield and quality of crops is well established but there was no means to quantify it until the introduction of the DRIS in which leaf analysis values are interpreted on the basis of inter-relationship among nutrients, rather than nutrient concentration themselves. The DRIS is based on the comparison of crop nutrient ratios with optimum values from a high yielding group (DRIS norms). The DRIS provides a means of simultaneous identifying imbalances, deficiencies and excesses in crop nutrients and ranking them in order of importance. The major advantage of this approach lies in its ability to minimize the effect of tissue age on diagnosis, thus enabling one to sample over a wider range of tissue age than permissible under the conventional critical value approach. Several researchers affirm that once DRIS norms based on foliar composition has been developed for a given crop; they are universal.

Disha *et al*. (2012) studied establishment of diagnosis and recommendation integrated system norms for plum cv. Santa Rosa and indicated that most limiting nutrient was boron followed by zinc. The DRIS showed higher diagnostic sensitivity compared to the conventional critical values or optimum ranges.

Goodarzi *et al*. (2012) determine nutritional elements' balance status and its effect on yield and quality of vineyards, using the DRIS. The nutritional survey was carried out in 50 vineyards by collecting leaf plus petiole samples. The established norms were used to calculate DRIS indices and nutritional balance index for those vineyards having low yields and showed that a negative and significant (at 1% probability level) relationship existed between NBI and yield and applicable to that particular crop grown at any place and at any stage of its development.

Xu *et al*. (2015) after applying DRIS norms to apple observed that the leaf concentration in the high yielding subpopulation had relatively symmetrical distribution, so as they provided realistic approximations of the likely range of interactive influences of different nutrients on crop productivity. Additionally, the selected nutrient ratios had relatively large variance ratios (low/ high) and therefore these nutrient ratios got the maximum potential to differentiate between “healthy” and “unhealthy” plants.

2.7.4 Comparison of diagnosis made by DRIS approach with that of sufficiency range approach.

DRIS approach has been successfully employed in interpreting the leaf analysis of various annual, perennial as well as fruit crops. DRIS approach identifies the mineral deficiencies and excesses in plants with a high degree of diagnostic precision as compared to critical values and sufficiency range diagnostic approaches. DRIS diagnostic approach successfully eliminates the effects of tissue age, position, variety, season and rootstock on nutrient uptake and accumulation (Sumner, 1986; Walworth and Sumner, 1987 and Sumner, 1990).

Sumner (1986) evaluated the diagnosis made by different diagnostic approaches in fertilizer experiments with peaches and citrus and observed that DRIS approach diagnosed nutrient insufficiencies in all experiments while as nutrient status was described as optimum by critical value and sufficiency range approaches. Davee *et al.* (1986) compared the relative nutrient deficiencies and excesses in sweet cherry indicated by DRIS approach and sufficiency ranges (Ohio state university and Cornell sufficiency ranges) and observed that DRIS diagnosis produced complete agreement with critical values as far as major relative deficiencies for B, P and K were concerned, Whereas in calcium 90 per cent agreements were achieved. However, in contrast Ohio State University sufficiency ranges and Cornell sufficiency ranges produces only 44, 17, 71 and 100 and 73, 56, 100 and 100 per cent agreements, respectively as for as major relative deficiencies of B, Ca, P and K are concerned. Superiority of DRIS approach over the crirical value and sufficiency range diagnostic approaches in making valid diagnosis for nutrient imbalance in grape vine have also been proved by Schaller (1988). Alkoshab *et al.* (1988) in a similar study with hazelnut obtained 93, 95, 41, 100 and 68 per cent agreement with sufficiency ranges as far as major relative deficiencies of K, P, Ca, Zn and B are concerned, using DRIS approach in comparison to diagnose made by OSU sufficiency ranges, which produces only 93, 18, 0, 100 and 54 per cent agreements for major relative deficiency of K, P Ca, Zn and B respectively.

Parent and Granger (1989) while evaluating the DRIS approach in making diagnosis in apple observed that DRIS diagnose nutrient concentrations independently. Angles *et al.* (1990) and Angles *et al.* (1993) compared DRIS norms for pineapple and banana, respectively with those derived by calculation from the average of published critical values and found that diagnose made by both the approaches are likely to be similar. They further reported that DRIS even diagnose nutrient imbalance in treatments where sufficiency range could not diagnose or diagnosed the nutrient as sufficient. Thus we concluded that DRIS approach has better diagnostic applicability and superior to sufficiency range approach.

Hundal and Arora (1996) reported that sufficiency range value suggested for litchi tree would not have achieved the same success as the DRIS systems. They further suggested that micronutrient status of litchi trees cannot be successfully determined from leaf composition with sufficiency range approach.

Raghupati and Bhargava (1998) while developing DRIS and compositional nutrient diagnosis indices for pomegranate reported that both were highly correlated and produced a similar nutrient value by nutrient diagnosis.

Singh *et al*. (2000) developed DRIS norms for apple in Himachal Pradesh and found that selected DRIS norms when compared with those derived from the average of published critical values or sufficiency ranges, a very close agreement was obtained for N/K, N×Ca, N×Mg, N/Zn, P/N, P/K, P×Ca, P×Mg, P×Mn, P/Zn, K×Ca, K×Mg, K/Zn, Mg/Ca and Mg×Zn norms.

Sharma and Bhargava (2002) while studying DRIS diagnostic approach in peach observed that DRIS approach can diagnose all the orchards for their deficiency and excess whereas sufficiency range approach sometimes cannot diagnose all the orchards. DRIS approach make a diagnose at any stage of crop development. Thus DRIS approach is better than sufficiency approach for making valid diagnosis.

Das (2004) while using DRIS diagnostic approach in apple revealed that DRIS approach could identify major relative deficiencies or excesses in all the orchards in both the years while as sufficiency range approach could diagnose deficiencies or excesses only in 44 and 22 per cent orchards during first and second year respectively. Hundal *et al*. (2005) found that 16, 15, 12, 17, 16, 19, 18, 12, 20 % of total leaf samples were deficient in N, P, K, Ca, Mg, Zn, Cu, Fe, and Mn, respectively.

Mourao (2005) reported that DRIS, when compared with sufficiency range approach complements nutritional diagnosis because it establishes an order of deficiency or excess for each nutrient and detects deficiencies or excesses not considered by Sufficiency Range Approach.

Bangroo *et al.* (2010) and Bhadhuri and Pal (2013) reviewed that DRIS has some advantages over other diagnosis methods viz., presents continuous scale and easy interpretation, allows nutrient classification (from the most deficient up to the most excessive) can detect cases of yield limiting due to nutrient imbalance even when none of the nutrients is below the critical level and finally, allows to diagnose the total plant nutritional balance, through an imbalance index.

Nayak *et al*. (2011) reported that on the basis of the sufficiency ranges 33, 51, 47 and 46 % samples were found sufficient whereas 34, 22, 18, and 27% of samples were low and 26, 8, 1 and 17% deficient in nitrogen, phosphorus, potassium, and zinc respectively.

Chapter-3

Materials and Methods

CHAPTER-3

MATERIALS AND METHODS

The present investigation titled **"Standardization of diagnosis and recommendation of integrated system of mango (*Mangifera indica* L.) cv. Dashehari under Jammu sub tropics"** was carried out during the year 2016-2017 and 2017-2018 by sampling the commercial mango cultivar Dashehari in Akhnoor and Samba regions of Jammu province. The details of material used and methods adopted in the study are presented below.

3.1 Location

The experimental sites were selected at two different regions of Jammu province, i.e., Akhnoor and Samba representing the main mango growing pockets. Jammu and Kashmir is situated between 32^0 15' to 33^0 30' north of equator and 74^0 to 76^0 15' east of prime meridian. It has both plain as well as mountainous regions. Present study was carried out at different sub-tropical mango areas of Jammu province viz., Akhnoor and Samba lying between 33^0 05' 06" to 32^0 30' 987" North of equator and 75^0 02' 861" East of prime meridian. The sub-tropical region falls between 300 to 1000 m above mean sea level with extreme summer having temperature as high as 46^0 C (115^0 F) while, temperatures in the winter month occasionally falls below 4^0 C (39^0 F). Average yearly precipitation is about 42 inches (1,100mm) with the bulk of rainfall in the month from June to September. The Figure (3.1) shows the spatial areas of location of mango orchards. The farmers name, collection site, geographical coordinates and altitude for areas are presented in table 1.

3.2 Technical programme

An extensive survey was concluded in the mango growing areas of Akhnoor and Samba of Jammu region. Fifty mango orchards were selected in these areas of Jammu region. Among these, twenty-eight orchards were selected in Akhnoor and twenty -two were selected in Samba. At each location well established mango orchards were selected.

Table 1. List of the farmers, collection site, geographical coordinates and altitude of mango orchard areas

S.NO	Name of farmer	Residence Constituency	Area	Latitude	Longitude	Altitude
1.	Sh.Mohinder Paul	Rajwal, Akhnoor	1.00 ha	N 32^{0} 84'700"	E 074^{0}50'717"	302 m
2	Sh. Ramesh Singh	Chowki, Akhnoor	1.00 ha	N 32^{0} 89'752"	E074^{0}74 '805"	301 m
3	Sh. Ajay Kumar	Sandal Akhnoor	1.00 ha	N 32^{0} 90 '130"	E 074^{0}74'198"	302 m
4	Sh.Ganga Ram	Sandal, Akhnoor	1.00 ha	N 32^{0} 90 '338"	E 074^{0}74'638"	302 m
5	Sh. Banarasi Lal	Sungal, (Nai Basti) khnoor	12 kanal	N 32^{0} 90 '185"	E 074^{0}74 '338"	337 m
6	Sh. Kuldeep Raj	Nai Basti Akhnoor	10 kanal	N 32^{0} 90 '875"	E 074^{0}70 '225"	335 m
7	Sh. Bodh Raj	Nai Basti Akhnoor	8 kanal	N 32^{0} 90' 325"	E 074^{0}69 '940"	335 m
8	Sh. Rashpal Chand	Nai Basti Akhnoor	8 Kanal	N 32^{0} 90 '347"	E074^{0}69 ' 897"	335m
9	Sh. Mohan Lal	Nai Basti Akhnoor	16 kanal	N 32^{0} 90 '373"	E074^{0} 69 '952"	334 m
10	Sh. Surya Prakash	Nai Basti Akhnoor	8 Kanal	N 32^{0}90 '298"	E 074^{0}69 '974"	336 m
11	Sh. Sham Lal	Nai Basti Akhnoor	8 Kanal	N 32^{0} 90 '225"	E 074^{0}70 '199"	336 m
12	Sh. Diwan Chand	Nai Basti Akhnoor	8 Kanal	N 32^{0} 90 '092"	E 074^{0}69 '965"	336 m
13	Sh. Sikander Kumar	Nai Basti Akhnoor	20 Kanal	N 32^{0} 90 '743"	E 074^{0}69 '656"	336 m
14	Sh. Jai Paul	Nai Basti Akhnoor	8 Kanal	N32^{0} 90 '274"	E 074^{0}69 '877"	335 m
15	Sh. Prabh Dayal	Nai Basti Akhnoor	1.50 ha	N32^{0} 87 '045"	E 074^{0}74 '776"	335 m
16	Sh. Ranjha Ram	Rakh Pangari Akhnoor	0.50 ha	N32^{0}88' 346"	E 074^{0}73' 760"	333 m
17	Sh. Prakash Chand	Rakh Pangari Akhnoor	0.50 ha	N32^{0}87' 452"	E 074^{0}74 '776"	332 m
18	Sh. Kaka Ram	Kangrail Sungal, Akhnoor	2.00 ha	N32^{0}89' 189"	E 074^{0}75 '423"	331m
19	Sh. Asha Nand	Jakhari Akhnoor	1.00	N32^{0}89' 695"	E 074^{0}73 '548"	401 m

20	Sh. Rashpal Chand	Nai Basti Akhnoor	8 Kanal	N32^{0}90' 347"	E 074^{0}69' 897"	335 m
21	Sh. Raghunath	Gurha Brahmna, Akhnoor	40 Kanal	N 32^{0}88'400"	E 074^{0}74' 291"	302 m
22	Sh. Rampaul	Palwan Akhnoor	8 Kanal	N 32^{0}88' 290"	E 074^{0}67' 622"	331 m
23	Sh. Pritam Lal	Panjgrain, Akhnoor	1.00 ha	N 32^{0}88' 067"	E 074^{0}73' 446"	337 m
24	Sh. Kaka Ram	Kangrail Sungal Akhnoor	2.00 ha	N 32^{0}89' 189"	E 074^{0}75' 423"	331 m
25	Sh. Guddi Ram	Sungal Akhnoor	10 Kanal	N 32^{0} 89' 463"	E 074^{0}70' 295"	337 m
26	Sh. Chaman Lal	Sandal Akhnoor	1.00 ha	N 32^{0}89' 882"	E 074^{0}73' 833"	302 m
27	Sh. Bara Singh	Barda Akhnoor	1.00 ha	N 32^{0}87' 536"	E 074^{0}73' 457"	402 m
28	Sh.Tirath Singh	Seuni	1.00 ha	N 32^{0}51' 584"	E 074^{0}29' 872"	402 m
29	Sh. Madan Lal	Patti Raya	1.00 ha	N 32^{0} 61' 746"	E 078^{0}64' 774"	324 m
30	Sh. Sat Paul	Patti Raya	1.00 ha	N 32^{0} 62' 637"	E 078^{0}64' 582"	324 m
31	Sh. Vinod Kumar	Patti Raya	3.00 ha	N 32^{0} 61' 477"	E 074^{0} 97' 241"	324 m
32	Sh. Sat Paul	Patti Raya	1.25 ha	N 32^{0} 62' 439"	E 074^{0}97' 359"	325 m
33	Sh. Deepak	Patti Raya	2.00 ha	N 32^{0} 64' 602"	E 074^{0}90.179	323 m
34	Dr. Vijay Gupta	Patti Raya	1.00 ha	N 32^{0} 64'736"	E 078^{0}64.577	324 m
35	Sh. Rajinder Sharma	Patti Raya	1.00 ha	N 32^{0} 65' 673"	E 078^{0}64' 437"	322 m
36	Sh. Rajinder Sharma	Patti Raya	1.50 ha	N 32^{0} 65' 983"	E 078^{0}64' 577"	324 m
37	Sh. Vinod Kumar	Patti Raya	3.00 ha	N 32^{0}61' 477"	E 074^{0}97' 241"	324 m
38	Sh. Gautam Singh	Datta Talab	3.00 ha	N 32^{0}68' 280"	E 074^{0}99' 829"	335 m
39	Sh. Kuldeep Singh	Anandpur, Khara Madana	1.00 ha	N 32^{0}635' 35"	E 074^{0}96' 757"	311 m
40	Sh. Babu Sat Paul	Patti	1.00 ha	N 32^{0}66' 476"	E 074^{0}98' 754"	300 m
41	Sh. Chaman Lal	Datta Talab Anandpur	3.00 ha	N 32^{0} 68' 329"	E 075^{0} 00' 076"	335 m
42	Sh. Chamail Singh	Meen Anandpur	1.20 ha	N 32^{0} 63' 923"	E 074^{0} 95' 324"	335 m

43	Sh. Bodh Raj	Bagune Katwalta	1.00 ha	N 32^0 66' 637"	E 074^0 98' 852"	308 m
44	Sh. Mohd Sadiq	Bagune Katwalta	1.0 ha	N 32^0 66' 756"	E 074^0 98' 735"	308m
45	Sh. Krishan Singh	Kamila Anandpur	1.00 ha	N 32^0 62' 473"	E075^0 01' 915"	335 m
46	Sh. Subash Chander	Smailpur Khara Madana	8.00 Kanal	N 32^0 61' 800"	E 074^0 99' 485"	314 m
47	Sh. Charan Dass	Sadral, Khara Madana	1.00 ha	N 32^0 60' 858"	E 075^0 00' 929"	313 m
48	Sh. Nand Lal	Anandpur, Khara Madana	1.00 ha	N 32^0 67' 461"	E 074^0 94'624"	311 m
49	Sh. Ram Lal	Sangar Purmandal	1.00 ha	N 32^0 68'641"	E 075^0 00' 785"	333 m
50	Sh. Ashutosh Maharaj	Tarore, Rajinder pura	1.00 ha	N 32^0 67' 966"	E 074^0 94' 743"	327 m

Fig.1. Locality map of Jammu region showing sampling locations.

3.3 Selection of orchards

Based on uniformity in respect of age and tree vigor, 50 representative orchards from Akhnoor and Samba district of Jammu division were selected (Fig.1) "Dashehari" variety of mango was selected for study as most of the well established orchards in these areas are under this variety.

3.3.1 Collection and preparation of samples

3.3.1.1 Soil sampling

The samples were collected from the basin of the tree at three different depths i.e. 0-30 cm, 30-60cm and 60-90 cm, with the help of manually drawn soil auger. The samples were air dried in shade and ground with the help of mortar and pestle then passed through a 2mm sieve. Stored in well labeled air tight amber coloured glass bottles. These grounded soil samples were analyzed for various physico-chemical characteristics of soil.

3.3.1.2 Soil Analysis

3.3.1.2.1 Soil pH and electrical conductivity

These were determined in 1:2.5 soil- water suspensions as per procedure suggested by Jackson (1973).

3.3.1.2.2 Organic Carbon

Organic carbon was estimated by wet digestion method (Walkley and Black, 1934).

3.3.1.2.2 Estimation of available macronutrient elements

The available soil nutrients were determined by the following methods:

3.3.1.2.2.1 Available Nitrogen

Available nitrogen content was determined using alkali potassium permanganate as described by Subbiah and Asija (1956).

3.3.1.2.2.2 Available Phosphorus

Soil available phosphorus was determined by Olsen's method (Olsen *et al*. 1954).The intensity of blue colour was determined by using UV-visible spectrometer as 660 nm wavelength.

3.3.1 2.2.3 Available Potassium

Available potassium was extracted with 1N neutral Ammonium Acetate and analyzed using flame photometer (Jackson, 1973).

3.3.1.2.2.4 Available calcium and magnesium

Exchangeable calcium and magnesium in the soil were determined by extracting a known weight of the soil with neutral normal ammonium acetate (Piper, 1966). They were analyzed following versenate titration method.

3.3.1.2.2.5 Available sulphur

Available sulphur content in soil samples was extracted by 0.15 % $CaCl_2$ $2H_2O$ and determined by the turbid method as described by Vogel (1978).

3.3.1.2.3 DTPA – Extractable Micronutrient

Available micronutrients (DTPA extractable) Zn, Cu, Fe and Mn were analyzed in soil samples by extracting with 1:2 soil to DTPA extractant ratio (Lindsay and Norvell, 1978).

3.3.1.2 Leaf Sampling

Representative leaf samples comprising of 25-30 leaves (latest mature flush from middle of the terminal growth) were collected from 8-10 randomly selected trees in each selected orchard as per the sampling time i.e.15 June- 15 July. The leaf samples were washed with ordinary water and then with 0.1N hydrochloric acid (HCl), followed by washing with distilled water. The washed leaf samples were surface dried and then oven dried at ± 65^0 for 48 hours till constant weight obtained. Further the dried leaf samples were grounded using Wiley grinding machine to pass through a 60 mesh stainless steel sieve to obtain homogenous samples. The samples were stored in labeled air tight amber coloured glass bottles till further estimation.

3.3.1.3 Leaf analysis

3.3.1.3.1 Estimation of available nutrient elements

3.3.1.3.1.1 Nitrogen

Nitrogen was estimated by hydrogen peroxide method. The previously grounded leaf sample (0.2g) was digested with 10 ml of concentrated sulphuric acid and the organic matter was oxidized by adding 30 per cent hydrogen peroxide drop by drop. This digested material was distilled by Kjeldhal method with 10 ml of 40 per cent sodium hydroxide. The ammonia thus released was collected in 4 per cent boric

Plate.1. Collection of soil samples

Plate 2. Collection of leaf samples

Plate 3. Mango fruit samples of Akhnoor region

Plate 4. Mango fruit samples of Samba region

Plate 5. High yielding orchard of mango fruit of Akhnoor region

Plate 6. High yielding orchard of mango fruits of Samba region.

Plate 7. Low yielding mango orchard in Akhnoor region.

Plate 8. Low yielding mango orchard in Samba region

acid mixed with bromocresol green and methyl red mixed indicator. This was titrated against 0.1 N sulphuric acid to a pink end point and the nitrogen content of the sample was calculated.

3.3.1.3.1.2 Other nutrients

Wet digestion of leaf

One gram of previously grounded dried leaf sample (0.2g) was taken in a 150 ml conical flask, to which 15 ml of diacid mixture of nitric acid and perchloric acid (7:3) was added and allowed for 1 hour digestion at $60^{0}C$ on a sand bath. The extract was made upto 100 ml with double distilled water and filtered through Whatman No. 40 filter paper (Jackson, 1973). A blank was also kept. The diacid extract was used for the estimation of P, K, S, Ca, Mg, Zn, Fe, Cu, and Mn in the leaf samples adopting the standard procedures as mentioned below.

(i) Phosphorus

Phosphorous content was determined by Vando-molybdophosphoric acid yellow colour method (Jackson, 1973). The colour intensity was measured at 420 nm in a spectrophotometer.

(ii) Potassium

The concentration of potassium in the leaf samples was estimated in the diacid extract by Flame Photometer method (Systronics, Model -121) as described by Piper (1944).

(iii) Calcium

Calcium in the diacid extract was estimated with Versenate titration.

(iv) Magnesium

The exchangeable magnesium in the diacid extract was estimated with Atomic Absorption Spectrophotometer (Varian, Model: AA 20).

(v) Sulphur

The sulphur content in leaf sample was determined in the diacid extract turbidimetrically using spectrophotometer (Spectronic, Model-20) at 340 nm wave length as described by Cottenie *et al.* (1979).

(vi) Micronutrients

The contents of Cu, Mn, Fe and Zn were estimated in the diacid extract by Atomic Absorption Spectrophotometer method.

3.4 Yield per tree

The total number of fruit harvested per tree and average fruit weight were taken into consideration to work out the yield per tree in kilograms.

3.5 Fruit characteristics

3.5.1 Physical characteristics

3.5.1.1 Fruit weight

The weight of ten randomly selected fruits was taken by electronic balance. Subsequently, the average fruit weight was calculated and expressed in gram (g).

3.5.1.2 Fruit length

Length of ten randomly harvested fruits was measured by using digital vernier caliper. mean length was computed and expressed in centimeter (cm).

3.5.1.3 Fruit diameter

A random sample of ten healthy fruits was selected and fruit breadth was recorded for individual fruits using digital vernier caliper. Mean value was expressed in centimeters (cm).

3.5.1.4 Fruit volume

Fruit volume was determined by water displacement method using a measuring cylinder of 1000 ml capacity and result was expressed in terms of cubic centimeters (cc).

3.5.1.5 Specific gravity

Specific gravity was calculated by the following formula:

$$\text{Specific gravity} = \frac{\text{Weight of the fruit}}{\text{Volume of water displaced by the fruit}}$$

3.5.1.6 Pulp weight

At proper maturity, pulp of ten selected fruits was separated from the stone by using sharp stainless steel knife. Pulp and stone weights were measured separately on digital electronic balance. The mean weight of pulp and stone of each treatment was expressed in gram (g).

3.5.1.7 Dry weight of pulp

The same samples of fresh weight of pulp were kept in an oven to dry at a temperature of ± 60^0C for 48 hours. The dry weight of pulp was recorded separately with the help of an electronic balance .The mean dry weight was expressed in gram (g).

3.5.1.8 Stone weight

The stones of ripe mango fruits were separated from the pulp and their weight was recorded in grams.

3.5.1.9 Pulp: stone weight

A random sample of ten healthy fruits was taken**.** The fruit flesh was separated from the stone and the ratio between weights of pulp and stone was worked out for all the treatments.

3.5.2 Chemical characteristics

3.5.2.1 Total soluble solids (TSS)

The total soluble solids (TSS) of the fruit pulp were recorded at edible ripe stage with the help of Erma hand refractometer (0-32^0B) according to standard procedure as given in A.O.A.C. (1995) in terms of degree Brix (B^0) at room temperature. A temperature correction was applied when the readings were taken at a temperature other than 20^0C .The refractometer was calibrated with distilled water before use.

3.5.2.2 Titrable acidity

Titrable acidity in fresh fruits was determined by the method as suggested in A.O.A.C. (1995). Twenty five gram of fruit pulp was taken in blender, homogenized in distilled water and the volume was made 250 ml and then, filtered through Whatman no.1 filter paper. Twenty- five ml of filtered solution was titrated against

0.1 N NaOH solution using phenolphthalein as in indicator. The total per cent titrable acidity was calculated on the basis of one ml NaOH equivalent to 0.0064 g of anhydrous citric acid. The results were expressed as per cent total titrable acidity.

3.5.2.3. TSS: acidity

TSS acidity ratio was estimated by dividing the value of TSS with titrable acidity.

3.5.2.4 Ascorbic acid

The ascorbic acid was estimated by the method of A.O.A.C. (1994).

Procedure

Ascorbic acid was extracted from the pulp by macerating 10 g of sample with metaphosphoric acid (3%). The extract was filtered and volume made to 100ml. 10 ml of the aliquot was tiltered against standardized dye (2, 6 dichlorophenolindophenol) till the light pink colour appeared at the end point. Results were expressed as mg/100 g of fruit weight.

Calculation

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{dye equivalent} \times \text{dilution}}{\text{Weight of sample (g)}} \times 100$$

3.5.2.5 Sugars

3.5.2.5.1 Total sugars

Twenty five grams of fruit pulp was thoroughly homogenized with distilled water. To this, 2 ml of saturated lead acetate solution was added and the precipitate was filterate into flask containing 5ml of potassium oxalate solution. The filtrate was shaken and refiltered. 100ml of this deleaded and clarified solution was hydrolyzed by adding 5ml concentrated HCl and was kept overnight. The excess of HCl was neutralized with concentrated sodium hydroxide solution. Total sugars was estimated by titrating boiling mixture of 5ml each of Fehling A and Fehling B solution against a hydrolyzed aliquot, using ethylene blue as an indicator. The end point was marked by the appearance of brick red colour. Total volume of aliquot used was recorded and total sugars were calculated by the procedure described in A.O.A.C. (1995).

$$\text{Total sugars (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Aliquot used} \times \text{Sample weight}} \times 100$$

3.5.2.5.2 Reducing sugar

The juice of well riped fruits was taken for the estimation of reducing sugar. 10 ml of juice was blended with distilled water and neutralized with 1 N NaOH. After adding lead acetate for clarification, potassium oxalate was added to remove excess of lead and volume was made up to 250 ml with distilled water and filtered. 10 ml of this filtrate was further diluted to 100 ml and used for the analysis. The reducing sugars were expressed as percent (%).

3.5.2.5.3 Non-reducing sugar

The non- reducing sugars were obtained by subtracting reducing sugars from total sugars and multiplying the difference by standard factor 0.95, the calculation was done as per the procedure described in A.O.A.C. (1995).

3.6 Derivation of DRIS norms

DRIS represents a holistic approach to the mineral nutrition of the crops and it is an integrated set of norms representing calibration of plant nutrient composition, soil composition, and environmental parameters and farming practices as a function of yield of a particular crop. The premise that the concentration of nutrients changes with the age of the crop or as the concentration of other nutrients increases or decreases, where as their ratio or product remain fairly constant over a period of time is the under lying principle of DRIS. The general procedure involves dividing the entire population into low and high yielding sub populations. Mean Variance and Coefficient of Variation for all the nutrient ratios and products are calculated separately for low and high yielding sub populations. Then, the variance ratios (variance of low yielding population/variance of high yielding population) are calculated for each form of expression (e.g., N/P, P/N and PXN). For each pair of nutrients, the expression with highest variance ratio and the corresponding mean for high yielding population are selected as DRIS norms (Awasthi *et al*. 2000). DRIS norms have been proposed by various scientists from time to time (Beaufils, 1973, Sumner, 1986 and Walworth and Sumner, 1987). For the present study, DRIS norms were derived by using the procedure developed by Walworth and Sumner (1987). DRIS norms were derived from a database of 2000 observations of leaf nutrient compositions and yield gathered during 2017 and 2018 from major mango growing areas of Jammu region. High yielding population was separated from the low yielding population using a fruit yield level of 50 kg/tree as the cut-off between low and high yielding sub-population. The observation units were arranged in an ascending order of yield. Units bearing yield level of 50 kg/tree or above were separated and formed high yielding population. The observations below 50 kg/tree were treated as low yielding population. For the two sub-population, the means, standard deviations, variances and coefficient of variation (CV) were calculated for each nutrient element concentration as well as for ratios, their reciprocals and their products (e.g., N/P, P/N, and N×P) of all the 55 nutrient pairs. Variance ratio was worked out for all forms of nutrient expression involving each pair of nutrients. Variance ratio was calculated by dividing the variance of low yielding sub-population with that of high yielding sub-population. The expression having the highest and significant variance ratio, for each pair of nutrient was selected as DRIS norm expression with corresponding mean value in the high yielding sub-population, considered as norm value for the selected expression.

3.6.1 Calculation of DRIS indices

To calculate the DRIS indices, the value of mean and coefficient of variance in the high yielding sub-population for the selected nutrient expression were used. DRIS indices were calculated using the method described by Walworth and Sumner (1987).

The following equations were developed for the calculation of DRIS indices based on leaf analysis:

$$\text{N Index} = \frac{f(N/P)+f(NxK)+f(N/S)-f(Ca/N)+f(N\times Mg)-f(Zn/N)+f(N/Fe)-f(Cu/N)+f(N/Mn)}{9}$$

$$\text{P Index} = \frac{(N/P)+f(P\times K)+f(P/S)-f(Ca/P)-f(Mg/P)-f(Zn/P)+f(P/Fe)-(Cu/P)-f(P\times Mn)}{9}$$

$$\text{K Index} = \frac{-f(NxK)-f(P\times K)+f(K/S)-f(Ca/K)+f(k\times Mg)-f(Zn/K)+f(K/Fe)-f(Cu/K)+f(k\times Mn)}{9}$$

$$\text{S Index} = \frac{- f(N/S)-f(P/S)-f(K/S)-f(Ca/s)-f(Mg/S)-f(Zn/S)-f(Fe/S)-f(Cu/S)-f(Mn/S)}{9}$$

$$\text{Ca Index} = \frac{f(Ca/N)+f(Ca/P)+f(Ca/K)+f(Ca/S)+f(Ca/Mg)+f(Ca/Zn)+f(Ca/Fe)+f(Ca/Cu)+Ca/Mn}{9}$$

$$\text{Mg Index} = \frac{f(N\times Mg)+f(Mg/P)-f(K\times Mg)+f(Mg/S)-f(Ca/Mg)-f(Zn/Mg)+f(Mg/Fe)f(Cu/Mg)+f(Mg/Mn)}{9}$$

$$\text{Zn Index} = \frac{f(Zn/N)+f(Zn/P)+f(Zn/K)+f(Zn/S)-f(Ca/Zn)+f(Zn/Mg)+f(Zn/Fe)-f(Cu/Zn)+f(Zn/Mn)}{9}$$

$$\text{Fe Index} = \frac{- f(N/Fe)-f(P/Fe)-f(K/Fe)+f(Fe/S)-f(Ca/Fe)-f(Mg/Fe)-f(Zn/Fe)-f(Cu/Fe)-f(Mn/Fe)}{9}$$

$$\text{Cu Index} = \frac{-f(Cu/N)+f(Cu/P)+f(Cu/K)+f(Cu/S)-f(Ca/Cu)+f(Cu/Mg)+f(Cu/Zn)_{+}f(Cu/Fe)-f(Cu/Mn)}{9}$$

$$\text{Mn Index} = \frac{f(N/Mn)-f(P\times Mn)-f(K\times Mn)+f(Mn/S)-f(Ca/Mn)-f(Mg/Mn)-f(Zn/Mn)+f(Mn/Fe)-f(Cu/Mn)}{9}$$

$P/N > p/n$, then $f(P/N) = [\{(P/N) / (p/n)\}-1] \times (1000/CV)$

or, when

$P/N < p/n$, then $f(P/N) = [1-\{(p/n)/(P/N)\}] \times (1000/CV)$

In these, P/N is the value of the ratio of the two elements in the tissue of the plant being diagnosed (test data), p/n is the optimum value (mean of high yielders) of norm for that ratio, CV is the coefficient of variation associated with the norm and z is the number of functions comprising the nutrient index. The procedure adopted for calculating the values of other functions such as f(N/K), f(P/K) etc., was same as adopted for calculation of f(P/N), using appropriate norms and CV.

3.6.2 Interpretation of nutrient indices

As the value of each function ratio is added to one index subtotal and subtracted from another, prior to averaging, all indices are balanced around zero and therefore, nutrient indices should sum to zero. As the index is more negative, the more lacking is the nutrient relative to other nutrients used in diagnosis. Alternatively, a large positive nutrient index indicates that, the corresponding nutrient is present in relatively excessive quantity. The nutrient indices were interperated accordingly with the developed DRIS norms (Walworth and Sumner, 1987).

3.6.3 Nutrient Imbalance Index

The Nutrient Imbalance Index (NII) was obtained by summing the DRIS indices for each nutrient, irrespective of sign.

3.6.4 Development of Leaf Nutrient Standards

Leaf nutrient standards for mango were derived based on five leaf nutrient guides or ranges derived using mean and standard deviation (SD) as deficient, low, optimum, high, and excess for each nutrient . The optimum nutrient range is the value derived from “mean – 4/3 SD” to “mean + 4/3 SD”. The range ‘Low was obtained by calculating “mean -4/3 SD” to mean -8/3 SD” and the value below “mean -8/3 SD” was considered as ‘deficient’. The value from “mean +4/3SD” to mean +8/3 SD” was taken as high and the value above “mean +8/3SD” was taken as excessive (Bhargava and Chadha, 1993).

3.7 Statistical analysis

Coefficient of variation, variance and variance ratio were statistically analyzed following the formulae given by Panse and Sukhatame (2000). Simple correlations were calculated using SPSS software.

Chapter-4

Results

CHAPTER-4

EXPERIMENTAL RESULTS

The results obtained in the present investigation entitled, **"Standardization of Diagnosis and Recommendation Integrated System of mango (*Mangifera indica* L.) cv. Dashehari under Jammu sub tropics"** are described under suitable heads and sub-heads.

4.1 Soil reaction, electrical conductivity and organic carbon

The data pertaining to soil reaction, electrical conductivity and organic carbon status in soil samples of different mango orchard at different locations is given in table 2.

4.1.1 Soil pH

A perusal of the data presented in Table 2 reveals the soil pH of the surface layer mango fruit crop orchards of the study area. From the data presented in the Table, it was observed that the overall soil pH in the surface layer (0-30 cm) ranged from 6.24 to 7.80 with the mean value of 6.97. At 30-60 cm soil depth, soil pH ranged between 6.30 and 7.82 with mean value of 7.02, whereas, it ranged from 6.33 to 7.83 with mean value of 7.05 at 60-90 cm soil depth. The means of soil pH at 0-30, 30-60, 60-90 cm soil depth were 6.99, 7.01 and 7.02, respectively, in orchards of Akhnoor, whereas, it was 6.96, 7.02 and 7.09, respectively in orchards of Samba.

4.1.2 Electrical conductivity (dS m^{-1})

The data presented in the Table 2, reveals that the overall electrical conductivity ranged from 0.05 to 0.27 dS m^{-1} with mean value 0.15 dS m^{-1} at soil depth 0-30 cm. At soil depth 30-60 cm electrical conductivity ranged from 0.04 to 0.25 dS m^{-1} with mean value of 0.13 dS m^{-1}, whereas, it ranged from 0.03 to 0.24 dS m^{-1} with mean value of 0.12 dS m^{-1}. At Akhnoor location the mean values of electrical conductivity from the soil depth 0-30, 30-60 and 60-90 cm i.e. 0.16, 0.15 and 0.14 dS m^{-1} respectively, whereas, at Samba location the mean values of electrical conductivity of 0.12 dS m^{-1}, 0.10 dS m^{-1} and 0.09 dS m^{-1} respectively.

4.1.3 Organic carbon

From the data presented in Table 2, it was observed that the overall range of organic carbon varied from 0.21 to 2.30 per cent with mean value 0.99 per cent from soil depth 0-30 cm and 0.18 to 2.25 per cent with mean value of 0.93 per cent from 30-60 cm soil depth, whereas, it ranged from 0.15 to 0.28 per cent with mean value 0.89 per cent from 60-90 cm soil depth. The mean of organic carbon content was 1.28, 1.24 and 1.20 per cent at 0-30 cm, 30-60 cm and 60-90 cm depths at Akhnoor, while at Samba the means of organic carbon content were 0.62, 0.59 and 0.54 per cent, respectively.

4.2 Soil nutrient status

Soil samples drawn from three depths of 0 to 30 cm, 30 to 60 cm and 60 to 90 cm from the basins of mango cultivar Dashehari trees of different orchards were characterized for available nitrogen (kg ha^{-1}), available phosphorous (kg ha^{-1}), available potassium (kg ha^{-1}), available calcium (kg ha^{-1}), available magnesium (kg ha^{-1}), available sulphur (kg ha^{-1}), available copper (ppm), available manganese (ppm), available iron (ppm) and available zinc (ppm).

4.2.1 Available Nitrogen (kg/ha)

The overall available nitrogen in mango orchard soil ranged from 107.10 to 298.26 kg/ha at 0-30 cm depth, from 75.60 to 282.63 kg/ha at 30-60 cm depth and from 57.80 to 280.15 kg/ha at 60-90 cm with mean value of 251.90 kg/ha, 230.38 kg/ha, 204.65 kg/ha, in 0-30 cm, 30-60 cm and 60-90 cm soil depth, respectively. The nitrogen content was higher in the surface soils which decreased linearly with the increase in soil depth. Among two different mango growing areas, the orchards of Akhnoor area had higher available nitrogen content (300.04 kg/ ha) as compared (190.59 kg/ha) in orchards of Samba respectively.

4.2.2 Available Phosphorus (kg/ha)

Data pertaining to available phosphorus content in mango orchards are presented in Table 3. The available phosphorus content in the surface layer soil 0-30 cm ranged from 7.60-22.90 kg/ha with mean value of 18.15 kg/ha. At 30-60 cm and 60-90 cm soil depth the available phosphorus content ranged from 6.90-20.00 kg/ha and 6.20 and 18.42 kg/ha respectively with mean value of 16.00 kg/ha and 14.13 kg/ha, respectively. Among the two locations, at Akhnoor the mean of available phosphorus were 21.03, 18.43 and 16.40 kg/ha at 0-30, 30-60 and 60-90 cm depth, respectively. Whereas in orchards of Samba the available phosphorus was 14.48, 12.90 and 11.24 kg/ha at respective soil depths.

Table 2. Soil reaction, electrical conductivity and organic carbon of mango orchard soils of Jammu region

Location	Orchard Number	Soil pH			Electrical Conductivity (dS m^{-1})			Organic Carbon (%)		
		Soil depth (cm)								
Akhnoor		**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**
	1	6.48	6.5	6.52	0.19	0.17	0.16	0.36	0.32	0.33
	2	6.43	6.45	6.50	0.07	0.06	0.04	0.45	0.39	0.30
	3	7.05	7.10	7.12	0.09	0.07	0.06	0.42	0.36	0.36
	4	6.50	6.52	6.55	0.11	0.10	0.09	0.65	0.62	0.60
	5	7.10	7.12	7.14	0.12	0.10	0.09	0.69	0.65	0.59
	6	6.85	6.87	6.89	0.09	0.08	0.07	0.70	0.68	0.65
	7	7.19	7.20	7.22	0.15	0.14	0.13	0.75	0.72	0.70
	8	7.15	7.17	7.19	0.21	0.20	0.19	0.44	0.40	0.36
	9	7.11	7.14	7.16	0.22	0.20	0.19	0.80	0.75	0.72
	10	6.70	6.71	6.72	0.26	0.25	0.24	0.85	0.82	0.80
	11	7.09	7.11	7.12	0.14	0.13	0.12	0.72	0.69	0.66
	12	7.26	7.28	7.30	0.08	0.07	0.06	0.90	0.87	0.84
	13	7.28	7.30	7.31	0.11	0.10	0.09	0.78	0.75	0.70
	14	6.75	6.78	6.80	0.22	0.20	0.19	1.10	0.99	0.97
	15	6.80	6.81	6.82	0.10	0.09	0.08	1.20	1.15	1.11
	16	6.75	6.78	6.79	0.25	0.24	0.23	1.30	1.25	1.20

	17	7.30	7.31	7.32	0.25	0.24	0.23	1.15	1.11	1.09
	18	6.42	6.44	6.45	0.16	0.15	0.13	1.25	1.10	1.89
	19	7.11	7.13	7.14	0.20	0.19	0.18	1.50	1.48	1.45
	20	7.59	7.60	7.61	0.15	0.13	0.11	1.85	1.80	1.79
	21	6.65	6.67	6.69	0.11	0.09	0.08	1.82	1.79	1.70
	22	6.76	6.80	6.81	0.26	0.24	0.23	2.20	2.15	2.10
	23	7.35	7.37	7.38	0.24	0.22	0.21	2.30	2.25	2.28
	24	6.65	6.67	6.68	0.18	0.16	0.14	1.9	1.86	1.84
	25	6.53	6.55	6.56	0.08	0.07	0.06	1.97	1.85	1.80
	26	6.94	6.97	6.98	0.15	0.13	0.11	1.78	1.75	1.70
	27	7.53	7.54	7.55	0.19	0.18	0.16	1.60	1.58	1.55
	28	7.80	7.82	7.83	0.23	0.21	0.20	1.79	1.75	1.70
	Mean	**6.99**	**7.01**	**7.02**	**0.16**	**0.15**	**0.14**	**1.28**	**1.24**	**1.20**
Samba	1	6.24	6.79	7.08	0.08	0.07	0.04	0.35	0.35	0.24
	2	6.78	6.85	7.22	0.07	0.05	0.04	0.24	0.20	0.22
	3	7.21	7.25	7.30	0.05	0.04	0.03	0.33	0.47	0.23
	4	7.14	7.16	7.20	0.12	0.07	0.05	0.38	0.35	0.21
	5	6.85	6.90	7.00	0.08	0.05	0.04	0.48	0.42	0.30
	6	7.20	7.25	7.28	0.09	0.06	0.04	0.26	0.28	0.20
	7	6.52	6.57	6.59	0.05	0.04	0.03	0.37	0.30	0.48
	8	6.85	7.02	7.08	0.08	0.06	0.05	0.42	0.40	0.35
	9	6.25	6.30	6.33	0.10	0.08	0.07	0.36	0.32	0.33
	10	6.30	6.38	6.42	0.11	0.09	0.06	0.37	0.30	0.27
	11	6.85	6.87	7.00	0.12	0.10	0.09	0.35	0.25	0.25

12	7.09	7.12	7.18	0.14	0.12	0.10	0.21	0.18	0.15
13	7.42	7.46	7.48	0.11	0.09	0.08	0.29	0.30	0.24
14	7.16	7.19	7.21	0.07	0.06	0.05	0.33	0.28	0.25
15	7.19	7.21	7.22	0.06	0.05	0.03	0.35	0.35	0.24
16	7.22	7.24	7.25	0.17	0.15	0.13	0.33	0.28	0.25
17	7.36	7.38	7.39	0.21	0.19	0.17	0.29	0.34	0.30
18	6.65	6.68	6.69	0.20	0.19	0.18	1.35	1.30	1.28
19	7.35	7.37	7.39	0.19	0.18	0.17	1.35	1.30	1.25
20	7.09	7.11	7.12	0.15	0.13	0.12	1.50	1.45	1.40
21	7.20	7.22	7.23	0.18	0.17	0.15	1.90	1.86	1.84
22	7.18	7.19	7.20	0.27	0.25	0.24	1.75	1.70	1.60
Mean	**6.96**	**7.02**	**7.09**	**0.12**	**0.10**	**0.09**	**0.62**	**0.59**	**0.54**
Overall Mean	**6.97**	**7.02**	**7.05**	**0.15**	**0.13**	**0.12**	**0.99**	**0.93**	**0.89**
Range	**6.24-7.80**	**6.30-7.82**	**6.33-7.83**	**0.05-0.27**	**0.04-0.25**	**0.03-0.24**	**0.21-2.30**	**0.18-2.25**	**0.15-0.28**

4.2.3 Available Potassium (kg/ha)

From the data presented in Table 3, it is observed that the soil available potassium varied from 95.19 kg/ha to 224.43 kg/ha with mean value of 156.23 kg/ha at surface layer 0-30 cm and at 30-60 and 60-90 cm soil depths it varied from 90.00 kg/ha to 217.19 kg/ha and 79.34 kg/ha to 210.00 kg/ha with mean value of 144.59 kg/ha and 133.71 kg/ha, respectively. At Akhnoor the mean values of available soil potassium was 157.75, 149.14 and 139.12 kg/ha, whereas, at Samba the mean of available soil potassium was 154.30, 138.80 and 126.83 kg/ha, at respective soil depths.

4.2.4 Available Sulphur (kg/ha)

From the data presented in the Table 4, it is evident that the available sulphur from the soil depth 0-30 cm varied from 12.60 kg/ha to19.74 kg/ha with mean value of 16.10 kg/ha and at soil depth 30-60 cm and 60-90 cm the values varied from 10.40 kg/ha to 17.90 kg/ha and 9.80 kg/ha to 16.95 kg/ha with mean values 14.95 kg/ha and 13.97 kg/ha, respectively. The mean available sulphur content of soil in orchards of Akhnoor was 16.26, 15.35 and 14.43 kg/ha at 0-30, 30-60 and 60-90 cm soil depths respectively. Whereas, the mean available sulphur in orchards of Samba was 15.89, 14.45 and 13.38 kg/ha at 0-30, 30-60 and 60-90 cm soil depths, respectively.

4.2.5 Available Calcium (cmol (p^+) kg^{-1})

The data depicted in Table 4, reveals that the available calcium in the soil depth 0-30 cm varied from 4.02 to 6.35 cmol (p^+) kg^{-1} with a mean value of 5.66 cmol (p^+) kg^{-1}. Whereas, at 30-60 and 60-90cm soil depths it varied from 4.00 to 6.32 cmol (p^+) kg^{-1} and 4.00 to 6.29 cmol (p^+) kg^{-1} with mean values of 5.63 cmol (p^+) kg^{-1} and 5.60 cmol (p^+) kg^{-1}, respectively. The mean value of available calcium from the soil depths 0-30, 30-60 and 60-90 cm were 5.95, 5.93 and 5.90 recorded from Akhnoor and from Samba were 5.28, 5.25 and 5.22 cmol (p^+) kg^{-1}, respectively.

4.2.6 Available Magnesium (cmol (p^+) kg^{-1})

It is evident from the data presented in the Table 4, that the available magnesium at soil depth 0-30 cm it varied from 2.18-3.32 cmol (p^+) kg^{-1} with mean value of 2.83 cmol (p^+) kg^{-1}. At 30-60 cm and 60-90cm soil depths, value varied from 2.16 to 3.18 cmol (p^+) kg^{-1} and 2.14 to 3.28 cmol (p^+) kg^{-1} with the mean values of 2.81 and 2.76 cmol (p^+) kg^{-1}. The mean available magnesium in orchards at

Akhnoor was 3.03, 3.00 and 2.94 cmol (p^+) kg^{-1}. Whereas, in orchards at Samba, the mean values were 2.58, 2.56 and 2.54 cmol (p^+) kg^{-1} at 0-30, 30-60 and 60-90 cm, respectively.

4.2.7 Available Zinc (ppm)

The perusal of data presented in table 5, shows that the available zinc in the surface soil 0-30 cm it varied from 0.52 to 0.99 ppm with a mean value of 0.76 ppm, whereas, at 30-60 cm and 60-90 cm soil depths, it varied from 0.50 to 0.97 ppm and 0.48 to 0.95 ppm with mean values of 0.74 and 0.72 ppm, respectively. The mean values of available zinc in orchards at Akhnoor at different soil depths of 0-30, 30-60 and 60-90 cm was 0.76, 0.74 and 0.72 ppm, while, at Samba the values were 0.67, 0.64 and 0.62 ppm, respectively.

4.2.8 Available Iron (ppm)

From the data presented in the Table 5, it is evident that the available iron in the surface soil 0-30 cm varied from 11.48 to 21.75 ppm with mean value of 17.71 ppm. Whereas, at 30 to 60 cm and 60-90 cm soil depth it varied from 11.10 to 20.94 and 10.99 to 20.75 ppm with mean values 17.11 and 16.58 ppm, respectively. The mean values of available Fe in soil of orchards at Akhnoor at different soil depths of 0-30, 30-60 and 60-90 cm was 18.33, 18.33, 17.79 and 17.39 ppm, respectively. Whereas, in soils of orchards at Samba it was 16.91, 16.08 and 15.56 ppm, respectively.

4.2.9 Available Copper (ppm)

It is evident from the data presented in the Table 5 that the available copper in the surface soil 0-30 cm varied from 0.90-1.65 ppm with mean value of 1.12 ppm. Whereas, the available copper at 30-60 cm and 60-90 cm soil depths, it varied from 0.80 to 1.63 ppm and 0.72 to 1.59 ppm with mean values of 1.12, 0.08 and 1.05 ppm, respectively. The mean of available Cu in depths of orchards soils at Akhnoor were recorded as 1.19, 1.15 and 1.12 ppm, whereas, in orchards at Samba the available Cu was 1.04, 0.09, and 0.95 ppm in 0-30, 30-60 and 60-90 cm soil depths, respectively.

Table 3. Soil macro nutrients status of mango orchards of Jammu region

Location	Orchard No.	Available Nitrogen (kg ha-^{1})			Available Phosphorous (kg ha-^{1})			Available Potassium (kg ha-^{1})		
		Soil depth (cm)								
		0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Akhnoor	1	244.82	212.56	198.34	23.50	11.90	8.2	168.32	152.1	120.00
	2	143.56	116.62	101.56	28.80	24.30	18.7	198.11	156.12	119.12
	3	154.88	168.54	112.67	22.80	12.50	10.2	187.10	182.10	180.65
	4	113.40	95.90	76.67	10.30	9.81	8.36	153.00	150.12	148.20
	5	298.25	289.90	270.60	9.27	8.91	8.00	186.30	185.10	182.20
	6	336.54	328.37	319.10	19.85	13.70	15.20	190.20	187.00	185.30
	7	230.25	225.15	213.19	13.50	21.00	19.70	150.42	148.20	140.23
	8	264.45	250.20	220.10	23.00	17.80	12.60	186.45	180.12	179.10
	9	300.20	280.25	275.25	19.20	14.60	9.60	154.50	135.23	134.12
	10	323.20	319.15	311.36	11.20	12.80	9.20	176.12	174.10	170.23
	11	382.63	377.29	365.50	21.50	20.20	19.70	168.10	152.00	120.12
	12	345.20	334.20	315.15	28.20	25.10	23.15	132.23	101.20	111.00
	13	312.10	309.20	300.10	15.20	14.20	12.20	119.30	120.00	87.12
	14	296.10	264.60	189.00	27.80	19.60	15.20	125.50	105.10	89.00
	15	390.60	352.80	239.40	32.80	25.20	22.80	112.13	114.32	86.32
	16	144.90	94.50	88.20	18.43	17.32	16.40	110.15	100.00	98.12
	17	125.60	115.17	79.30	16.10	15.20	14.20	120.19	115.32	110.15

	18	382.46	376.68	360.30	11.10	12.12	9.18	150.40	145.23	140.19
	19	401.33	396.76	385.20	29.12	28.11	26.10	190.23	185.23	178.28
	20	365.52	361.20	359.19	31.11	30.16	29.10	125.23	119.10	117.12
	21	428.72	419.38	415.40	15.30	14.45	12.60	95.10	92.20	90.23
	22	370.54	361.22	357.45	23.40	20.12	19.45	125.12	123.36	120.00
	23	473.20	465.60	450.32	29.23	27.26	25.12	110.20	102.15	100.10
	24	367.45	350.43	345.32	19.32	17.12	16.15	145.26	143.13	139.10
	25	289.30	285.30	280.50	25.12	23.13	22.28	246.20	243.12	240.10
	26	380.30	376.10	370.40	26.24	24.12	22.32	190.13	189.15	187.12
	27	245.56	242.10	239.80	19.23	18.36	17.32	200.20	198.10	190.15
	28	290.20	280.15	275.30	18.43	17.17	16.32	201.00	177.12	132.25
Samba	**Mean**	**300.04**	**287.47**	**268.38**	**21.03**	**18.43**	**16.40**	**157.75**	**149.14**	**139.12**
	1	113.40	100.8	69.33	16.70	18.80	11.30	139.20	95.93	79.34
	2	157.50	94.5	75.65	16.20	17.10	11.40	120.11	114.20	112.32
	3	189.00	113.4	76.70	12.70	12.40	8.00	150.21	149.23	147.26
	4	181.20	138.6	107.10	12.30	11.80	11.70	113.43	111.10	110.00
	5	120.10	119.7	75.10	20.20	13.90	14.10	132.20	114.10	112.21
	6	201.60	152.8	63.30	11.70	8.90	7.60	120.12	118.10	115.00
	7	162.30	88.2	75.66	15.20	11.70	9.30	140.20	139.10	136.12
	8	195.60	136.7	57.80	13.05	9.85	8.70	129.00	125.23	120.13
	9	265.40	158.3	73.10	12.60	9.60	8.90	117.15	112.27	110.23
	10	285.16	276.22	265.15	7.80	7.35	6.90	112.11	110.11	109.15
	11	250.78	245.17	239.30	13.00	12.8	11.7	210.15	208.10	205.11
	12	298.26	282.63	280.15	7.60	6.90	6.20	209.21	200.15	198.00
	13	178.26	170.20	169.10	22.00	20.00	17.60	170.45	168.45	159.20

	14	192.23	189.26	180.32	12.05	9.85	7.65	185.12	115.23	102.10
	15	197.35	188.46	170.50	10.85	9.05	7.80	119.13	120.20	87.12
	16	168.32	152.87	120.86	7.80	7.35	6.90	121.11	114.15	97.00
	17	198.34	156.32	119.04	22.90	19.40	18.30	201.00	177.18	132.23
	18	120.10	119.70	115.20	12.26	11.32	10.12	219.32	154.23	87.43
	19	151.20	113.40	81.90	19.10	18.20	17.14	198.10	156.21	119.22
	20	258.30	226.80	126.00	19.23	16.23	17.32	95.10	90.00	85.12
	21	107.10	75.60	63.30	13.35	12.23	10.32	168.10	143.20	156.00
	22	201.60	170.10	113.40	20.00	19.13	18.42	224.23	217.19	210.00
	Mean	**190.59**	**157.71**	**123.54**	**14.48**	**12.90**	**11.24**	**154.30**	**138.80**	**126.83**
	Overall Mean	**251.90**	**230.38**	**204.65**	**18.152**	**16.00**	**14.13**	**156.23**	**144.59**	**133.71**
	Range	**107.10-298.26**	**75.60-282.63**	**57.80-280.15**	**7.60-22.90**	**6.90-20.00**	**6.20-18.42**	**95.10-224.23**	**90.00-217.19**	**79.34-210.00**

Table 4. Soil macro nutrients status of mango orchards of Jammu region

Location	Orchard Number	Sulphur (kg ha^{-1})			Calcium[c mol (p+) kg $^{-1}$			Magnesium[cmol(p+) kg $^{-1}$		
		Soil depth (cm)								
		0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Akhnoor	1	17.35	16.15	15.95	5.75	5.72	5.70	2.68	2.65	2.62
	2	14.95	13.90	12.00	5.65	5.62	5.60	2.75	2.72	2.70
	3	13.20	12.30	11.70	5.50	5.48	5.45	2.72	2.70	2.68
	4	15.45	14.50	13.90	5.54	5.52	5.50	2.80	2.78	2.76
	5	16.24	15.85	14.30	5.40	5.48	5.45	2.85	2.82	2.80
	6	13.50	12.80	11.98	5.85	5.82	5.80	2.89	2.85	2.82
	7	14.00	13.90	12.85	5.52	5.49	5.46	2.92	2.90	2.91
	8	15.60	14.76	13.95	5.85	5.82	5.80	2.95	2.92	2.90
	9	17.75	16.75	15.80	5.55	5.53	5.50	3.00	2.98	2.96
	10	18.10	16.50	15.70	5.87	5.83	5.80	3.10	3.06	3.00
	11	18.48	17.90	16.95	5.82	5.80	5.78	2.98	2.96	2.93
	12	17.45	16.00	15.90	5.95	5.93	5.90	2.94	2.92	2.90
	13	18.90	17.50	16.20	6.00	5.98	5.95	3.08	3.05	3.00
	14	16.50	15.90	14.89	6.10	6.05	6.00	3.10	3.07	3.01
	15	16.95	15.70	14.45	6.05	6.00	6.00	3.15	3.13	3.11
	16	14.87	13.95	12.98	6.25	6.22	6.20	3.05	3.00	3.00
	17	17.65	16.20	15.90	6.20	6.18	6.15	3.18	3.14	3.10
	18	16.20	15.75	14.95	6.22	6.20	6.18	2.98	2.94	2.92
	19	15.30	14.50	13.45	6.09	6.04	6.00	3.32	3.00	3.28
	20	17.75	16.45	15.80	6.18	6.15	6.12	3.24	3.22	3.20

	21	17.75	16.45	15.80	6.18	6.15	6.12	3.24	3.22	3.20
	22	18.25	17.75	16.45	6.12	6.10	6.06	2.80	2.78	2.75
	23	16.40	15.90	15.10	6.19	6.15	6.12	2.95	2.92	2.90
	24	14.35	13.95	12.50	6.15	6.12	6.10	3.12	3.08	3.05
	25	17.45	16.50	15.78	6.16	6.14	6.11	3.15	3.12	3.10
	26	15.65	14.30	13.45	6.20	6.18	6.14	3.25	3.22	3.20
	27	14.87	13.75	12.20	6.28	6.26	6.22	3.28	3.25	3.22
	28	16.55	15.40	15.00	6.35	6.32	6.29	3.30	3.28	3.25
	Mean	**16.26**	**15.35**	**14.43**	**5.95**	**5.93**	**5.90**	**3.03**	**3.00**	**2.94**
Samba	1	12.6	10.40	9.80	5.45	5.42	5.04	2.18	2.16	2.14
	2	14.28	13.50	12.60	5.49	5.45	5.42	2.20	2.18	2.15
	3	14.70	13.20	12.60	4.50	4.48	4.45	2.22	2.20	2.20
	4	17.22	15.45	14.40	5.19	5.15	5.11	2.25	2.23	2.22
	5	17.36	15.21	14.43	5.20	5.16	5.13	2.28	2.26	2.24
	6	18.06	16.54	15.25	5.35	5.32	5.30	2.30	2.28	2.24
	7	19.74	17.22	16.35	5.15	5.11	5.10	2.32	2.30	2.26
	8	16.24	15.45	13.20	4.02	4.00	4.00	2.36	2.35	2.32
	9	13.50	11.24	10.21	4.92	4.90	4.87	2.40	2.38	2.36
	10	12.90	11.50	10.12	5.25	5.20	5.18	2.44	2.42	2.40
	11	13.95	12.85	10.75	4.85	4.82	4.80	2.46	2.43	2.40
	12	13.95	12.85	10.75	4.85	4.82	4.80	2.46	2.43	2.40
	13	16.75	14.43	13.26	5.30	5.25	5.22	2.50	2.48	2.46
	14	15.25	13.25	12.10	5.50	5.48	5.45	2.56	2.54	2.52
	15	14.35	13.60	12.50	5.15	5.12	5.10	2.60	2.58	2.55
	16	17.25	16.20	14.10	5.18	5.16	5.14	2.65	2.63	2.60

	17	15.50	14.10	12.98	5.40	5.39	5.35	2.70	2.68	2.65
	18	17.00	16.50	16.00	5.45	5.42	5.40	3.20	3.18	3.15
	19	17.87	16.85	15.95	6.15	6.12	6.10	3.22	3.20	3.18
	20	16.95	15.00	14.90	6.18	6.15	6.12	3.28	3.25	3.22
	21	14.70	13.70	12.90	5.84	5.80	5.78	3.30	3.28	3.25
	22	18.20	17.50	16.90	6.30	6.28	6.25	3.28	3.26	3.23
	Mean	**15.89**	**14.45**	**13.38**	**5.28**	**5.25**	**5.22**	**2.58**	**2.56**	**2.54**
	Overall mean	**16.10**	**14.95**	**13.97**	**5.66**	**5.63**	**5.60**	**2.83**	**2.81**	**2.76**
	Overall range	**12.60-19.74**	**10.40-17.90**	**9.80-16.95**	**4.02-6.35**	**4.00-6.32**	**4.00-6.29**	**2.18-3.32**	**2.16-3.28**	**2.14-3.28**

Table 5. Soil micro nutrients status of mango orchards of Jammu region

Location		Orchard Number	Zinc(ppm)			Iron (ppm)			Copper (ppm)			Manganese (ppm)		
			Soil Depth (cm)											
			0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
		1	0.55	0.53	0.51	16.75	15.85	14.65	1.02	1.00	0.99	13.40	13.1	12.95
		2	0.88	0.86	0.84	20.45	19.20	18.50	0.96	0.93	0.90	13.50	13.20	12.87
		3	0.68	0.66	0.64	21.75	20.15	19.75	1.11	1.07	1.04	14.50	14.25	13.99
		4	0.52	0.5	0.48	16.48	15.20	14.10	0.94	0.92	0.88	15.10	14.99	14.79
		5	0.78	0.76	0.74	18.43	17.40	16.89	1.15	1.13	1.10	20.25	19.92	19.79
		6	0.92	0.9	0.89	19.26	18.32	17.20	0.96	0.94	0.91	17.30	17.01	16.95
		7	0.63	0.62	0.61	16.25	15.75	14.99	1.13	1.11	1.07	18.23	17.92	17.75
		8	0.69	0.67	0.65	18.48	17.32	16.43	1.05	1.00	0.97	16.13	15.90	15.74
Akhnoor		9	0.75	0.73	0.72	17.22	16.22	15.25	1.15	1.12	1.09	16.32	15.99	15.78
		10	0.86	0.84	0.82	15.75	15.30	15.04	0.95	0.92	0.90	18.26	17.92	17.80
		11	0.91	0.89	0.87	19.43	18.45	18.20	0.93	0.90	0.88	14.60	13.99	13.81
		12	0.62	0.6	0.58	20.05	19.80	19.75	1.25	1.20	1.18	19.78	19.20	18.91
		13	0.73	0.7	0.68	18.25	18.05	17.95	1.30	1.28	1.25	12.50	12.00	11.98
		14	0.81	0.79	0.77	15.21	14.95	14.85	1.08	1.04	1.00	15.35	15.00	14.94
		15	0.89	0.87	0.84	16.22	16.10	15.98	1.35	1.32	1.30	22.25	20.98	20.75
		16	0.68	0.64	0.62	20.22	20.10	19.93	1.40	1.38	1.35	18.20	17.98	17.90
		17	0.8	0.78	0.76	18.29	18.10	17.94	0.95	0.92	0.90	19.24	18.99	18.67
		18	0.7	0.68	0.66	18.20	18.00	17.90	1.43	1.39	1.36	14.50	13.99	13.78

		19	0.71	0.69	0.67	19.43	19.36	19.16	1.33	1.29	1.26	16.80	15.77	15.55
		20	0.67	0.65	0.63	18.56	18.23	18.00	1.21	1.19	1.17	14.75	14.29	13.95
		21	0.67	0.65	0.63	17.90	17.70	17.42	1.44	1.42	1.39	17.10	16.94	16.30
		22	0.99	0.96	0.94	16.48	16.26	16.02	1.29	1.26	1.22	12.55	12.10	11.95
		23	0.6	0.58	0.56	18.79	18.42	18.09	1.58	1.54	1.50	18.39	18.00	17.92
		24	0.87	0.85	0.83	17.58	17.29	17.03	0.91	0.80	0.76	20.24	19.90	19.83
		25	0.83	0.8	0.79	19.09	18.92	18.75	0.93	0.88	0.86	19.48	18.91	18.78
		26	0.89	0.86	0.84	20.67	20.45	20.12	1.50	1.47	1.44	16.76	16.14	15.90
		27	0.75	0.73	0.7	19.49	19.29	19.09	1.23	1.19	1.14	19.90	18.80	18.72
		28	0.94	0.92	0.9	18.56	18.16	17.93	1.65	1.63	1.59	21.10	20.95	20.89
		Mean	**0.76**	**0.74**	**0.72**	**18.33**	**17.79**	**17.39**	**1.19**	**1.15**	**1.12**	**17.01**	**16.56**	**16.39**
		Range	**0.52-0.99**	**0.50-0.96**	**0.48-0.94**	**14.95-20.45**	**14.10-20.12**	**11.95-20.89**	**0.91-1.65**	**0.80-1.63**	**0.76-1.59**	**12.50-22.25**	**12.00-20.98**	**11.95-20.89**
Samba		1	0.55	0.53	0.51	14.06	12.70	11.90	0.94	0.82	0.75	9.81	7.78	6.65
		2	0.88	0.86	0.84	14.23	13.43	12.23	0.98	0.85	0.72	8.24	8.15	8.01
		3	0.68	0.66	0.64	13.25	12.90	11.50	0.90	0.84	0.80	4.15	4.00	3.92
		4	0.52	0.5	0.48	15.40	14.87	13.76	0.91	0.86	0.82	12.25	12.10	11.98
		5	0.78	0.76	0.74	16.95	15.90	14.86	0.97	0.92	0.87	18.23	18.11	17.20
		6	0.92	0.9	0.89	17.42	15.56	14.40	1.01	0.99	0.94	20.25	19.90	19.85
		7	0.63	0.62	0.61	15.36	14.78	13.43	1.00	0.97	0.93	16.13	16.01	15.98
		8	0.69	0.67	0.65	18.34	17.30	16.50	0.99	0.94	0.92	20.25	19.80	19.70
		9	0.75	0.73	0.72	15.75	14.19	13.43	0.93	0.89	0.83	19.26	19.03	18.92
		10	0.86	0.84	0.82	16.3	16.00	15.99	1.10	1.06	1.08	18.33	17.89	17.76
		11	0.91	0.89	0.87	17.42	16.36	15.20	0.98	0.94	0.90	20.22	19.99	19.75
		12	0.62	0.6	0.58	11.48	11.10	10.99	0.94	0.91	0.89	15.30	14.90	14.85

	13	0.59	0.58	0.56	19.72	18.20	17.90	1.11	1.06	1.03	18.18	17.94	17.87
	14	0.62	0.60	0.58	18.36	18.25	18.08	1.07	1.04	1.00	17.24	16.96	16.81
	15	0.76	0.74	0.73	19.69	19.78	18.43	0.90	0.87	0.84	18.23	17.87	17.79
	16	0.82	0.80	0.78	18.45	17.85	16.56	1.20	1.18	1.16	12.25	11.97	11.79
	17	0.67	0.65	0.64	19.05	18.30	18.11	0.91	0.87	0.84	11.65	10.99	10.85
	18	1.04	0.97	0.95	21.29	20.94	20.75	0.99	0.94	0.90	20.21	19.90	19.87
	19	0.97	0.95	0.93	17.36	17.25	17.10	1.29	1.26	1.20	16.2	15.98	15.82
	20	0.85	0.83	0.81	18.22	18.10	17.95	0.92	0.88	0.83	19.11	18.90	18.70
	21	0.64	0.62	0.60	16.75	16.55	16.25	1.42	1.39	1.33	16.77	16.67	16.45
	22	0.96	0.93	0.91	17.25	17.05	16.96	1.40	1.36	1.32	15.25	15.00	14.90
	Mean	**0.67**	**0.64**	**0.62**	**16.91**	**16.08**	**15.56**	**1.04**	**0.99**	**0.95**	**15.80**	**15.45**	**15.25**
	overall mean	**0.76**	**0.74**	**0.72**	**17.71**	**17.11**	**16.58**	**1.12**	**1.08**	**1.05**	**16.48**	**16.08**	**15.89**
	overall range	**0.52-1.04**	**0.50-0.97**	**0.48-0.95**	**11.48-21.75**	**11.10-20.94**	**10.99-20.75**	**0.9-1.65**	**0.8-1.63**	**0.72-1.59**	**4.15-22.25**	**4.00-20.98**	**3.92- 20-89**

Table 6. Soil nutrient status of low and high yielding mango orchards

Sr. No.	Nutrients	Low yielding orchards		High yielding orchards	
		Mean	Range	Mean	Range
1	**Nitrogen (kg/ha)**	152.89	80.17-345.32	299.20	136.55-463.04
2	**Phosphorus(kg/ha)**	15.34	7.35-26.93	16.79	6.90-30.12
3	**Potassium (kg/ha)**	135.26	88.15-217.14	153.70	91.47-243.14
4	**Sulphur (kg/ha)**	15.16	10.93-18.05	14.86	11.42-17.92
5	**Calcium[cmol(P^+)kg^{-1}]**	5.57	4.28-6.28	5.68	4.01-6.32
6	**Magnesium[cmol(P^+)kg^{-1}]**	2.73	2.12-3.28	2.87	2.30-3.30
7	**Zinc(ppm)**	0.73	0.42-0.96	0.74	0.49-1.01
8	**Iron (ppm)**	16.67	12.48-21.15	17.53	11.19-20.41
9	**Copper (ppm)**	1.02	0.81-1.39	1.14	0.82-1.62
10	**Manganese (ppm)**	10.71	0.19-28.89	17.21	12.15-20.98

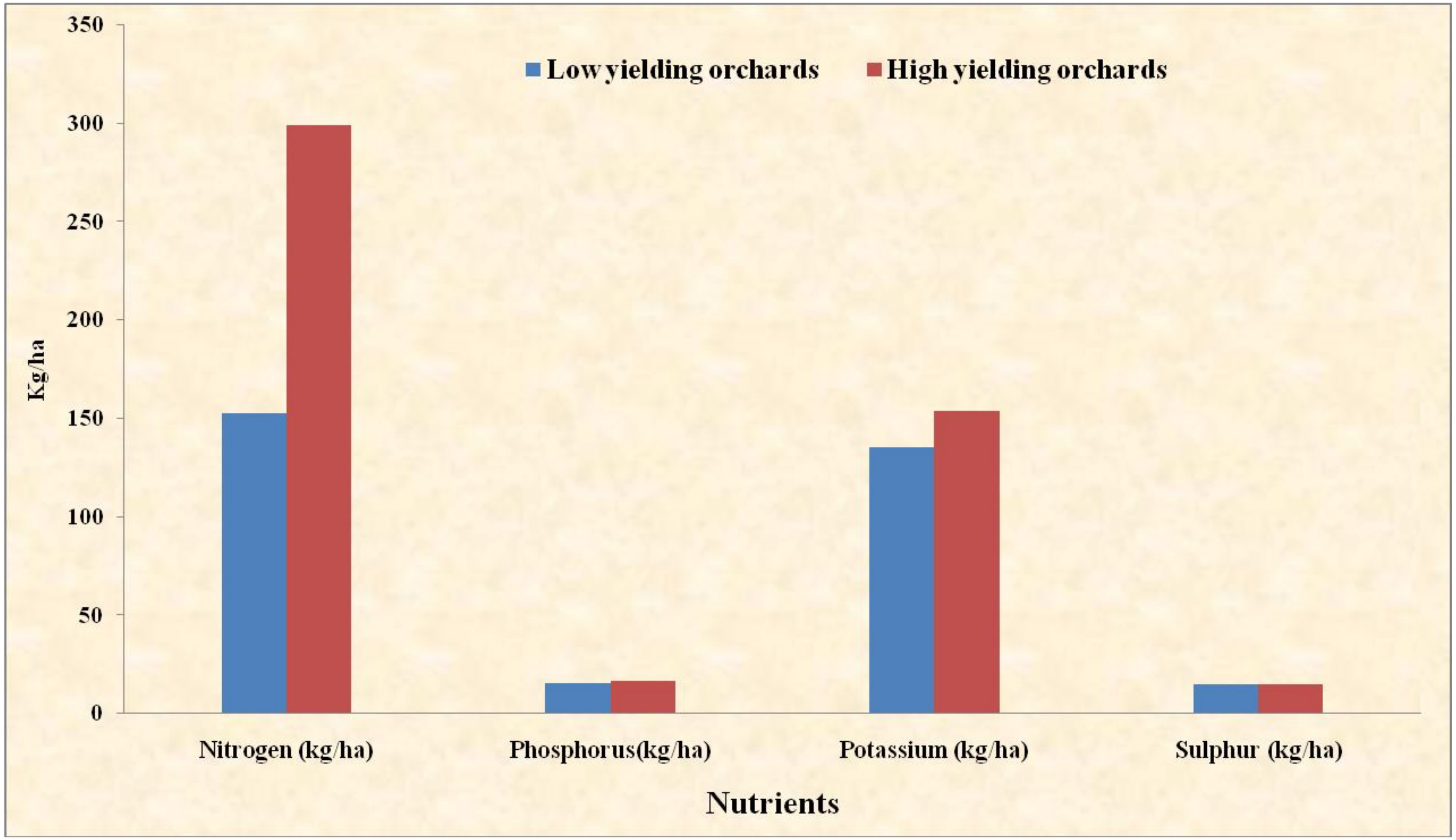

Figure 2. Mean N. P, K and S content in mango soil of low and high yielding orchards

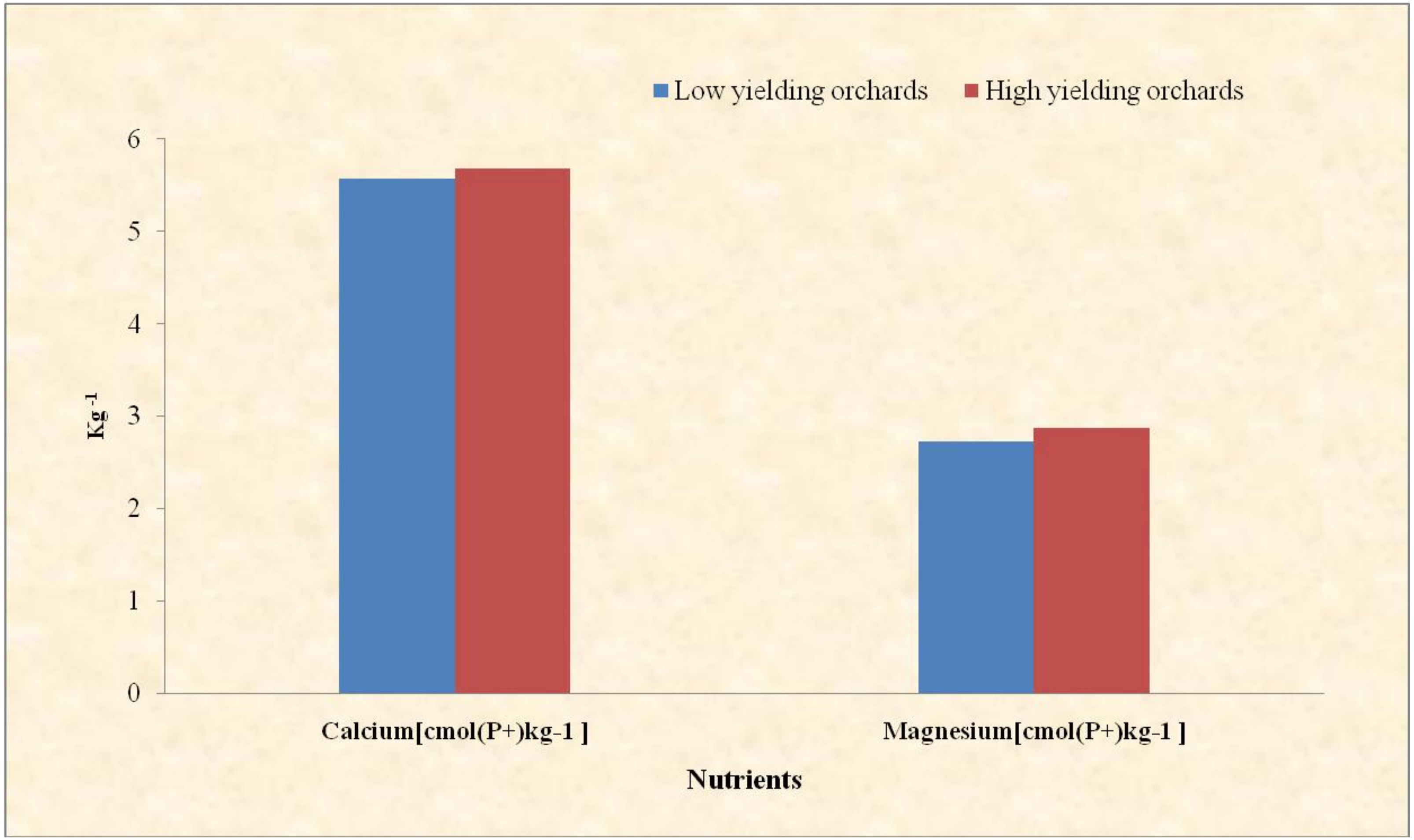

Figure 3. Mean Ca and Mg content in mango soil of low and high yielding orchards

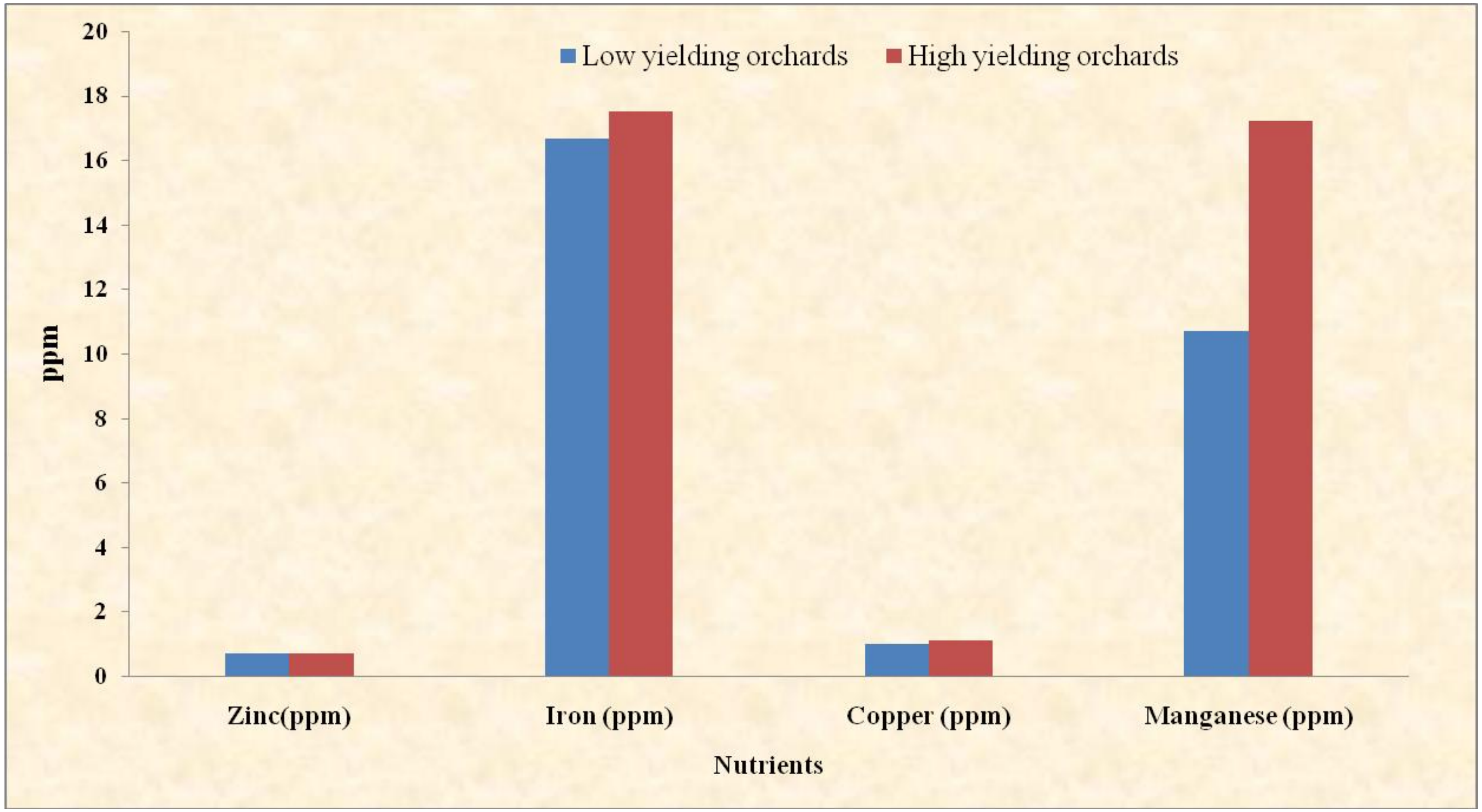

Figure 4 Mean Zn, Fe, Cu and Mn content in mango soil of low and high yielding orchards.

4.2.10 Available Manganese (ppm)

From the data presented in the Table 5, it is evident that the available manganese in the surface soils 0-30cm varied from 4.15 to 22.25 ppm with mean value of 16.48 ppm whereas, in 30-60 cm and 60-90 cm soil depths, available manganese content varied from 4.00 to 20.98 ppm and 3.92 to 20.89 ppm with mean values of 16.08 and 15.89 ppm, respectively. The mean available of Mn in three depths of soil, 0-30cm, 30-60 cm and 60-90 cm, varied from 17.01, 16.56 and 16.39 ppm, whereas, in orchards at Samba the mean of available Mn were 15.80, 15.45 and 15.25ppm, for respective soil depths.

4.2.11 Soil nutrients status of low and high yielding orchards

The mean and range of nutrients in low and high yielding orchards are presented in Table 6 and Fig. 2, 3 and 4. In low yielding orchards the available nitrogen content ranged from 80.17 to 345.32 kg/ha with a mean value of 152.89 kg/ha. Whereas, in higher yielding orchards the available nitrogen ranged from 136.55 to 463.04 kg/ha with a mean value 299.20 kg/ha. Similarly, available phosphorous in soils of low yielding orchards ranged from 7.35 to 26.93 kg/ha with a mean value of 15.34 kg/ha. However, in soils of high yielding orchards, the available phosphorus ranged from 6.90 to 30.12 kg/ha with a mean value of 16.79 kg/ha. The available potassium content ranged from 88.15 to 217.54 kg/ha with mean values of 135.26 kg/ha in low yielding orchards. Whereas, in high yielding orchards the available potassium content ranged from 91.47 to 243. 14 kg/ha with mean value of 153.70 kg/ha.

In low yielding orchards available calcium and magnesium content ranged from 4.28 to 6.28 (cmol (p^+) kg^{-1}) and 2.12 to 3.28 (cmol (p^+) kg^{-1}) with mean values of 5.57 and 2.73 **(**cmol (p^+) kg^{-1}), respectively, whereas in high yielding orchards available calcium and magnesium content ranged from 4.01 to 6.32 (cmol (p^+) kg^{-1}) and 2.30 to 3.30 (cmol (p^+) kg^{-1}) with mean values 5.68 and 2.87 (cmol (p^+) kg^{-1}), respectively. In low yielding orchards available sulphur content in soil ranged from 10.93 to 18.05 kg/ha with mean values of 15.16 kg/ha, whereas, in high yielding orchards available sulphur content ranged from 11.42 to 17.92 kg/ha with a mean value of 14.86 kg/ha.

The range and mean values for available zinc, available iron, and available copper and available manganese content in low yielding orchards were 0.42 to 0.96, 12.48 to 21.15, 0.81 to 1.39 and 0.19 to 28.89 ppm with mean values of 0.73, 16.67, 1.02 and 10.71 ppm, respectively. However, in high yielding orchards the available zinc ranged from 0.49 to 1.01 ppm with mean value of 0.74 ppm. Similarly, available iron, copper and manganese content ranged from 11.91 to 20.41 ppm, 0.82 to 1.62 ppm and 12.15 to 20.98 ppm with mean values 17.53 ppm, 1.14 ppm and 17.21 ppm, respectively.

4.3 Leaf nutrient status

The data related to leaf nutrient status of different orchards are presented in table 7.

4.3.1 Nitrogen (per cent)

It is clear from the data presented in Table 7 that the overall nitrogen content of mango leaves varied between 1.10 to 2.25 per cent with mean value 1.97 per cent. Among two locations, the higher mean leaf nitrogen content of 2.05 per cent was recorded in orchards at Akhnoor while, lower mean leaf nitrogen content of 1.86 per cent was recorded in orchards of Samba.

4.3.2 Phosphorus (per cent)

It is observed from the data presented in Table 7, that the overall phosphorus content of mango leaves ranged from 0.09 to 0.27 per cent with mean value of 0.17 per cent. The maximum mean leaf phosphorus content of 0.19 per cent was recorded in orchard at Akhnoor, while, minimum mean leaf phosphorus content of 0.15 per cent was recorded in orchards of Samba.

4.3.3 Potassium (per cent)

It is revealed from the data presented in the Table 7 that the overall potassium content of mango leaves varied from 0.80 to 0.45 per cent with mean value of 0.30 per cent. The higher mean leaf potassium content of 0.33 per cent was recorded in orchards at Akhnoor while, lower mean 0.27 per cent was recorded in orchards at Samba.

Table 7. Leaf nutrients status of mango orchards of Jammu region

Location	Orchard Number	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulphur (%)	Calcium (%)	Magnesium (%)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)
Akhnoor	1	2.11	0.16	0.29	0.22	2.12	0.63	20.20	218.10	22.40	123.90
	2	2.11	0.17	0.30	0.23	2.14	0.62	24.20	200.40	20.50	131.80
	3	2.15	0.16	0.28	0.24	2.40	0.95	25.80	299.20	17.20	123.90
	4	1.95	0.22	0.25	0.21	2.05	0.76	21.90	210.30	18.20	170.90
	5	2.23	0.19	0.45	0.2	2.21	0.76	26.50	245.20	20.20	147.80
	6	2.18	0.20	0.39	0.21	2.22	0.78	23.50	256.50	18.50	154.90
	7	2.14	0.18	0.26	0.19	2.15	0.69	22.20	219.60	16.40	139.80
	8	2.15	0.19	0.35	0.20	2.20	0.50	24.20	239.40	19.60	147.40
	9	2.14	0.20	0.40	0.21	2.25	0.77	20.24	287.20	18.20	154.90
	10	2.19	0.21	0.41	0.24	2.28	0.86	23.80	292.50	20.30	162.90
	11	2.16	0.21	0.28	0.21	2.23	0.80	23.31	275.40	19.50	162.90
	12	2.25	0.25	0.36	0.29	2.45	1.01	28.50	310.50	24.20	193.90
	13	2.24	0.22	0.36	0.27	2.32	0.90	25.60	298.50	20.50	170.90
	14	2.18	0.22	0.20	0.18	2.18	0.49	22.20	200.20	21.50	170.40
	15	2.22	0.23	0.39	0.25	2.35	0.90	26.50	299.20	18.40	177.90
	16	2.21	0.24	0.41	0.28	2.40	0.92	27.50	309.50	24.70	184.20
	17	2.2	0.21	0.42	0.23	2.30	0.88	26.50	298.50	22.60	160.9
	18	2.14	0.18	0.34	0.22	2.19	0.70	23.20	234.2	19.60	147.90

	19	1.35	0.11	0.19	0.06	1.86	0.44	18.40	120.20	20.40	85.60
	20	1.33	0.09	0.2	0.12	1.83	0.43	24.20	124.20	22.20	69.90
	21	2.12	0.17	0.30	0.18	2.14	0.67	20.50	116.50	20.10	132.20
	22	1.98	0.16	0.28	0.21	2.10	0.60	20.10	212.80	14.30	124.50
	23	2.20	0.21	0.42	0.25	2.30	0.87	26.20	298.50	24.20	163.40
	24	1.45	0.11	0.20	0.07	1.88	0.44	14.60	115.80	11.50	85.20
	25	2.14	0.13	0.34	0.25	2.20	0.75	23.30	235.50	17.50	100.80
	26	1.88	0.19	0.28	0.08	1.96	0.47	17.60	152.30	13.40	147.30
	27	2.15	0.19	0.36	0.20	2.21	0.76	23.60	240.10	22.10	147.80
	28	1.96	0.15	0.26	0.12	1.99	0.51	19.30	180.50	18.80	116.30
	Mean	**2.05**	**0.18**	**0.32**	**0.20**	**2.18**	**0.71**	**22.99**	**231.81**	**19.54**	**142.86**
Samba	1	2.14	0.18	0.33	0.24	2.16	0.69	22.50	214.50	18.60	139.80
	2	2.15	0.21	0.41	0.23	2.20	0.74	20.90	192.20	17.90	162.90
	3	1.87	0.15	0.24	0.12	1.98	0.55	25.30	225.20	17.40	116.20
	4	1.98	0.16	0.27	0.13	2.04	0.53	19.50	205.20	17.50	123.90
	5	1.79	0.16	0.39	0.18	2.08	0.55	19.70	212.50	21.20	123.90
	6	2.14	0.16	0.33	0.18	2.18	0.69	20.21	230.70	18.40	123.90
	7	1.78	0.12	0.22	0.10	2.00	0.45	19.80	125.20	15.60	93.20
	8	1.89	0.14	0.23	0.06	1.96	0.48	17.80	148.50	16.40	108.90

	9	1.10	0.11	0.19	0.06	1.80	0.42	10.60	110.50	12.80	85.60
	10	1.48	0.12	0.20	0.04	1.88	0.45	12.40	126.50	15.60	93.20
	11	2.22	0.20	0.40	0.22	2.24	0.82	24.80	289.20	19.50	155.20
	12	1.77	0.18	0.32	0.16	2.05	0.52	17.60	210.40	17.40	139.40
	13	1.28	0.13	0.23	0.08	1.82	0.42	11.80	101.20	10.50	101.10
	14	1.65	0.13	0.21	0.09	1.90	0.47	17.50	132.10	12.10	100.80
	15	2.08	0.11	0.19	0.13	2.12	0.48	20.50	140.60	22.30	85.60
	16	1.95	0.15	0.25	0.25	1.99	0.58	19.40	218.20	19.40	116.60
	17	2.00	0.16	0.29	0.21	2.11	0.60	20.20	214.30	22.50	124.50
	18	1.92	0.14	0.23	0.10	1.98	0.48	18.10	160.40	16.20	108.60
	19	2.12	0.18	0.31	0.21	2.15	0.68	21.80	220.50	18.20	139.40
	20	1.97	0.15	0.27	0.15	2.02	0.55	19.50	195.60	19.60	116.40
	21	1.96	0.14	0.24	0.11	1.98	0.50	18.20	165.30	16.10	108.50
	22	1.75	0.18	0.23	0.09	1.92	0.47	17.50	142.60	12.70	139.60
	Mean	**1.86**	**0.15**	**0.27**	**0.14**	**2.03**	**0.55**	**18.89**	**180.97**	**17.18**	**118.51**
	Overall Mean	**1.97**	**0.17**	**0.30**	**0.18**	**2.11**	**0.64**	**21.22**	**209.88**	**18.52**	**132.36**
	Overall Range	**1.10-2.25**	**0.09-0.25**	**0.19-0.45**	**0.04-0.29**	**1.8-2.45**	**0.42-1.01**	**10.6-28.5**	**101.2-310.5**	**10.5-24.7**	**69.9-193.9**

4.3.4 Sulphur (per cent)

It is clear from the data presented in the Table 7 that the overall sulphur content of mango leaves varied from 0.04 to 0.29 per cent with mean value 0.17 per cent. The maximum mean leaf sulphur content of 0.20 per cent was recorded in orchards at Akhnoor while, minimum mean 0.14 per cent was recorded in orchards at Samba.

4.3.5 Calcium (per cent)

It is observed from the data presented in Table 7, that the overall calcium content of mango leaves ranged from 1.8 to 2.45 per cent with mean value 2.11 per cent. The higher mean calcium content of 2.18 per cent was recorded in orchards at Akhnoor, while, the lower mean per cent of 2.03 calcium recorded in orchards at Samba.

4.3.6 Magnesium (per cent)

It is revealed from the data presented in the Table 7 and that the overall magnesium content of mango leaves varied from 0.42 to 1.01 per cent with mean value of 0.64 per cent. The higher mean leaf magnesium content of 0.71 per cent was observed in orchards at Akhnoor while lower mean leaf magnesium content of 0.55 was observed in orchards at Samba.

4.3.7 Zinc (ppm)

It is observed from the data presented in the Table 7 that the overall zinc content of mango leaves varied between 10.06 to 28.05 ppm with mean value of 21.22 ppm. Among different location, the higher mean leaf zinc content of 22.99 ppm was recorded in orchard at Akhnoor, while lower mean leaf zinc content of 18.89 ppm was recorded in orchards at Samba.

4.3.8 Iron (ppm)

It is cleared from the data presented in the Table 7, that the overall iron content of mango leaves varied from 101.2 to 310.5 ppm with mean value of 209.88 ppm. Among two different locations, the highest and the lowest mean of iron content of 231.88 ppm and 180.97 ppm was recorded in the orchard of Akhnoor and Samba, respectively.

4.3.9 Copper (ppm)

It is apparent from the data presented in Table 7 that the overall copper content of mango leaves varied between 10.5 to 24.7 ppm with mean value of 18.52 ppm. Among two different locations, the higher mean leaf copper content of 19.54 ppm was recorded in orchards at Akhnoor, while lower mean leaf copper content of 17.18 ppm was recorded in orchards at Samba.

4.3.10 Manganese (ppm)

It is showed from the data presented in the Table 7 that the overall manganese content of mango leaves varied from 69.9 to 193.9 ppm with mean value of 132.36 ppm. Among different locations, the highest and the lowest mean of manganese content of 142.86 and 118.51 ppm was recorded in orchards at Akhnoor and Samba, respectively.

4.3.11 Leaf nutrient status of low and high yielding orchards

The mean and range of leaf nutrients in low and high yielding orchards are presented in Table 8 and Fig.5, 6. In low yielding orchards the nitrogen content ranged from 1.10 to 2.20 per cent with a mean value of 1.81 per cent, whereas, in higher yielding orchards the nitrogen content ranged from.77 to 2.25 per cent with a mean value of 2.12 per cent. Similarly, phosphorous and potassium content ranged from 0.09 to 0.21 per cent and 0.19 to 0.42 per cent with mean values of 0.14 to 0.26 per cent, respectively. However, phosphorous and potassium concentration in leaves in high yielding orchards ranged from 0.15 to 0.25 and 0.45 to 2.20 per cent and with mean values of 0.19 to 0.34 per cent, respectively. Sulphur calcium and magnesium concentration in low yielding orchard leaf ranged from 0.04 to 0.25 1.80 to 2.30, 0.42 to 0.87 per cent with mean values of 0.13, 2.00, 0.54 and per cent, respectively, while, in high yielding orchard sulphur, calcium and magnesium content ranged from 0.12 to 0.29 per cent with mean value of 0.21 per cent, 1.98 to 2.45 with mean value of 2.21, and 0.49 to 1.01 with mean value 0.73 per cent. The range and mean values for zinc, iron, copper and manganese content in low yielding orchards were 10.60 to 26.20, 101.20 to 298.50, 10.50 to 24.20 and 69.90 to 163.40 ppm with mean values of 18.87, 166.58, 17.27 and 112. 29 ppm, respectively. Whereas, the range and mean values for zinc, iron, copper and manganese content in high yielding orchards were

Table 8. Leaf nutrients status of low and high yielding mango orchards

Sr. No.	Nutrients	Low yielding orchards		High yielding orchards	
		Mean	Range	Mean	Range
1	**Nitrogen (%)**	1.81	1.10-2.20	2.12	1.77-2.25
2	**Phosphorus (%)**	0.14	0.09-0.21	0.19	0.15-0.25
3	**Potassium (%)**	0.26	0.19-0.42	0.34	0.20-0.45
4	**Sulphur (%)**	0.13	0.04-0.25	0.21	0.12-0.29
5	**Calcium (%)**	2.00	1.80-2.30	2.21	1.98-2.45
6	**Magnesium (%)**	0.54	0.42-0.87	0.73	0.49-1.01
7	**Zinc (ppm)**	18.87	10.60-26.20	23.32	17.60-28.50
8	**Iron (ppm)**	166.58	101.20-298.50	249.01	192.20-310.50
9	**Copper (ppm)**	17.27	10.50-24.20	19.63	16.40-24.70
10	**Manganese(ppm)**	112.29	69.90-163.40	150.48	116.20-193.90

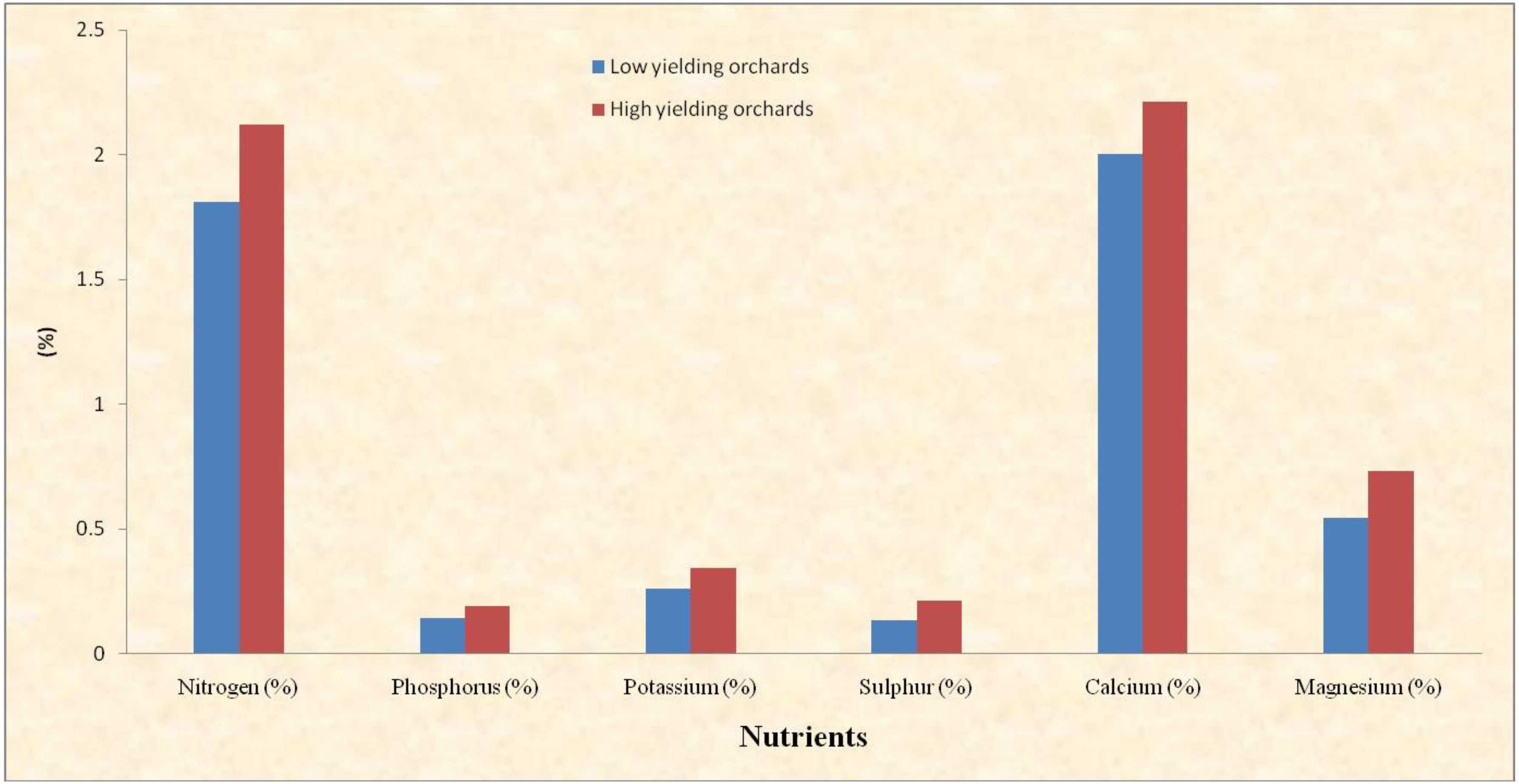

Figure 5: Mean N,P, K.S, Ca and Mg content in mango leaves of low and high yielding orchards

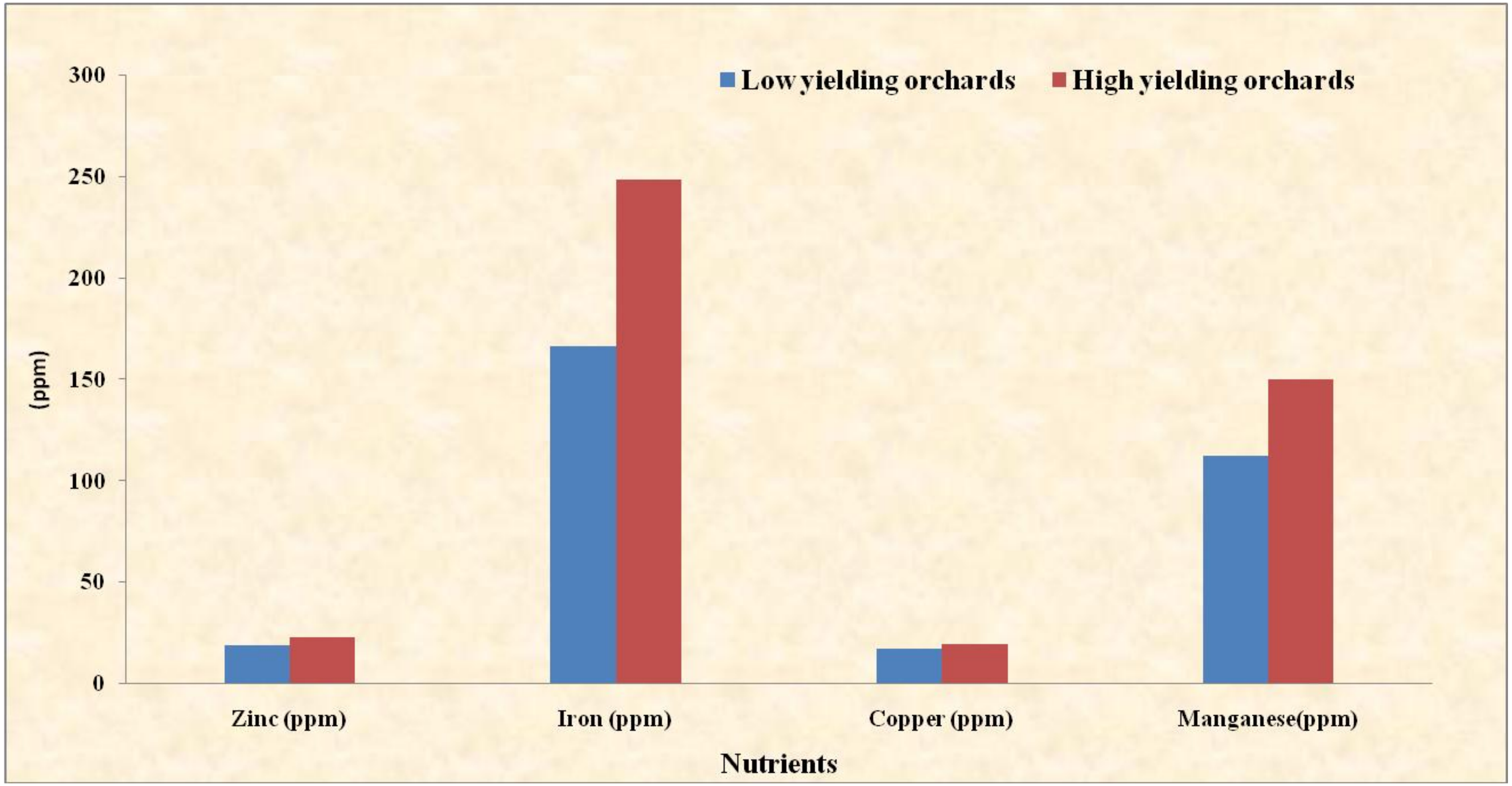

Figure 6 : Mean Zn, Fe, Cu and Mn content in mango leaves of low and high yielding orchards

17.60 to 28.50, 192.20 to 310.50, 16.40 to 24.70 and 116.20 to 193.90 ppm with mean values of 23.32, 249.01, 19.63 and 150.48, respectively.

4.4 Fruit characteristics

4.4.1 Physical characteristics

The result with respect to fruit physical characteristics of fruits viz., fruit weight, fruit length, diameter, volume specific gravity, fresh weight of pulp, dry weight of pulp, stone weight, pulp: stone ratio and fruit yield are presented in table 9.

4.4.1.1 Fruit length (cm)

A perusal of data presented in table 9 indicated that average fruit length varied from 9.05 cm to 10.45 cm with mean value of 9.91 cm. The higher mean fruit length of 10.01 cm was recorded in orchards at Akhnoor while, lower mean fruit length of 9.91 cm was recorded in orchards at Samba.

4.4.1.2 Fruit weight (g)

A perusal of data presented in table 9 indicated that average fruit weight varied from 139.98 g to 171.03 g with the mean value of 157.15 g. The higher mean fruit weight 160.37 g was recorded in orchard at Akhnoor while, lower mean fruit weight of 153.06 g was recorded at Samba.

4.4.1.3 Fruit Diameter (cm)

A perusal of data presented in table 9 indicated that average fruit diameter varied from 5.00 cm to 6.17 cm with mean value of 5.66 cm. The higher mean fruit diameter of 5.76 cm was recorded in orchards at Akhnoor while, lower mean of fruit diameter (5.53cm) was recorded at Samba.

4.4.1.4 Fruit volume (cm^3)

Data related to fruit volume (cm^3) under different locations of mango orchards are presented in Table 9. A perusal of data presented in table 9 indicated that average fruit volume varied from 138.90 cm^3 to 170.00 cm^3 with the mean value of 156.10 cm^3. The maximum mean fruit volume of 159.31 cm^3 was recorded in orchards at Akhnoor while, minimum mean fruit volume of 152.01 cm^3 was recorded at Samba.

4.4.1.5 Specific gravity

A perusal of data presented in table 9 indicated that average specific gravity varied from 1.006 to 1.008 with the mean value of 1.007. The mean of specific gravity 1.007 was recorded in Akhnoor.

4.4.1.6 Fresh weight of pulp (g)

Data pertaining to fresh weight of pulp (g) under different locations of mango orchards are presented in Table 9. From the data it is evident that average fresh weight of pulp of mango varied from 87.05 g to 109.80 g per fruit with the mean value of 97.45 g per fruit. The higher mean pulp weight of 99.43 g per fruit was recorded in orchard at Akhnoor while, the lower mean fresh pulp weight of 94.93 g per fruit was recorded at Samba.

4.4.1.7 Dry weight of pulp (g)

Data pertaining to dry weight of pulp (g) under different locations of mango orchards are presented in Table 9. From the data it is evident that average dry pulp weight of mango varied from 4.83 g to 6.97 g per fruit with mean value of 5.65 g per fruit. The maximum mean dry weight of pulp of 5.73 g per fruit was recorded in orchards at Samba while, the minimum mean dry weight of pulp of 5.59 per fruit was recorded at Akhnoor.

4.4.1.8 Stone weight (g)

Data pertaining to stone weight (g) under different locations of mango orchards are presented in Table 9. From the data it is evident that average stone weight of mango varied from 26.32 g to 31.10 g per fruit with mean value of 28.68 g per fruit. The maximum mean stone weight of 29.20 g per fruit was observed in orchard at Akhnoor while, minimum mean stone weight of 28.02 g per fruit recorded at Samba**.**

4.4.1.9 Pulp: stone ratio

Data pertaining to pulp: stone ratios under different locations of mango orchards are presented in Table 9. It is apparent from data that average pulp: stone ratio of mango fruit varied from 3.23 to 3.55 per fruit. The maximum mean pulp: stone ratio of 3.41 per fruit was recorded in orchards at Akhnoor while, minimum mean pulp: stone ratio of 3.39 per fruit was recorded at Samba.

Table 9. Physical characteristics of mango fruit of Jammu region

Location	Orchard Number	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cm^3)	Specific gravity	Fresh Pulp weight (g)	Dry Pulp Weigh t (g)	Stone Weigh t (g)	Pulp: stone ratio	Yield (kg/plant
Akhnoor	1	166.20	10.32	5.75	165.20	1.006	99.25	5.51	29.35	3.38	60.5
	2	167.44	10.34	5.77	166.40	1.006	99.07	5.55	29.43	3.37	62.13
	3	154.00	9.05	5.63	153.00	1.007	97.20	5.51	28.70	3.39	50.30
	4	165.44	10.22	5.85	164.35	1.007	98.66	5.33	28.76	3.44	56.30
	5	169.85	10.40	6.11	168.75	1.007	105.66	5.84	30.45	3.48	82.35
	6	168.70	10.39	5.93	167.65	1.006	103.49	5.69	30.80	3.36	75.18
	7	167.00	10.34	5.89	166.00	1.006	99.52	5.41	29.50	3.37	63.20
	8	161.32	9.85	5.79	160.20	1.007	98.52	5.38	28.71	3.44	53.00
	9	166.32	10.38	5.75	165.20	1.007	99.26	5.61	29.40	3.38	59.20
	10	168.48	10.38	5.95	167.44	1.006	102.36	5.62	29.48	3.48	74.16
	11	168.26	10.35	5.92	167.15	1.007	101.42	5.51	29.78	3.41	72.97
	12	171.03	10.45	6.17	170.00	1.006	109.80	5.97	31.10	3.54	84.69
	13	170.13	10.41	6.14	169.10	1.006	107.52	5.75	30.65	3.51	83.34
	14	169.28	10.39	5.98	168.18	1.007	106.40	5.93	30.15	3.54	78.77
	15	170.42	10.42	6.16	169.38	1.006	108.44	5.86	30.85	3.52	84.31
	16	169.50	10.40	6.10	168.45	1.006	103.67	5.59	30.25	3.42	81.26

	17	169.92	10.42	6.12	168.80	1.007	106.49	5.68	30.55	3.49	82.32
	18	165.85	9.75	5.68	164.76	1.007	98.44	5.79	28.69	3.44	56.25
	19	144.36	9.52	5.41	143.29	1.007	90.36	4.83	27.32	3.31	42.30
	20	144.26	9.59	5.39	143.15	1.008	89.46	5.27	27.30	3.28	40.26
Akhnoor	21	152.20	9.72	5.58	151.10	1.007	98.40	5.79	28.44	3.47	49.50
	22	150.30	9.71	5.56	149.25	1.007	97.65	5.43	28.75	3.40	49.20
	23	145.76	9.64	5.42	144.74	1.007	92.40	5.78	27.95	3.31	43.55
	24	155.18	9.73	5.59	154.15	1.007	98.43	5.24	29.04	3.40	49.64
	25	148.43	9.70	5.49	147.40	1.007	95.38	5.84	28.46	3.36	47.85
	26	146.26	9.58	5.43	145.20	1.007	91.44	5.70	28.34	3.23	43.50
	27	152.35	9.72	5.57	151.30	1.007	98.36	5.49	29.00	3.40	49.55
	28	142.24	9.19	5.14	141.14	1.008	87.05	5.62	26.40	3.30	34.92
	Mean	**160.37**	**10.01**	**5.76**	**159.31**	**1.007**	**99.43**	**5.59**	**29.20**	**3.41**	**61.09**
Samba	1	167.56	10.36	5.90	166.40	1.007	99.55	5.57	29.45	3.39	65.75
	2	168.25	10.38	5.98	167.25	1.006	100.22	5.42	29.75	3.38	72.97
	3	164.46	10.10	5.66	163.35	1.007	98.10	5.77	28.78	3.41	55.20
	4	167.48	10.35	5.80	166.40	1.006	99.44	5.62	29.51	3.38	63.90
	5	159.43	9.95	5.65	158.40	1.007	97.40	5.78	28.42	3.43	51.30
	6	164.35	9.90	5.64	163.33	1.006	98.20	5.78	28.45	3.45	52.50
	7	164.43	9.95	5.75	163.41	1.006	98.34	5.59	28.51	3.45	46.50

	8	169.11	10.38	5.96	168.10	1.006	105.51	5.76	29.79	3.55	46.95
	9	146.18	9.62	5.40	145.12	1.007	89.75	6.00	27.18	3.30	43.20
	10	147.32	9.64	5.45	146.20	1.008	92.55	5.29	27.46	3.37	46.87
	11	139.98	9.10	5.00	138.90	1.008	88.25	6.30	26.32	3.35	30.50
	12	145.00	9.55	5.42	144.00	1.007	92.48	5.31	26.95	3.44	43.15
	13	142.56	9.20	5.15	141.50	1.007	88.52	5.21	26.80	3.31	36.50
	14	143.50	9.52	5.40	142.45	1.007	89.62	5.97	26.55	3.38	42.28
	15	149.28	9.69	5.50	148.25	1.007	96.49	5.68	28.20	3.43	48.20
	16	148.46	9.68	5.48	147.40	1.007	95.34	5.51	27.85	3.43	47.70
	17	146.33	9.65	5.44	145.25	1.007	93.85	5.75	27.44	3.42	46.50
	18	147.42	9.68	5.46	146.40	1.007	93.36	5.49	28.32	3.30	46.95
	19	148.40	9.67	5.47	147.39	1.007	94.65	5.50	28.42	3.33	47.50
	20	144.38	9.61	5.43	143.35	1.007	90.56	6.97	27.45	3.30	44.20
	21	143.15	9.56	5.22	142.11	1.007	89.55	5.24	26.42	3.39	39.69
	22	150.20	9.70	5.54	149.18	1.007	96.80	6.45	28.43	3.41	48.65
	Mean	**153.06**	**9.78**	**5.53**	**152.01**	**1.007**	**94.93**	**5.73**	**28.02**	**3.39**	**48.50**
	Overall Mean	**157.15**	**9.91**	**5.66**	**156.10**	**1.007**	**97.45**	**5.65**	**28.68**	**3.40**	**55.55**
	Range	**139.98-171.03**	**9.05-10.45**	**5.00-6.17**	**138.90-170.00**	**1.006-1.008**	**87.05-109.80**	**4.83-6.97**	**26.32-31.10**	**3.23-3.55**	**30.50-84.69**

4.4.1.10 Fruit Yield (kg/tree)

Data pertaining to fruit yield (kg/tree) under different locations of mango orchards are presented in Table 9. From the data it is evident that average fruit yield of mango varied from 30.50 kg per tree to 84.69 kg per tree with the mean value of 55.55 kg per tree. The maximum mean fruit yield of 61.09 kg per tree was recorded in orchards at Akhnoor while, the minimum mean fruit yield of 48.50 kg per tree was recorded at Samba.

4.4.2 Chemical characteristics

4.4.2.1 Total soluble solids (^{0}Brix)

The data pertaining to chemical characteristics of fruits of different mango orchards of Akhnoor and Samba are presented in Table 10.

Total soluble solids (TSS) of fruits in different locations of mango orchards are presented in Table 10. From the data it is evident that irrespective of the location average total soluble solids of mango fruit varied from 17.11 Brix^0 to 20.17 Brix^0 with the mean value of 17.69 Brix^0. The higher total soluble solids content of 17.97 Brix^0 was recorded in orchards at Akhnoor while, lower total soluble solids of 17.32 Brix^0 was recorded in fruits of mango orchards at Samba.

4.4.2.2 Titrable acidity (per cent)

Data pertaining to titrable acidity under different locations of mango orchards are presented in Table 10. From the data it is evident that average titrable acidity of mango varied from 0.21 per cent to 0.28 per cent with the mean value of 0.24 per cent. Orchards of Akhnoor had higher mean titrable acidity of 0.25 per cent as compared in orchard at Akhnoor while, minimum titrable acidity 0.24 per cent was found at Samba.

4.4.2.3 TSS: Acidity

Data related to TSS: acidity of two locations of mango orchards are presented in Table 10. A perusal of data indicated that average TSS: acidity of mango fruit varied from 66.55 to 82.19 with the mean value of 72.82. The mean TSS: acidity (73.43) was higher in fruits of orchards at Samba while, it was lower (72.35) in fruits of orchards at Akhnoor.

4.4.2.4 Total Sugars

The data presented in Table 10 showed that irrespective of the location, fruit total sugar content varied from 12.58 to 15.27 per cent with mean value of 13.93 per cent. The higher mean total sugar content was observed 14.18 per cent in fruits of orchards at Akhnoor, whereas, it was lower in fruits of orchards at Samba whereas lowest mean of sugar content was found in Samba.

4.4.2.5 Reducing sugar

The range of reducing sugar content varied from 2.95 to 3.98 per cent with mean value of 3.48 per cent as presented in table 10. Reducing sugar content was found higher (3.58 per cent) in orchards at Akhnoor while lower sugar content of 3.36 per cent was found in orchards at Samba.

4.4.2.6 Non –reducing sugar

It is revealed that non –reducing sugar content varied from 9.63 to 11.29 per cent with mean value of 10.45 per cent as presented in Table 10. The higher mean non – reducing sugar content of 10.60 per cent was observed in orchards at Akhnoor. Whereas, lower value was reduced at Samba with 10.25 per cent.

4.4.2.7 Ascorbic Acid (mg /100g pulp)

Data related to ascorbic acid of two locations of mango orchards are presented in Table 10. A perusal of data indicated that average ascorbic acid varied from 35.59 to 41.82 mg /100g pulp with the mean value of 39.23 mg/100 g pulp. The mean ascorbic acid (39.79 mg/100 pulp) was higher in fruits of orchards at Akhnoor while, it was lower (38.52 mg /100 pulp) in fruits of orchards at Samba.

4.5 Relationship of available soil nutrients with soil properties, leaf nutrients and fruit characteristics

The relationship between soil nutrients and soil properties; leaf nutrient content and soil properties; available soil nutrients and leaf nutrient status; leaf nutrients and fruit characteristics has been calculated on the basis of coefficient of correlation (r) for mango orchards at both the locations.

Table 10. Chemical characteristics of mango fruits of Jammu region

Location	Orchard No.	Total Soluble Solids (Brix^0)	Titrable acidity (%)	TSS: acidity	Ascorbic acid (mg/100g)	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)
Akhnoor	1	17.30	0.26	66.55	40.62	14.30	3.64	10.66
	2	17.32	0.26	66.63	40.69	14.33	3.66	10.67
	3	17.24	0.24	71.82	39.60	13.16	3.40	9.76
	4	17.27	0.25	69.09	39.80	14.00	3.50	10.50
	5	19.25	0.26	74.05	41.73	15.04	3.90	11.14
	6	18.83	0.25	75.32	40.93	14.71	3.78	10.93
	7	17.44	0.26	67.08	40.82	14.38	3.65	10.73
	8	17.27	0.24	71.94	39.75	13.62	3.46	10.16
	9	17.31	0.24	72.11	39.85	14.03	3.53	10.50
	10	18.46	0.25	73.84	40.90	14.64	3.74	10.90
	11	18.26	0.24	76.10	40.87	14.55	3.72	10.83
	12	20.17	0.28	72.04	41.82	15.27	3.98	11.29
	13	20.03	0.26	77.05	41.78	15.10	3.94	11.16
	14	19.23	0.26	73.96	40.99	14.84	3.80	11.04
	15	20.09	0.27	74.41	41.80	15.15	3.96	11.19
	16	19.16	0.26	73.68	41.70	15.05	3.89	11.16

	17	19.34	0.27	71.64	41.75	15.08	3.92	11.16
	18	17.30	0.24	72.10	39.78	13.92	3.49	10.43
	19	17.15	0.23	74.57	37.45	13.45	3.27	10.18
	20	17.15	0.23	74.58	37.30	13.43	3.25	10.18
	21	17.25	0.24	71.86	38.68	13.89	3.42	10.47
	22	17.24	0.24	71.83	38.66	13.87	3.41	10.46
	23	17.17	0.23	74.65	37.50	13.47	3.29	10.19
	24	17.25	0.25	68.99	38.70	13.92	3.47	10.45
	25	17.20	0.24	71.68	37.98	13.69	3.34	10.35
	26	17.19	0.23	74.74	37.52	13.56	3.28	10.28
	27	17.25	0.25	69.01	38.69	13.89	3.45	10.44
	28	17.11	0.23	74.41	36.40	12.63	3.00	9.63
	Mean	**17.97**	**0.25**	**72.35**	**39.79**	**14.18**	**3.58**	**10.60**
Samba	1	17.51	0.25	70.04	40.70	14.42	3.68	10.74
	2	17.57	0.26	67.56	40.86	14.53	3.70	10.83
	3	17.28	0.24	71.99	39.95	13.72	3.48	10.24
	4	17.29	0.25	69.15	40.70	14.38	3.67	10.71
	5	17.26	0.21	82.19	39.54	13.17	3.42	9.75
	6	17.26	0.22	78.47	39.55	13.00	3.42	9.85
	7	17.27	0.23	75.09	39.67	13.52	3.44	10.08

	8	19.13	0.26	73.58	40.95	14.74	3.77	10.97
	9	17.16	0.23	74.62	37.48	13.54	3.28	10.26
	10	17.19	0.24	71.64	37.55	13.59	3.32	10.27
	11	17.13	0.22	77.85	35.59	12.58	2.95	9.63
	12	17.18	0.23	74.70	37.42	13.51	3.27	10.24
	13	17.13	0.23	74.49	36.59	12.65	3.00	9.65
	14	17.18	0.24	71.60	37.43	13.41	3.26	10.15
	15	17.22	0.24	71.75	38.64	13.72	3.35	10.37
	16	17.21	0.24	71.71	37.95	13.66	3.33	10.33
	17	17.19	0.23	74.74	37.91	13.59	3.31	10.28
	18	17.19	0.24	71.63	37.92	13.61	3.32	10.29
	19	17.20	0.24	71.65	38.20	13.64	3.32	10.32
	20	17.17	0.24	71.56	37.89	13.56	3.30	10.26
	21	17.14	0.23	74.52	36.98	12.90	3.00	9.90
	22	17.23	0.23	74.93	38.00	13.85	3.39	10.46
	Mean	**17.32**	**0.24**	**73.43**	**38.52**	**13.60**	**3.36**	**10.25**
	Overall Mean	**17.69**	**0.24**	**72.82**	**39.23**	**13.93**	**3.48**	**10.45**
	Range	**17.11-20.17**	**0.21-0.28**	**66.55-82.19**	**35.59-41.82**	**12.58-15.27**	**2.95-3.98**	**9.63-11.29**

4.5.1 Relationship of available soil nutrients with soil properties of mango orchards

A perusal of data predicted in Table 11 shows the relationship of available soil nutrient elements viz., nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper and manganese with soil pH, electrical conductivity and organic carbon contents. The perusal of data reveals that the soil pH of the surface layer 0-30 cm was significantly and positively correlated with available magnesium (r=0.285**) and available copper (r=0.319*). For the sub- surface layer (30-60 cm) the soil pH was found to be positively and significantly correlated with available copper (r=0.295*). A positive and significant correlation of electrical conductivity was found with available soil calcium (r=0.551), magnesium (r=0.601**) and copper (r=0.414*). For the sub- surface layer (30- 60) cm layer electrical conductivity was found to be significantly and positively correlated with available calcium (r= 0.574**), magnesium (0.639**) and copper (r=0.420**) and for the sub-surface layer (60-90) cm the available calcium (r=0.573**), available magnesium (r= 0.647**) and copper (r=0.420**).The organic carbon content in the surface soil (0-30 cm) was found to be significantly and positively correlated with available soil nitrogen (r=0.477**), phosphorus (r=0.429**), calcium (r=0.758**), magnesium (r= 0.788**), zinc(0.282*) and copper (r=0.635**) and manganese (r=0.290*). For the sub- surface layer (30-60 cm) it was found to be positively and significantly correlated with available nitrogen (r=0.473**), phosphorus (r=0.429**), calcium (r= 0.747**), magnesium (r=0.782**) and copper (r=0.631**). The organic carbon content was positively and significantly correlated with available nitrogen (r= 0.504**), available phosphorus (r=0.395**), available calcium (r=0.763**), available magnesium (r=0.778**) and available copper (r=0.657**).

4.5.2 Relation of soil properties with macro and micro leaf nutrients of mango orchards at Akhnoor region

A perusal of data presented in Table 12, showed that soil pH, electrical conductivity and organic carbon contents of soil of mango orchards was not significantly correlated with the leaf nutrients viz., N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn .

4.5.3 Relation of soil properties with macro and micro leaf nutrients of mango orchards at Samba region

The perusal of the data in Table 13 shows the relationship of leaf nutrient elements with soil pH, EC and organic carbon contents. The correlation of the soil pH was non significant with leaf nutrients N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn for the soil depth 0-30 cm and 30-60 cm. While, for 60-90 cm soil depth, the soil pH was significantly and positively correlated with available N(r=0.455*), P(r=0.427*), S(r=0.501*), Zn (r=0.465*) and Mn (r=0.433*). The electrical conductivity and organic carbon content of soil were not significantly correlated with all the leaf nutrients viz., N, P, K, Ca, Mg, S, Zn, Fe, Cu and Mn .

4.5.4 Relationship of available soil nutrients with leaf nutrients of mango orchards of Jammu region from the surface layer 0-30 cm

The data presented in Table 14 showed that the available magnesium from the surface soil was significant but negatively correlated with leaf nitrogen (r=-0.380*) and leaf sulphur (r=-0.482**) and the available soil zinc showed significant but negative correlation with leaf copper (r=-0.469*).

4.5.5 Relationship of soil properties with leaf nutrients of mango orchards of Jammu region from the sub- surface layer 30-60 cm

Data related to correlation presented in Table 15 found that the at 30-60 cm soil depth, available phosphorous was significantly and negatively correlated with leaf nitrogen (r =-0.406*). Available soil potassium showed negative but significant correlation with leaf phosphorous (r=-0.377*) and manganese (r=-0.375*). The available soil zinc showed negative but significant relationship with leaf copper (r = -0.474*).

4.5.6 Relationship of soil nutrients with leaf nutrients of mango orchards of Jammu region from 60-90 cm soil depth

The data presented in Table 16 showed the negative but significant relationship of soil available phosphorus content with leaf nitrogen (r= -0.435) and available soil magnesium showed significant but negative correlation with leaf nitrogen (r =-0.400), leaf sulphur (r=-0.497**) and with leaf iron (r=-0.380*). The available soil zinc showed highly significant but negative relationship with leaf copper (r =-0.482**).

Table 11. Relationship of soil chemical properties with soil macro and micro nutrients of mango orchards of Jammu region

Nutrient elements (soil)	Soil pH			Electrical conductivity			Organic carbon		
	Soil depth (cm)			Soil depth (cm)			Soil depth(cm)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Nitrogen	0.048	-0.009	-0.068	0.202	0.201	0.206	0.477**	0.473**	0.504**
Phosphorus	0.147	0.131	0.107	0.183	0.192	0.206	0.429**	0.429**	0.395**
Potassium	0.120	0.097	0.076	0.143	0.171	0.176	0.053	0.049	0.045
Sulphur	0.230	0.170	0.102	0.250	0.235	0.263	0.269	0.265	0.267
Calcium	0.165	0.115	0.060	0.551**	0.574**	0.573**	0.758**	0.747**	0.763**
Magnesium	0.285*	0.207	0.105	0.601**	0.639**	0.647**	0.788**	0.782**	0.778**
Zinc	-0.018	-0.069	-0.078	0.228	0.233	0.239	0.282*	0.274	0.250
Iron	0.242	0.193	0.112	0.112	0.133	0.142	0.272	0.266	0.270
Copper	0.319*	0.295*	0.247	0.414**	0.420**	0.420**	0.635**	0.631**	0.657**
Manganese	0.067	0.012	-0.066	0.127	0.132	0.145	0.290*	0.270	0.272

Table 12. Relationship of soil chemical properties with macro and micro leaf nutrients of mango orchards of Akhnoor region

Nutrient elements (leaf)	Soil pH			Electrical conductivity			Organic carbon		
	Soil depth (cm)			Soil depth (cm)			Soil depth(cm)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Nitrogen	-0.114	-0.113	-0.109	-0.098	-0.077	-0.047	-0.331	-0.337	-0.341
Phosphorus	-0.093	-0.094	-0.090	-0.023	0.008	0.033	-0.343	-0.339	-0.338
Potassium	-0.075	-0.079	-0.078	-0.011	0.018	0.040	-0.168	-0.162	-0.163
Sulphur	-0.198	-0.197	-0.194	-0.138	-0.107	-0.075	-0.308	-0.316	-0.316
Calcium	-0.034	-0.031	-0.030	-0.109	-0.082	-0.050	-0.320	-0.325	-0.322
Magnesium	0.050	0.051	0.050	-0.184	-0.157	-0.128	-0.202	-0.201	-0.196
Zinc	0.028	0.030	0.030	-0.125	-0.095	-0.062	-0.266	-0.268	-0.267
Iron	-0.004	-0.002	-0.001	-0.057	-0.028	0.009	-0.315	-0.316	-0.311
Copper	0.077	0.080	0.084	-0.005	0.009	0.033	-0.302	-0.307	-0.295
Manganese	0.114	0.118	0.118	-0.045	-0.026	0.014	-0.221	-0.224	-0.222

****Correlation is significant at the 0.01 level**
***Correlation is significant at the 0.05 level**

Table 13. Relationship of soil chemical properties with macro and micro leaf nutrients of mango orchards of Samba region

Nutrient elements (leaf)	Soil pH			Electrical conductivity			Organic carbon		
	Soil depth (cm)			Soil depth (cm)			Soil depth(cm)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Nitrogen	0.242	0.335	0.455*	0.067	0.068	0.051	0.117	0.124	0.104
Phosphorus	0.152	0.232	0.427*	0.257	0.223	0.227	0.061	0.055	0.035
Potassium	0.025	0.088	0.292	-0.057	-0.101	- 0.096	- 0.167	- 0.182	- 0.188
Calcium	0.124	0.208	0.385	-0.066	-0.080	- 0.097	- 0.123	- 0.124	- 0.140
Magnesium	0.043	0.119	0.320	0.005	-0.012	- 0. 021	- 0.156	- 0.171	- 0.164
Sulphur	0.229	0.339	0.501*	0.105	0.092	0.071	- 0.145	- 0.139	- 0.166
Zinc	0.193	0.285	0.465*	-0.046	- 0.045	- 0.041	0.005	0.007	- 0.017
Iron	0.235	0.303	0.401	0.061	0.033	0.014	- 0.088	- 0.088	- 0.118
Copper	0.186	0.235	0.302	- 0.028	-0.046	- 0.078	- 0. 129	- 0.106	- 0.160
Manganese	0.255	0.299	0.433*	0.141	0.163	0.159	0.158	0.156	0.148

****Correlation is significant at the 0.01 level**
***Correlation is significant at the 0.05 level**

Table 14. Relationship of soil available nutrients with leaf nutrients of mango orchards of Jammu region from the surface layer

Soil	**Nitrogen**	**Phosphorus**	**Potassium**	**Sulphur**	**Calcium**	**Magnesium**	**Zinc**	**Iron**	**Copper**	**Manganese**
Leaf	0-30 cm									
Nitrogen	-0.251	-0.279	-0.059	0.130	-0.246	-0.380*	-0.020	-0.046	-0.035	0.066
Phosphorus	-0.183	-0.194	-0.348	0.131	-0.154	-0.216	-0.101	-0.103	0.048	0.107
Potassium	-0.076	-0.277	-0.069	0.165	-0.099	-0.141	0.012	0.090	0.055	0.333
Sulphur	-0.306	-0.123	-0.211	0.227	-0.232	-0.482**	-0.218	0.003	-0.139	-0.070
Calcium	-0.232	-0.111	-0.208	0.097	-0.204	-0.338	-0.123	0.119	-0.040	0.120
Magnesium	-0.227	-0.220	-0.219	0.118	-0.232	-0.295	-0.197	0.157	-0.053	0.173
Zinc	-0.262	0.029	-0.216	0.106	-0.149	-0.241	-0.245	0.227	-0.012	0.107
Iron	-0.267	-0.122	-0.118	0.139	-0.245	-0.359	-0.070	0.075	-0.100	0.099
Copper	-0.137	0.110	-0.269	0.237	0.125	0.019	-0.469*	0.125	0.147	0.024
Manganese	-0.167	-0.209	-0.347	0.132	-0.149	-0.221	-0.108	-0.106	0.062	0.095

Table 15. Relationship of available soil nutrients with leaf nutrients of mango orchards of Jammu region from sub- surface soil depth

Soil	Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium	Zinc	Iron	Copper	Manganese
Leaf	30-60 cm									
Nitrogen	-0.261	-0.406*	-0.095	0.124	-0.237	-0.236	-0.023	-0.101	-0.007	0.083
Phosphorus	-0.221	-0.247	-0.377*	0.097	-0.155	-0.120	-0.108	-0.117	0.071	0.111
potassium	-0.087	-0.295	-0.036	0.126	-0.072	-0.061	0.004	0.084	0.073	0.340
Sulphur	-0.321	-0.236	-0.248	0.202	-0.232	-0.369	-0.228	-0.041	-0.113	-0.062
Calcium	-0.240	-0.251	-0.232	0.065	-0.202	-0.242	-0.131	0.086	-0.025	0.123
Magnesium	-0.217	-0.262	-0.205	0.068	-0.226	-0.219	-0.204	.0131	-0.033	0.173
Zinc	-0.262	0.013	-0.239	0.062	-0.136	-0.172	-0.251	0.203	0.015	0.105
Iron	-0.269	-0.230	-0.131	0.117	-0.243	-0.277	-0.077	0.027	-0.082	0.098
Copper	-0.167	0.093	-0.362	0.170	0.125	-0.006	-0.474*	0.154	0.174	0.023
Manganese	-0.203	-0.257	-0.375*	0.102	-0.150	-0.125	-0.115	-0.119	0.084	0.098

Table 16. Relationship of available soil nutrients with leaf nutrients of mango orchards of Jammu region from 60-90 cm soil depth

Soil	Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium	Zinc	Iron	Copper	Manganese
Leaf	60-90 cm									
Nitrogen	0-.310	-0.435*	-0.125	0.132	-0.233	-0.400*	-0.022	-0.110	-0.004	0.088
Phosphorus	-0.288	-0.269	-0.348	0.111	-0.150	-0.237	-0.114	-0.108	0.072	0.118
Potassium	-0.094	-0.283	0.028	0.113	-0.062	-0.162	0.004	0.070	0.082	0.344
Sulphur	-0.356	-0.262	-0.230	0.219	-0.222	-0.497**	-0.228	-0.041	-0.103	-0.058
Calcium	-0.312	-0.273	-0.189	0.092	-0.195	-0.354	-0.133	0.099	-0.017	0.127
Magnesium	-0.255	-0.215	-0.149	0.108	-0.217	-0.302	-0.205	0.139	-0.024	0.173
Zinc	-0.326	0.012	-0.189	0.083	-0.129	-0.245	-0.258	0.221	0.027	0.103
Iron	-0.324	-0.238	-0.115	0.142	-0.235	-0.380*	-0.078	0.028	-0.073	0.112
Copper	-0.170	0.047	-0.356	0.234	0.126	0.005	-0.482**	0.165	0.187	0.020
Manganese	-0.270	-0.281	-0.345	0.115	-0.144	-0.243	-0.121	-0.109	0.085	0.104

4.6 Correlation of leaf nutrients with fruit characteristics.

4.6.1 Relationship of leaf nutrients with physical characteristics of mango fruit of Akhnoor region

A positive and significant correlation of fruit weight with leaf nutrients viz., N, P, K, S, Ca, Mg, Zn, Fe, and Mn with respective r –values of (0.599*), (0.692**), (0.437*), (0.594**), (0.598**), (0.519**), (0.470*), (0.583**), (0.694**) respectively is presented in table 17.

The relationship between fruit length and leaf N (r= 0.479**), P (r=0.649**), K (r=0.429*), S (r=0.500**), Ca (r=0.441*), Mg(r=0.410*), Zn(r=0.386*), Fe (r=0.465*) and Mn (r=0.640**) was found to be positive and significant, whereas, leaf Cu showed non-significant relationship. The correlation of fruit diameter with N (r=0.573**), P (r=0.732 **), K (r=0.493**), S (r=0.621**), Ca (r=0.662**), Mg (r=0.608**), Zn (r=0.600**), Fe (r=0.628**), and Mn (r=0.725**) was positive and significant. Fruit volume showed positive and significant correlation with leaf N(r= 0.599**), P(r=0.692**), K (r=0.437*), S(0.595**), Ca(r=0.599**), Mg(r=0.520**), Zn(0.470*), Fe(r=0.584**), Mn (r=0.694**), whereas negative but significant correlation of specific gravity with leaf N (r=-0.490**), P(r=-0.528**), K(r=-0.389*) S (r=-0.563**), Ca (r=-0.544**), Mg (r=-0.513**), Fe (r=-0.584**) and Mn (r=0.523**) whereas leaf Zn, and Cu showed non- significant relationship. Fresh pulp weight found to be highly positive and significantly correlated with leaf N, P, K, S, Ca, Mg, Zn, Fe, and Mn with respective r- values of (0.617**), (0.712**), (0.486**), (0.634**), (0.696**), (0.609**), (0.545**), (0.604**) and (0.708**), respectively. Dry weight of pulp showed positive and significant relationship with leaf N (r=0.749**), P (r=0.595**), K (r=0.563**), S (r=0.580**), Ca (r=0.636), Mg (r=0.504**), Zn (r=0.485**), Fe(r=490**) and Mn(r=0.603**) whereas dry weight of pulp showed non- significant relationship with leaf Cu (r=0.247). Stone weight exhibited positive and significant relationship with leaf N (r=0.598**), P (r= 0.698**), K (r=0.517**), S (r=0.604**), Ca (r=0.672**), Mg (r=0.606**), Zn (r=0.522*), Fe (r=0.616**) and Mn (r=0.690**) whereas, Cu (r=0.196) showed non-significant relationship. Pulp: stone ratio showed positive and significant correlation with leaf N (r=0.537**), P (r=0.597**), S (r=0.564**), Ca (r=0.602**), Mg (r=0.493**),Zn (r=0.468*), Fe (r=0.456*), and Mn (r=0.600**) whereas, leaf K (r=0.340) and Cu (r=0.277) showed non- significant relationship with pulp: stone ratio, respectively. The correlation between fruit yield and leaf N (r= 0.585**), P (r=0.727**), K (r=0.514**), S (r=0.602**), Ca (r=0.664**), Mg (r=0.605**), Zn (r=0.599**), Fe (r=0.634**) and Mn (r=0.719**) was significant and positive whereas leaf Cu (r=0.346) showed non-significant relationship with fruit yield.

4.6.2 Relationship of leaf nutrients with physical characteristics of mango fruit of Samba region

It is clear from the data in Table 18 that fruit weight, fruit length, fruit diameter, fruit volume, specific gravity, fresh and dry pulp weight, stone weight, pulp: stone ratio and fruit yield showed non-significant correlation with all leaf nutrients viz., nitrogen, phosphorous, potassium, sulphur, calcium, manganese, zinc, iron, copper and manganese .

4.6.3 Relationship of leaf nutrients with chemical characteristics of mango fruit of Akhnoor region

The relationship between total soluble solids (TSS) and leaf nitrogen (r=0.467*), phosphorous (r=0.602**), potassium (r=0.396*), sulphur (r=0.508**), calcium (r=0.604**), magnesium (r=0.585**), zinc (r=0.638**), iron (r=0.543**), copper (r=0.382*) and manganese (r=0.618*) were found to be highly significant (Table 19). A positive and highly significant correlation between titrable acidity and leaf nitrogen (r=0.480**), phosphorous (r=0.538**), sulphur (r=0.557**), calcium (r=0.551**), magnesium (r=503**) , zinc (r=0.554**), iron (r=0.465*), copper (r=400*) and manganese (r= 419*) whereas, non significant relationship of titrable acidity with leaf potassium (r=0.354). Total soluble solids: acid ratio showed positive but non- significant relationship with leaf nitrogen, phosphorous, potassium, calcium, magnesium, zinc, iron , copper and manganese with respective r-values of (0.012), (0.134), (0.080), (0.113), (0.158), (0.161),(0.144),(0.001) and (0.319). Total soluble solids: acid ratio showed negative and non significant correlation with leaf sulphur (r= -0.037).

A positive and highly significant correlation of ascorbic acid with leaf nitrogen (r= 0.614**), phosphorous (0.646**), potassium (r=0.472*), sulphur (r= 0.657**), calcium (r=0.679**), magnesium (r=0.599**), zinc (r=0.650**), iron (r=0.628**), copper (r=0.465*) and available manganese (r=0.522) was observed. Highly significant and positive correlation of total sugar was observed with leaf

Table 17. Relationship of leaf nutrients with physical characteristics of mango fruits of Akhnoor region

Nutrient elements (leaf)	Fruit weight	Fruit length	Fruit diameter	Fruit volume	Specific gravity	Fresh Pulp weight	Dry Pulp weight	Stone weight	Pulp: stone ratio	Yield
Nitrogen	0.599**	0.479**	0.573**	0.599**	-0.490**	0.617**	0.749**	0.598**	0.537**	0.585**
Phosphorus	0.692**	0.649**	0.732**	0.692**	-0.528**	0.712**	0.595**	0.698**	0.597**	0.727**
Potassium	0.437*	0.429*	0.493**	0.437*	-0.389*	0.486**	0.563**	0.517**	0.340	0.514**
Sulphur	0.594**	0.500**	0.621**	0.595**	-0.563**	0.634**	0.580**	0.604**	0.564**	0.602**
Calcium	0.598**	0.441*	0.662**	0.599**	-0.544**	0.696**	0.636**	0.672**	0.602**	0.664**
Magnesium	0.519**	0.410*	0.608**	0.520**	-0.513**	0.609**	0.504**	0.606**	0.493**	0.605**
Zinc	0.470*	0.386*	0.600**	0.470*	-0.343	0.545**	0.485**	0.522**	0.468*	0.599**
Iron	0.583**	0.465*	0.628**	0.584**	-0.480**	0.604**	0.490**	0.616**	0.456*	0.634**
Copper	0.253	0.313	0.299	0.253	-0.165	0.251	0.247	0.196	0.277	0.346
Manganese	0.694**	0.640**	0.725**	0.694**	-0.523**	0.708**	0.603**	0.690**	0.600**	0.719**

****Correlation is significant at the 0.01 level**
***Correlation is significant at the 0.05 level**

Table18. Relationship of leaf nutrients with physical characteristics of mango fruits of Samba region

Nutrient elements (leaf)	Fruit weight	Fruit length	Fruit diameter	Fruit volume	Specific gravity	Fresh Pulp weight	Dry Pulp weight	Stone weight	Pulp: stone ratio	Yield
Nitrogen	0.310	0.312	0.267	0.310	-0.195	0.390	0.095	0.368	0.272	0.349
Phosphorus	0.192	0.179	0.158	0.192	-0.036	0.190	0.118	0.240	0.021	0.349
Potassium	0.240	0.162	0.141	0.240	-0.056	0.152	0.041	0.176	0.042	0.304
Sulphur	0.128	0.121	0.108	0.128	-0.016	0.134	0.009	0.160	0.042	0.328
Calcium	0.290	0.234	0.215	0.291	-0.129	0.303	0.048	0.295	0.194	0.346
Magnesium	0.194	0.125	0.084	0.194	0.025	0.136	0.119	0.175	-0.008	0.281
Zinc	0.350	0.295	0.238	0.349	-0.101	0.356	0.195	0.330	0.254	0.301
Iron	0.136	0.087	0.003	0.135	0.100	0.115	0.173	0.099	0.096	0.164
Copper	0.165	0.207	0.173	0.165	0.022	0.281	0.095	0.226	0.274	0.237
Manganese	0.191	0.179	0.158	0.192	-0.035	0.191	0.119	0.240	0.022	0.349

****Correlation is significant at the 0.01 level**
***Correlation is significant at the 0.05 level**

Table 19. Relationship of leaf nutrients with chemical characteristics of mango fruits of Akhnoor region

Nutrient elements (leaf)	Total soluble solids	Titratable acidity	TSS :Acidity	Ascorbic acid	Total sugar	Reducing sugar	Non reducing sugar
Nitrogen	0.467*	0.480**	0.012	0.614**	0.497**	0.552**	0.458*
Phosphorus	0.602**	0.538**	0.134	0.646**	0.617**	0.632**	0.599**
Potassium	0.396*	0.354	0.080	0.472*	0.442*	0.461*	0.426*
Sulphur	0.508**	0.557**	-0.037	0.657**	0.555**	0.615**	0.512**
Calcium	0.604**	0.551**	0.113	0.679**	0.564**	0.647**	0.508**
Magnesium	0.585**	0.503**	0.158	0.599**	0.541**	0.604**	0.497**
Zinc	0.638**	0.554**	0.161	0.650**	0.552**	0.634**	0.497**
Iron	0.543**	0.465*	0.144	0.628**	0.504**	0.585**	0.452*
Copper	0.382*	0.400*	0.001	0.465*	0.318	0.403*	0.266
Manganese	0.618**	0.419*	0.319	0.522**	0.447*	0.519**	0.401*

****Correlation is significant at the 0.01 level**
***Correlation is significant at the 0.05 level**

nitrogen (r=0.497**), phosphorous (0.617**), potassium (r=0.442), sulphur (r=0.555**), calcium (r=0.564**), magnesium (r=0.541**), zinc (r=0.552**), iron (r=0.504**) manganese (r=0.447) and total sugars was found to be non- significant with leaf copper (r=0.318). Reducing sugar content had positive and highly significant relationship with nitrogen (r= 0.552**), phosphorous (r=0.632**), potassium (r=0.461*), sulphur (0.615**), calcium (r= 0.647**), magnesium (r=0.604*), zinc (r=0.634**), iron (r= 0.585*), copper (r=0.403*) and manganese (r=0.519*). A positive and significant relationship of non- reducing sugar with leaf nitrogen (r=0.458*), leaf phosphorus, (r=0.599**) leaf potassium (r=0.426*), leaf sulphur (r=0.512**), leaf calcium (r=0.508**), leaf magnesium (r=0.497**), leaf zinc (r=0.497**), leaf iron (r=0.452*) and leaf manganese (r=0.401*). Non reducing sugar exhibited non significant relationship with leaf available copper (r=0.266).

4.6.4 Relationship of leaf nutrients with chemical characteristics of mango fruits of Samba region

A perusal of data in Table 20, reveals a non-significant correlation of total soluble solids, titratable acidity, TSS: acidity, ascorbic acid, reducing sugar and non-reducing sugar with leaf nutrients viz., nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, zinc, iron, copper and manganese.

4.7 Diagnosis of leaf nutrient status of mango orchards using DRIS and sufficiency range diagnostic approach

4.7.1 Derivation of DRIS norms for mango

Diagnosis and Recommendation Integrated System (DRIS) norms were derived from a population of 85 high yielding mango trees. High yielding and low yielding sub-populations were separated, using a fruit yield level of 50 kg per tree as the cut off between high and low yielding sub-population. Tree yielding 50 kg/tree and above during 2017 and 2018 were separated to form high yielding population. The mean values of various nutrient expressions in high yielding groups were selected as the norms for calculation of DRIS indices. Means, coefficient of variations, variance and variance ratios obtained for different nutrient expressions (ratios, their reciprocals and products), from all possible nutrient pairs among nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, iron and zinc, copper and manganese are given in Table 21. From 55 nutrient pairs, 145 nutrient expressions were evaluated for their influence in achieving higher yields in mango. Separation of observation into low and high yielding sub-populations was made on the basis of total fruit yield in kg/tree. Variance ratio (variance of low yielding population v/s variance of high yielding population.) was used as the criteria for identifying the important nutrient expression that discriminate between high and low yielding sub- populations. Data in Table 21, depicts the various (DRIS) norms, derived from the current studies. The reference ratios/ DRIS norm expressions that produce highest variance ratios were selected as DRIS norms. The DRIS norm expressions, which produced highest variance, were selected as DRIS norms. In all there were 55 such ratios, out of such ratios and out of which 45 ratios were identified as important, as they significantly discriminate between high yielding and low yielding sub-populations. Among nutrient pairs involving macro-nutrients, N/P, N×K, N/S, Ca/N, N×Mg, Zn/N, N/Fe, Cu/N, N/Mn, P×K, P/S, Ca/P, Mg/P, Zn/P, P/Fe, Cu/P, P×Mn, K/S, Ca/K, K× Mg, Zinc/K, K/Fe, Cu/K, K× Mn, Ca/S, Mg/S, Zinc/S, Fe/S, Cu/S, Mn/S, Ca/Mg, Ca/Zn, Ca/Fe, Ca/Cu, Ca/Mn, Zn/Mg, Mg/Fe, Cu/Mg, Mg/Mn, Zn/Fe, Cu/Zn, Zn/Mn, Cu/Fe, Mn/Fe, Cu/Mn with corresponding mean values of 11.074, 0.005,10.248, 1.045, 1.559, 0.001, 86.679, 0.001, 142.609, 0.006, 0.930, 11.553, 3.783, 0.012, 7.898, 0.010, 0.003, 1.626, 6.736, 0.253, 0.007, 13.784, 0.006, 0.005, 10.691, 3.457, 0.011, 0.119, 0.009, 0.072, 3.125, 955.608, 90.283, 1133.510, 148.785, 0.003, 48.726, 0.095, 0.849, 0.157, 0.080, 0.613, 0.132 respectively and Coefficients of variation of 11.962, 22.455, 18.365, 4.305, 24.546, 9.585, 13.993, 10.709, 11.853, 27.599, 16.093, 11.794, 17.267, 14.199, 15.903, 13.803, 27.953, 20.622, 22.082, 33.060, 22.204, 19.567, 22.530, 27.378, 18.278, 13.942, 21.269, 18.102, 19.040, 15.947, 18.323, 9.535, 12.378, 9.477, 11.755, 18.161, 12.562, 22.511, 17.342, 12.156, 12.452, 14.181, 16.116, 15.947, 13.833 per cent, respectively were selected as DRIS norm expressions for mango.

4.7.2 Diagnosis of leaf nutrient status of mango orchards using DRIS and Sufficiency Range diagnostic approaches

Leaf nutrient status of mango orchards surveyed at different locations for nitrogen, phosphorous, potassium, calcium, magnesium, zinc, copper iron and manganese were diagnosed, using (DRIS) diagnostic approach and compared with diagnosis made by sufficiency range approach. DRIS indices for leaf nitrogen, phosphorous, potassium, calcium, magnesium, zinc, copper iron and manganese

Table 20. Relationship of leaf nutrients with chemical characteristics of mango fruit of Samba region

Nutrient elements (leaf)	Total soluble solids	Titratable acidity	TSS: Acidity	Ascorbic Acid	Total sugars	Reducing Sugar	Non-Reducing Sugar
Nitrogen	0.126	0.199	- 0.146	0.333	0.247	0.272	0.218
Phosphorus	0.021	0.059	- 0.027	0.145	0.166	0.173	0.151
Potassium	- 0.017	- 0.172	0.244	0.175	- 0.028	0.116	- 0.107
Sulphur	- 0.161	- 0.015	- 0.042	0.124	0.059	0.095	0.036
Calcium	0.015	0.037	0.000	0.275	0.144	0.217	0.096
Magnesium	- 0.007	0.092	- 0.078	0.141	0.097	0.130	0.075
Zinc	0.087	0.192	- 0.147	0.340	0.256	0.293	0.220
Iron	- 0.095	- 0.163	0.164	0.092	- 0.053	0.040	- 0.101
Copper	- 0.024	- 0.026	0.040	0.236	0.124	0.187	0.082
Manganese	- 0.114	0.187	- 0.268	0.069	0.058	0.018	0.081

****Correlation is significant at the 0.01 level**
***Correlation is significant at the 0.05 level**

Table 21. Mean, coefficient of variation and variances of various nutrient expressions for plant macro- and micro-nutrients in low and high yielding populations of mango orchards

S.NO.	Nutrients	Low yielding population				High yielding population				Ratio
		Mean	SD	CV (%)	Variance (Sa)	Mean	SD	CV (%)	Variance (Sb)	(Sa/Sb)
1	N	1.812	0.317	17.511	0.10068678	2.116	0.132	6.260	0.01753846	5.74
2	P	0.145	0.031	21.291	0.00094764	0.194	0.027	14.152	0.00075262	1.26
3	K	0.255	0.059	23.272	0.00352174	0.340	0.066	19.505	0.00438785	0.80
4	S	0.134	0.068	50.786	0.00464275	0.213	0.040	18.949	0.00163015	2.85
5	Ca	2.004	0.136	6.766	0.01839058	2.207	0.118	5.351	0.01394354	1.31
6	Mg	0.540	0.124	22.888	0.01529982	0.731	0.151	20.584	0.02265062	0.68
7	Zn	0.002	0.000	20.051	0.00000014	0.002	0.0003	11.954	0.00000008	1.75
8	Fe	0.017	0.005	31.007	0.00002668	0.025	0.004	16.371	0.00001662	1.61
9	Cu	0.002	0.000	22.866	0.00000016	0.002	0.0002	10.908	0.00000005	3.20
10	Mn	0.011	0.002	21.295	0.00000572	0.015	0.002	13.983	0.00000443	1.29
11	N/P	12.761	2.146	16.814	4.60363094	11.074	1.325	11.962	1.75464638	2.62
12	P/N	0.080	0.013	15.980	0.00016499	0.722	0.011	12.007	0.00012085	1.37
13	N×P	0.268	0.091	34.034	0.00833761	10.248	0.075	18.083	0.00555078	1.50

14	N/K	7.238	1.158	16.002	1.34159930	1.045	1.369	21.173	1.87397928	0.72
15	K/N	0.141	0.022	15.268	0.00046577	1.559	0.030	18.468	0.00087863	0.53
16	N×K	0.475	0.179	37.686	0.03206100	0.005	0.162	22.455	0.02625301	1.22
17	N/S	16.476	7.248	43.993	52.53858652	10.248	1.882	18.365	3.54193907	14.83
18	S/N	0.072	0.029	40.037	0.00082161	0.100	0.016	15.648	0.00024623	3.34
19	N×S	0.258	0.159	61.612	0.02526194	0.454	0.104	22.884	0.01080999	2.34
20	N/Ca	0.899	0.113	12.557	0.01273612	0.959	0.039	4.081	0.00153192	8.39
21	Ca/N	1.133	0.170	15.034	0.02901588	1.045	0.045	4.305	0.00202217	14.48
22	NxCa	3.669	0.851	23.198	0.72436360	4.680	0.501	10.697	0.25060512	2.88
23	N/Mg	3.404	0.480	14.103	0.23051259	2.998	0.566	18.874	0.32006351	0.72
24	Mg/N	0.300	0.043	14.492	0.00188417	0.344	0.059	17.180	0.00349430	0.54
25	NxMg	1.007	0.380	37.702	0.14423849	1.559	0.383	24.546	0.14645104	0.98
26	N/Zn	974.939	128.448	13.175	16498.89230722	915.693	86.439	9.440	7471.62002654	1.79
27	Zn/N	0.001	0.0002	18.502	0.00000004	0.001	0.0002	9.585	0.00000001	2.17
28	N×Zn	0.004	0.001	32.079	0.00000126	0.005	0.001	16.176	0.00000064	1.89
29	N/Fe	113.818	23.204	20.387	538.41935467	86.679	12.129	13.993	147.10370973	3.22
30	Fe/N	0.009	0.002	19.441	0.00000314	0.012	0.002	13.510	0.00000252	1.09

31	N×Fe	0.031	0.014	44.336	0.00019305	0.053	0.011	20.474	0.00011765	1.55
32	N/Cu	1082.204	215.592	19.922	46479.75359853	1087.003	109.847	10.106	12066.39472232	3.85
33	Cu/N	0.001	0.000	24.317	0.00000006	0.001	0.0001	10.709	0.00000001	5.58
34	N×Cu	0.003	0.001	33.844	0.00000117	0.004	0.001	14.354	0.00000036	3.26
35	N/Mn	164.303	27.627	16.815	763.27228577	142.609	16.903	11.853	285.70403301	2.67
36	Mn/N	0.006	0.001	15.999	0.00000100	0.007	0.001	11.824	0.00000071	1.41
37	N×Mn	0.008	0.000	0.001	1.61663778	0.032	0.006	17.927	0.00003288	1.53
38	P/K	0.573	0.073	12.746	0.00532553	0.590	0.144	24.383	0.02070958	0.26
39	K/P	1.776	0.248	13.974	0.06157396	1.769	0.334	18.867	0.11134214	0.55
40	P×K	0.038	0.017	43.795	0.00028105	0.066	0.018	27.599	0.00033610	0.84
41	P/S	1.332	0.636	47.745	0.40450416	0.930	0.150	16.093	0.02238403	18.07
42	S/P	0.919	0.411	44.748	0.16901521	1.102	0.172	15.572	0.02942910	5.74
43	P×S	0.020	0.013	64.178	0.00017218	0.042	0.013	30.128	0.00016023	1.07
44	P/Ca	0.072	0.013	17.662	0.00016088	0.088	0.010	11.392	0.00009977	1.61
45	Ca/P	14.356	2.604	18.137	6.77899895	11.553	1.362	11.794	1.85632727	3.65
46	P×Ca	0.292	0.077	26.395	0.00595487	0.430	0.078	18.193	0.00611195	0.97
47	P/Mg	0.271	0.047	17.392	0.00222722	0.273	0.052	19.238	0.00274825	0.81

48	Mg/P	3.787	0.641	16.933	0.41116520	3.783	0.653	17.267	0.42663956	0.96
49	PMg	0.081	0.034	42.481	0.00117358	0.144	0.046	31.576	0.00207117	0.57
50	P/Zn	78.668	17.478	22.218	305.48736119	83.625	11.017	13.174	121.37138802	2.52
51	Zn/P	0.013	0.004	28.193	0.00001441	0.012	0.002	14.199	0.00000299	4.82
52	P×Zn	0.000	0.000	35.347	0.00000001	0.000	0.000	23.070	0.00000001	0.87
53	P/Fe	9.092	2.164	23.798	4.68222256	7.898	1.256	15.903	1.57775298	2.97
54	Fe/P	0.115	0.025	21.896	0.00063954	0.129	0.019	14.902	0.00037217	1.72
55	P×Fe	0.003	0.001	49.498	0.00000154	0.005	0.001	27.412	0.00000179	0.86
56	P/Cu	87.495	24.809	28.354	615.47420444	99.161	12.857	12.966	165.30225071	3.72
57	Cu/P	0.012	0.004	32.144	0.00001592	0.010	0.001	13.803	0.00000200	7.94
58	P×Cu	0.000	0.0001	35.987	0.00000001	0.000	0.000	22.394	0.00000001	1.12
59	P/Mn	12.876	0.022	0.171	0.00048311	12.881	0.151	1.172	0.02279666	0.02
60	Mn/P	0.078	0.000	0.171	0.00000002	0.078	0.001	1.231	0.00000091	0.02
61	P×Mn	0.002	0.001	42.465	0.00000052	0.003	0.001	27.953	0.00000069	0.75
62	K/S	2.282	0.950	41.623	0.90197893	1.626	0.335	20.622	0.11248491	8.02
63	S/K	0.508	0.192	37.882	0.03697588	0.641	0.134	20.965	0.01806603	2.05
64	K×S	0.037	0.027	71.234	0.00070425	0.074	0.023	31.086	0.00052288	1.35

65	K/Ca	0.126	0.021	16.970	0.00045864	0.154	0.027	17.713	0.00073996	0.62
66	Ca/K	8.132	1.311	16.117	1.71787353	6.736	1.353	20.082	1.82974305	0.94
67	K×Ca	0.518	0.157	30.275	0.02456215	0.753	0.168	22.249	0.02806637	0.88
68	K/Mg	0.473	0.040	8.398	0.00157625	0.475	0.101	21.323	0.01027263	0.15
69	Mg/K	2.129	0.168	7.881	0.02814566	2.197	0.471	21.454	0.22207879	0.13
70	K×Mg	0.144	0.072	49.588	0.00513227	0.253	0.084	33.060	0.00698771	0.73
71	K/Zn	137.210	25.151	18.330	632.56606628	146.792	29.756	20.271	885.42395790	0.71
72	Zn/K	0.008	0.002	20.744	0.00000245	0.007	0.002	22.204	0.00000249	0.98
73	K×Zn	0.000	0.000	41.183	0.00000004	0.001	0.000	26.016	0.00000004	0.97
74	K/Fe	15.851	3.062	19.317	9.37529137	13.784	2.697	19.567	7.27453220	1.29
75	Fe/k	0.065	0.010	15.782	0.00010497	0.075	0.014	18.890	0.00020138	0.52
76	K×Fe	0.004	0.003	56.438	0.00000645	0.009	0.003	30.398	0.00000681	0.95
77	K/Cu	152.245	35.096	23.052	1231.71612679	173.757	32.730	18.836	1071.22320207	1.15
78	Cu/k	0.007	0.002	27.110	0.00000357	0.006	0.001	22.530	0.00000182	1.96
79	K×Cu	0.000	0.000	41.502	0.00000003	0.001	0.000	25.177	0.00000003	1.23
80	K/Mn	22.864	3.197	13.981	10.21855683	22.779	4.300	18.875	18.48617612	0.55
81	Mn/K	0.044	0.006	12.708	0.00003193	0.046	0.011	24.315	0.00012413	0.26

82	K×Mn	0.003	0.001	43.846	0.00000170	0.005	0.001	27.378	0.00000199	0.85
83	S/Ca	0.065	0.030	45.829	0.00089994	0.096	0.015	15.192	0.00021287	4.23
84	Ca/s	18.992	9.523	50.142	90.68616904	10.691	1.954	18.278	3.81866243	23.75
85	S×Ca	0.276	0.155	56.191	0.02408304	0.474	0.111	23.353	0.01225296	1.97
86	S/Mg	0.237	0.083	34.882	0.00685552	0.295	0.044	14.769	0.00189803	3.61
87	Mg/S	4.823	2.030	42.082	4.11921680	3.457	0.482	13.942	0.23236111	17.73
88	S×Mg	0.080	0.057	72.110	0.00328675	0.160	0.059	36.546	0.00343965	0.96
89	S/Zn	68.601	26.692	38.908	712.43953579	91.445	13.646	14.922	186.19998578	3.83
90	Zn/S	0.017	0.007	39.758	0.00004508	0.011	0.002	21.269	0.00000574	7.85
91	S×Zn	0.000	0.000	63.826	0.00000003	0.001	0.000	27.963	0.00000002	1.51
92	S/Fe	7.811	2.673	34.217	7.14398103	8.625	1.483	17.199	2.20034998	3.25
93	Fe/S	0.144	0.055	38.390	0.00305986	0.119	0.022	18.102	0.00046696	6.55
94	S×Fe	0.003	0.002	78.902	0.00000395	0.005	0.002	32.204	0.00000303	1.30
95	S/Cu	76.585	32.469	42.396	1054.22478414	108.609	18.016	16.588	324.57351124	3.25
96	Cu/S	0.016	0.008	50.241	0.00006301	0.009	0.002	19.040	0.00000326	19.30
97	S×Cu	0.000	0.000	64.502	0.00000003	0.000	0.000	26.955	0.00000001	1.94
98	S/Mn	11.828	5.292	44.738	28.00300410	14.187	2.197	15.486	4.82655536	5.80

99	Mn/S	0.103	0.049	47.738	0.00243893	0.072	0.012	15.947	0.00013244	18.41
100	S×Mn	0.002	0.001	64.239	0.00000104	0.003	0.001	29.945	0.00000095	1.09
101	Ca/Mg	3.823	0.533	13.950	0.28436740	3.125	0.573	18.323	0.32790362	0.87
102	Mg/Ca	0.267	0.043	16.041	0.00183813	0.329	0.054	16.330	0.00289225	0.64
103	Ca×Mg	1.098	0.331	30.175	0.10972828	1.628	0.413	25.370	0.17054845	0.64
104	Ca/Zn	1100.241	212.430	19.308	45126.48009512	955.608	91.115	9.535	8301.85869104	5.44
105	Zn/Ca	0.001	0.000	16.507	0.00000002	0.001	0.000	9.338	0.00000001	2.46
106	Ca×Zn	0.004	0.001	25.268	0.00000093	0.005	0.001	16.236	0.00000070	1.32
107	Ca/Fe	128.928	30.669	23.788	940.58710852	90.283	11.175	12.378	124.87711746	7.53
108	Fe/Ca	0.008	0.002	25.092	0.00000425	0.011	0.001	12.086	0.00000184	2.30
109	Ca×Fe	0.034	0.013	37.549	0.00016233	0.055	0.012	21.263	0.00013844	1.17
110	Ca/Cu	1213.124	251.422	20.725	63212.92412627	1133.510	107.425	9.477	11540.12845577	5.48
111	Cu/Ca	0.001	0.000	20.156	0.00000003	0.001	0.000	9.435	0.00000001	4.24
112	Ca×Cu	0.003	0.001	27.387	0.00000091	0.004	0.001	14.497	0.00000040	2.31
113	Ca/Mn	184.834	33.492	18.120	1121.69923557	148.785	17.490	11.755	305.88685139	3.67
114	Mn/Ca	0.006	0.001	17.643	0.00000097	0.007	0.001	11.275	0.00000059	1.64
115	Ca×Mn	0.023	0.006	26.417	0.00003598	0.033	0.006	17.989	0.00003601	1.00

116	Mg/Zn	290.166	47.830	16.484	2287.67638699	312.911	47.377	15.141	2244.55479923	1.02
117	Zn/Mg	0.004	0.001	18.261	0.00000042	0.003	0.001	18.161	0.00000036	1.18
118	Mg×Zn	0.001	0.000	41.178	0.00000019	0.002	0.001	30.084	0.00000027	0.69
119	Mg/Fe	33.601	6.371	18.962	40.59489258	29.338	3.685	12.562	13.58252246	2.99
120	Fe/Mg	0.031	0.005	14.827	0.00002052	0.035	0.005	13.172	0.00002080	0.99
121	Mg×Fe	0.010	0.005	56.118	0.00002862	0.019	0.007	35.472	0.00004401	0.65
122	Mg/Cu	320.713	63.863	19.913	4078.48054399	374.377	75.985	20.296	5773.74409250	0.71
123	Cu/Mg	0.003	0.001	22.614	0.00000054	0.003	0.001	22.511	0.00000039	1.37
124	Mg×Cu	0.0010	0.0004	41.623	0.00000016	0.0014	0.0004	27.029	0.00000015	1.05
125	Mg/Mn	48.756	8.254	16.929	68.12554954	48.726	8.450	17.342	71.40569398	0.95
126	Mn/Mg	0.021	0.004	17.333	0.00001334	0.021	0.004	19.191	0.00001648	0.81
127	Mg×Mn	0.006	0.003	42.537	0.00000710	0.011	0.004	31.346	0.00001229	0.58
128	Zn/Fe	0.119	0.028	23.986	0.00080912	0.095	0.012	12.156	0.00013299	6.08
129	Fe/Zn	8.830	1.772	20.070	3.14038920	10.691	1.301	12.166	1.69190597	1.86
130	Zn×Fe	0.00002	0.00003	47.862	0.00000000	0.000	0.000	26.214	0.00000000	1.03
131	Zn/Cu	1.112	0.183	16.442	0.03344120	1.195	0.145	12.117	0.02095409	1.60
132	Cu/Zn	0.923	0.155	16.763	0.02394766	0.849	0.106	12.452	0.01118038	2.14

133	ZnxCu	0.000003	0.000001	38.859	0.000000000002	0.000005	0.000001	20.040	0.0000000000009	2.01
134	Zn/Mn	0.173	0.049	28.183	0.00238702	0.157	0.022	14.181	0.00049430	4.83
135	Mn/Zn	6.110	1.357	22.217	1.84267121	6.492	0.850	13.085	0.72165751	2.55
136	ZnxMn	0.00002	0.00001	35.386	0.0000000001	0.00004	0.00001	22.854	0.00000000007	0.89
137	Fe/Cu	9.783	2.373	24.258	5.63234009	12.748	2.042	16.019	4.17050811	1.35
138	Cu/Fe	0.109	0.031	28.496	0.00096720	0.080	0.013	16.116	0.00016789	5.76
139	FexCu	0.00003	0.00001	48.468	0.00000000021	0.00005	0.00001	23.485	0.00000000	1.56
140	Fe/Mn	1.487	0.326	21.896	0.10602335	1.668	0.251	15.033	0.06284666	1.69
141	Mn/Fe	0.706	0.168	23.798	0.02824309	0.613	0.098	15.947	0.00956526	2.95
142	FexMn	0.0002	0.0001	49.555	0.00000001	0.0004	0.0001	27.137	0.00000001	0.88
143	Cu/Mn	0.160	0.051	32.088	0.00262972	0.132	0.018	13.833	0.00033405	7.87
144	Mn/Cu	6.794	1.923	28.298	3.69682941	7.699	0.995	12.921	0.98947260	3.74
145	CuxMn	0.00002	0.00001	36.058	0.000000000050	0.00003	0.00001	22.130	0.00000000004	1.15

Table 22. Diagnosis and Recommendation Integrated System (DRIS) norms for mango

S.NO.	Nutrient expression	Mean	SD	CV (%)
1	N	2.116	0.132	6.260
2	P	0.194	0.027	14.152
3	K	0.340	0.066	19.505
4	S	0.213	0.040	18.949
5	Ca	2.207	0.118	5.351
6	Mg	0.731	0.151	20.584
7	Zn	0.002	0.0003	11.954
8	Fe	0.025	0.004	16.371
9	Cu	0.002	0.0002	10.908
10	Mn	0.015	0.002	13.983
11	N/P	11.074	1.325	11.962
12	N× K	0.005	0.162	22.455
13	N/S	10.248	1.882	18.365
14	Ca/N	1.045	0.045	4.305
15	N×Mg	1.559	0.383	24.546
16	Zn/N	0.001	0.0002	9.585
17	N/Fe	86.679	12.129	13.993
18	Cu/N	0.001	0.0001	10.709
19	N/Mn	142.609	16.903	11.853
20	P×K	0.066	0.018	27.599
21	P/S	0.930	0.150	16.093

22	Ca/P	11.553	1.362	11.794
23	Mg/P	3.783	0.653	17.267
24	Zn/P	0.012	0.002	14.199
25	P/Fe	7.898	1.256	15.903
26	Cu/P	0.010	0.001	13.803
27	P×Mn	0.003	0.001	27.953
28	K/S	1.626	0.335	20.622
29	Ca/K	6.736	1.353	20.082
30	K×Mg	0.253	0.084	33.060
31	Zn/K	0.007	0.002	22.204
32	K/Fe	13.784	2.697	19.567
33	Cu/K	0.006	0.001	22.530
34	K×Mn	0.005	0.001	27.378
35	Ca/S	10.691	1.954	18.278
36	Mg/S	3.457	0.482	13.942
37	Zn/S	0.011	0.002	21.269
38	Fe/S	0.119	0.022	18.102
39	Cu/S	0.009	0.002	19.040
40	Mn/S	0.072	0.012	15.947
41	Ca/Mg	3.125	0.573	18.323
42	Ca/Zn	955.608	91.115	9.535
43	Ca/Fe	90.283	11.175	12.378
44	Ca/Cu	1133.510	107.425	9.477
45	Ca/Mn	148.785	17.490	11.755
46	Zn/Mg	0.003	0.001	18.161

47	Mg/Fe	29.338	3.685	12.562
48	Cu/Mg	0.003	0.001	22.511
49	Mg/Mn	48.726	8.450	17.342
50	Zn/Fe	0.095	0.012	12.156
51	Cu/Zn	0.849	0.106	12.452
52	Zn/Mn	0.157	0.022	14.181
53	Cu/Fe	0.080	0.013	16.116
54	Mn/Fe	0.613	0.098	15.947
55	Cu/Mn	0.132	0.018	13.833

were calculated using DRIS norms derived in the present study and thereby DRIS order of nutrient requirement, indicating major relative deficiencies and excesses in different orchards at different locations in Jammu region during the year 2017 and 2018 were worked out which are described in the Table 23, 24 and 25.

4.7.3 Diagnosis of leaf nutritional status of mango orchards of Akhnoor

Data pertaining to DRIS indices, Nutrient Imbalance Index (NII), order of nutrient requirement and yield of orchards surveyed at Akhnoor is given in Tables 23, 24 and 25.

4.7.3.1 Nitrogen

Diagnosis by DRIS indices for leaf nitrogen ranged between from -41.01 to +9.05 with 50 per cent orchards showed positive indices (Table 24). Major relative excesses diagnosed in 3 per cent orchards while diagnosing with DRIS approach. In comparison to this, 10 per cent of the orchards were classified as deficient, using sufficiency range approach (Table 25).

4.7.3.2 Phosphorus

DRIS indices for leaf phosphorous ranged between -45.49 to + 25.68 with 53 per cent orchards showed negative indices (Table 24, 25). DRIS indices diagnosed 17 per cent orchards as having major relative major deficiency. However, sufficiency range approach diagnosed 3 per cent orchards as deficient.

4.7.3.3 Potassium

DRIS diagnostic approach showed potassium indices in the range of -22.88 to + 11.73 (Table 24) with 60 per cent orchards having negative indices. DRIS identified 10 per cent orchards in relatively deficient. In comparison to this none of the orchards were classified either as deficient or excess, using sufficiency range approach (Table 24, 25).

4.7.3.4 Sulphur

Leaf sulphur indices ranged from -74.57 to + 20.52 with 50 per cent orchards showing positive indices and 50 per cent orchards showed negative indices. (Table 24, 25). 21 per cent of the orchards were identified as having major relative excess using DRIS approach. In sufficiency range approach 10 per cent orchards having deficient (Table 24, 25).

4.7.3.5 Calcium

Diagnosis by DRIS approach indicated that leaf available calcium indices ranged from -9.85 to + 45.32 with 50 per cent orchards showed positive indices and 50 per cent orchards showed negative indices .(Table 24, 25). A Major relative deficiency was diagnosed in 25 per cent orchards while diagnosing with DRIS approach. In comparison to this 10 per cent of the orchards were classified as deficient, using sufficiency range approach (Table 24 and 25).

4.7.3.6 Magnesium

DRIS diagnostic showed available magnesium indices in the range of -16.28 to + 20.03 (Table 24, 25) with 82 per cent orchards having positive indices. DRIS identified 3 per cent orchards as relatively deficient. In comparison to this none of the orchards were classified either as deficient or excess, using sufficiency range approach. (Table 25).

4.7.3.7 Zinc

Leaf available zinc indices ranged from -10.24 to + 39.29 with 57 per cent orchards showing negative indices (Table 24, 25). 7 per cent of the orchards were identified as having major relative excess using DRIS approach. In sufficiency range approach 3 per cent orchards were classified as deficient (Table 25).

4.7.3.8 Iron

DRIS available iron indices were observed to vary from -48.84 to -12.75 with 67 per cent orchards showing negative leaf Fe indices (Table 24, 25).DRIS diagnostic approach revealed Fe as the major relative deficiency in 14 per cent orchards. However, sufficiency range approach could diagnose 14 per cent orchards deficient in leaf P (Table 25).

4.7.3.9 Copper

DRIS diagnostic approach showed available copper indices in the range of -7.69 to +48.45 (Table 24, 25) with 71 per cent orchards having positive indices. DRIS identified 39 per cent orchards in relatively excess. On the other hand sufficiency range approach diagnosed 7 per cent orchards in deficient category (Table 25).

4.7.3.10 Manganese

Diagnosis by DRIS approach indicated that leaf available manganese indices ranged from -18.25 to + 27.45 with 50 per cent orchards showed positive indices and 50 per cent orchards showed negative indices. (Table 24). Major relative excess was diagnosed in 3 per cent orchards while diagnosing with DRIS approach. In comparison to this none of the orchards were classified either as deficient or excess, using sufficiency range approach (Table 25).

4.7.4 Diagnosis of leaf nutritional status of mango orchards at Samba

The nutritional status as evaluated by DRIS diagnostic approach as well as by sufficiency range diagnostic approach at Samba location indicate the following nutritional deficiencies and excesses.

4.7.4.1 Nitrogen

Diagnosis by DRIS approach indicated that leaf available nitrogen indices ranged from -84.88 to +4.43 with 72 per cent orchards showed negative indices (Table 24). Major relative deficient diagnosed in 18 per cent orchards while diagnosing with DRIS approach. On the other hand sufficiency range approach diagnosed 22 per cent orchards in deficient category (Table 25).

4.7.4.2 Phosphorus

DRIS indices for leaf available phosphorous ranged from -35.59 to + 20.39 with 72 per cent orchards showed negative indices (Table 24). DRIS indices diagnosed 18 per cent orchards as having major relative deficient. However, none of the orchards were classified either as deficient or excess, using sufficiency range approach (Table 25).

4.7.4.3 Potassium

DRIS diagnostic approach showed available potassium indices in the range of -24.02 to +4.55 (Table 24) with 86 per cent orchards having negative indices. DRIS identified 4 per cent orchards in relatively deficient. In comparison to this none of the orchards were classified as deficient, using sufficiency range approach (Table 25).

4.7.4.4 Sulphur

Leaf available sulphur indices ranged from -133.91 to +24.79 with 77 per cent orchards showing negative indices (Table 24). 50 per cent of the orchards were identified as having major relative deficient using DRIS approach. In comparison to this 27 per cent of the orchards were classified as deficient, using sufficiency range approach (Table 25).

4.7.4.5 Calcium

Diagnosis by DRIS approach identified that leaf available calcium indices ranged from -5.80 to +57.03 with 86 per cent orchards showed positive indices (Table 24). Major relative excesses were diagnosed in 36 per cent orchards while diagnosing with DRIS approach. In comparison to this 13 per cent of the orchards were classified as deficient, using sufficiency range approach (Table 25).

4.7.4.6 Magnesium

DRIS diagnostic approach showed available manganese indices in the range of -4.32 to +28.90 (Table 24) with 72 per cent orchards having positive indices. DRIS identified none of the orchards relatively deficient or in relatively excess. However, none of the orchards were also classified either as deficient or excess, using sufficiency range approach. (Table 25).

4.7.4.7 Zinc

Leaf available zinc indices ranged from -4.31 to +24.30 with 81 per cent orchards showing positive indices (Table 24). Major relative excesses were diagnosed in 4 per cent orchards while diagnosing with DRIS approach. In sufficiency range approach 8 per cent orchards were classified as deficient.

4.7.4.8 Iron

DRIS available iron indices were observed to vary from -18.88 to +8.80 with 72 per cent orchards showing negative leaf Fe indices (Table 24). DRIS diagnostic approach revealed Fe as the major relative deficiency in 9 per cent orchards. However, sufficiency range approach could diagnose 27 per cent orchards in deficient category (Table 25).

Table 23. DRIS indices, nutrient imbalance index (NII) and order of requirement of leaf of mango orchards

Location	Orchard No.	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	(NII)	Order of requirement	Yield (kg/plant)
Akhnoor	1	0.09	-10.59	-5.15	9.89	1.59	0.24	-1.80	-2.01	12.89	-4.68	48.93	P>K>Mn>Fe>Zn>N>Mg>Ca>S>Cu	60.50
	2	1.01	-6.85	-4.29	11.8	0.76	-2.91	7.55	-9.49	5.44	-2.76	52.86	Fe>P>K>Mg>Mn>Ca>N>Cu>Zn>S	62.13
	3	-2.85	-19.14	-4.12	8.36	7.07	10.92	4.16	12.75	-5.26	-11.4	86.03	P>Mn>Cu>K>N>Zn>Ca>S>Mg>Fe	50.30
	4	-6.39	11.27	-6.73	2.68	-3.89	3.52	0.06	-8.09	-0.84	8.32	46.43	Fe>K>N>Ca>Cu>Zn>S>Mg>Mn>P	56.30
	5	7.35	-1.42	7.71	-5.37	-5.72	0.48	4.67	-2.94	-1.38	-3.71	40.75	Ca>S>Mn>Fe>P>Cu>Mg>Zn>K>N	82.32
	6	2.06	2.49	3.04	-1.35	-2.92	1.27	-1.16	1.07	-4.33	0.26	19.95	Cu>Ca>S>Zn>Mn>Fe>Mg>N>P>K	75.18
	7	-0.36	-1.49	-8.19	-0.02	3.96	1.90	4.30	-1.33	-1.58	2.76	25.89	K>Cu>P>Fe>N>S>Mg>Mn>Ca>Zn	63.20
	8	-0.12	2.45	-0.65	1.28	1.22	-16.28	6.12	2.46	1.37	2.32	34.37	Mg>K>N>Ca>S>Cu>Mn>P>Cu>Zn	53.00
	9	-1.91	3.36	3.47	-1.17	-0.22	0.78	-10.24	10.07	-4.60	0.91	36.73	Zn>Cu>N>S>Ca>Mg>Mn>P>K>Fe	59.20
	10	1.26	1.84	4.83	3.11	-5.8	2.18	-5.78	-4.72	5.34	-2.09	36.95	Ca>Zn>Fe>Mn>N>P>Mg>S>K>Cu	74.16
	11	-0.87	2.93	-4.05	-1.05	-2.63	2.53	-2.34	-2.29	5.52	2.41	26.62	K>Ca>Zn>Fe>S>N>Mn>Mg>P>Cu	72.98
	12	2.60	5.49	2.49	8.53	-9.57	3.92	-4.90	-6.66	0.35	-2.05	46.56	Ca>Fe>Zn>Mn>Cu>K>N>Mg>P>S	84.69

13	1.76	1.61	1.34	9.27	-7.15	2.05	-3.92	-7.02	4.17	-2.18	40.47	Ca>Fe>Zn>Mn>K>P>N>Mg>Cu>S	83.34
14	-0.32	12.22	-18.07	-3.16	3.33	-12.21	3.93	8.44	-7.69	13.96	83.33	K>Mg>Cu>S>N>Ca>Zn>Fe>P>Mn	78.77
15	0.88	6.56	3.6	3.82	-5.52	0.86	-1.95	-12.5	4.34	0.61	40.64	Fe>Ca>Zn>Mn>N>Mg>K>S>Cu>P	84.31
16	1.89	6.00	6.34	7.28	-9.85	0.98	-5.37	-4.73	1.83	-2.25	46.52	Ca>Zn>Fe>Mn>Mg>Cu>N>P>K>S	81.26
17	3.48	1.2	6.71	-1.18	-7.81	2.91	-1.88	-2.15	4.62	-3.5	35.44	Ca>Mn>Fe>Zn>S>P>Mg>N>Cu>K	82.35
18	1.19	-8.76	-0.56	4.66	-0.76	-0.62	1.4	0.87	-2.13	-5.21	26.16	P>Mn>Cu>Ca>Mg>K>Fe>N>Zn>S	56.25
19	-35.73	-16.32	-14.05	-74.57	37.94	20.03	31.75	-12.2	46.27	16.49	305.35	S>N>P>K>Fe>Mn>Mg>Zn>Ca>Cu	42.30
20	-41.01	-45.49	-13.97	-9.69	29.34	12.48	39.29	-17.89	48.45	-1.56	259.17	P>N>Fe>K>S>Mn>Mg>Ca>Zn>Cu	40.26
21	9.05	-1.48	-7.2	-0.84	11.51	10.84	7.3	-48.84	14.1	5.29	116.45	Fe>K>P>S>Mn>Zn>N>Mg>Ca>Cu	49.50
22	-9.32	-5.54	-8.39	11.15	9.27	-1.55	3.91	1.54	43.49	1.27	95.43	N>K>P>Mg>Mn>Fe>Zn>Ca>S>Cu	49.20
23	-1.06	-1.22	11.73	3.49	-9.23	2.11	-3.54	3.69	43.42	-5.46	85.95	Ca>Mn>Zn>P>N>Mg>S>Fe>K>Cu	43.50
24	-39.29	-9.24	-22.88	-51.83	45.32	17.51	27.78	-8.48	27.57	18.36	268.26	S>N>K>P>Fe>Mg>Mn>Cu>Zn>Ca	49.64
25	0.57	-28.84	-1.03	20.52	7.9	6.37	8.33	3.37	13.44	-18.25	108.58	P>Mn>K>N>Fe>Mg>Ca>Zn>Cu>S	47.85
26	-4.59	25.68	-5.11	-62.09	17.07	0.2	8.48	-11.01	35.44	27.45	197.12	S>Fe>K>N>Mg>Zn>Ca>P>Mn>Cu	43.55

Table 23. DRIS indices, nutrient imbalance index (NII) and order of requirement of leaf of mango orchards

Location	Sr. no.	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	NII	Order of requirement	Yield kg/plant
	27	2.97	-1.76	2.02	-3.43	-2.72	3.05	-0.27	-2.49	10.07	-2.08	30.86	S>Ca>Fe>Mn>P>Zn>K>N>Mg>Cu	49.55
	28	-1.49	-4.53	-7.78	-22.96	9.58	1.39	8.22	-2.94	14.21	5.41	78.51	S>K>P>Fe>N>Mg>Mn>Zn>Ca>Cu	34.92
Samba	1	0.56	-3.12	-2.54	12.39	-0.09	-0.59	1.35	-6.75	0.18	-1.43	29.00	Fe>P>K>Mn>Mg>Ca>Cu>N>Zn>S	65.75
	2	2.06	9.06	1.88	6.51	-0.44	1.50	-4.31	-17.55	-3.76	5.21	52.28	Fe>Zn>Cu>Ca>Mg>K>N>Mn>S>P	72.97
	3	-6.65	-8.29	-6.28	-26.19	6.07	0.30	20.43	8.80	9.19	3.05	95.25	S>P>N>K>Mg>Mn>Ca>Fe>Cu>Zn	55.20
	4	-4.03	-1.47	-6.12	-19.33	8.90	-0.79	5.58	3.15	9.20	5.40	63.97	S>K>N>P>Mg>Fe>Mn>Zn>Ca>Cu	63.90
	5	-12.24	-3.74	3.34	-1.59	5.76	-3.16	0.23	-0.9	13.87	-1.09	45.92	N>P>Mg>S>Mn>Fe>Zn>K>Ca>Cu	51.30
	6	1.05	-7.87	-1.25	-3.58	5.98	3.58	-0.96	4.1	2.54	-3.11	34.02	P>S>Mn>K>Zn>N>Cu>Mg>Fe>Ca	52.50
	7	-10.12	-15.09	-16.63	-26.11	29.2	6.35	24.3	-18.55	19.59	7.01	172.95	S>Fe>K>P>N>Mg>Mn>Cu>Zn>Ca	43.20
	8	2.63	2.48	-8.26	-89.9	26.17	12.71	17.75	-4.35	24.15	16.29	204.69	S>K>Fe>P>N>Mg>Mn>Zn>Cu>Ca	46.87
	9	-84.88	-2.45	-24.02	-56.12	57.03	21.69	19.54	-3.19	43.49	28.51	340.52	N>S>K>Fe>P>Zn>Mg>Mn>Cu>Ca	30.50
	10	-25.2	4.53	-13.31	-133.91	50.55	28.9	15.56	1.62	43.42	27.8	344.8	S>N>K>Fe>P>Zn>Mn>Mg>Cu>Ca	43.15
	11	3.26	-0.28	4.55	-5.98	-5.80	1.37	3.88	-4.66	6.46	-2.67	38.91	S>Ca>Fe>Mn>P>Mg>N>Zn>K>Cu	76.28

	12	-16.85	7.33	-2.57	-6.42	8.79	-4.32	-2.54	2.74	6.42	7.90	65.88	N>S>Mg>K>Zn>Fe>Cu>P>Mn>Ca	50.50
	13	-60.25	9.59	-21.06	-33.14	45.74	8.94	13.68	-18.88	27.57	27.53	266.38	N>S>K>Fe>Mg>P>Zn>Mn>Cu>Ca	36.50
	14	-21.98	-3.67	-19.4	-32.41	28.7	9.70	20.78	-9.65	13.44	14.73	174.46	S>N>K>Fe>P>Mg>Cu>Mn>Zn>Ca	42.28
	15	4.43	-35.59	-21.28	-11.46	25.99	6.07	18.77	-16.85	35.44	-5.92	181.8	P>K>Fe>S>Mn>N>Mg>Zn>Ca>Cu	48.20
	16	-8.88	-13.78	-11.06	24.79	1.18	-2.03	0.91	2.15	10.07	-3.56	78.41	P>K>N>Mn>Mg>Zn>Ca>Fe>Cu>S	47.70
	17	-4.17	-9.6	-4.78	7.70	3.17	-0.77	-0.61	-1.93	14.21	-3.61	50.55	P>K>N>Mn>Fe >Mg>Zn>Ca>S>Cu	46.50
	18	-4.27	-5.14	-12.84	-32.21	18.47	4.26	12.02	-4.5	46.27	8.56	148.54	S>K>P>Fe>N>Mg>Mn>Zn>Ca>Cu	46.95
	19	-0.22	-1.63	-3.33	4.43	1.43	0.27	1.06	-2.96	48.45	0.51	64.29	K>Fe>P>N>Mg>Mn>Zn>Ca>S>Cu	47.50
	20	-3.55	-8.03	-6.32	-8.96	7.01	1.14	4.92	-1.98	14.1	0.75	56.76	S>P>K>N>Fe>Mn>Mg>Zn>Ca>Cu	44.20
	21	-2.86	-6.40	-11.55	-25.28	15.54	3.97	10.38	-4.21	19.59	7.17	106.95	S>K>P>Fe>N>Mg>Mn>Zn>Ca>Cu	39.69
	22	-14.76	20.39	-14.67	-43.23	19.09	2.47	12.00	-12.64	24.15	25.84	189.24	S>N>K>Fe>Mg>Zn>Ca>P>Cu>Mn	48.65

Table 24 . Distribution of DRIS N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn indices at different locations

Location	Range of DRIS Indices										Orchards having positive indices (%)										Orchards having negative indices (%)									
	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn
Akhnoor	-41.01 to9.05	-45.49 to25.68	-22.88 to11.73	-74.57 to20.52	-9.85 to 45.32	-16.28 to20.03	-10.24 to39.29	-48.84 to12.75	-7.69 to48.45	-18.25 to27.45	50	46	39	50	50	82	42	32	71	50	50	53	60	50	50	17	57	67	28	50
Samba	-84.88 to4.43	-35.59 to20.39	-24.02 to4.55	-133.91 to24.79	-5.80 to57.03	-4.32 to28.90	-4.31 to24.30	-18.88 to8.80	-3.76 to 48.45	-5.92 to 28.51	27	27	13	22	86	72	81	27	95	68	72	72	86	77	13	27	18	72	4	31
Overall	-84.88 to 9.05	-45.49 to 25.68	-24.02 to 11.73	-133.91 to 24.89	-9.85 to 57.03	-16.28 to 28.9	-10.24 to 39.29	-48.84 to12.75	-7.69 to48.45	-18.25 to28.51	40	38	28	38	66	78	60	30	82	58	60	62	72	62	34	22	40	70	18	42

Table 25. DRIS approach in identifying deficiencies and excess of macro-micro nutrients in mango orchards (per cent) at different locations

Location	DRIS approach																				Sufficiency range approach																			
	Major relatively deficiency										Major relatively excess										Deficiency										Excess									
	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn
Akhnoor	3	17	10	14	25	3	3	14	3	0	3	7	7	21	3	0	7	7	39	3	10	3	0	10	10	0	3	14	7	10	0	0	0	0	0	0	0	0	0	0
samba	18	18	4	50	0	0	0	9	0	0	0	4	0	9	36	0	4	0	40	4	22	0	0	27	13	0	13	27	18	18	0	0	0	0	0	0	0	0	0	0
Overall	10	18	8	30	14	2	2	12	2	0	2	6	4	16	18	0	6	4	40	4	16	2	0	18	12	0	8	20	12	14	0	0	0	0	0	0	0	0	0	0

4.7.4.9 Copper

DRIS diagnostic approach showed available copper indices in the range of -3.76 to + 48.45 (Table 24) with 95 per cent orchards having positive indices. DRIS identified 40 per cent orchards in relatively excess. On the other hand sufficiency range approach diagnosed 18 per cent orchards in deficient category (Table 25)

4.7.4.10 Manganese

Diagnose by DRIS approach indicated that leaf available manganese indices ranged from -5.92 to +28.51 with 68 per cent orchards showed positive indices (Table 24). Major relative excess was diagnosed in 4 per cent orchards while diagnosing with DRIS approach. On the other hand sufficiency range approach diagnosed 18 per cent orchards in deficient category (Table 25).

4.7.5 Comparison of DRIS and Sufficiency Range Diagnostic Approach in identifying deficiencies and excesses of macronutrients in mango orchards

Comparison of DRIS and sufficiency range approach in identifying deficiencies and excesses of macronutrients viz., available nitrogen, available phosphorous, available potassium, available calcium, available magnesium and available sulphur, in different mango orchards of Jammu region presented in table 24 and 25.

4.7.5.1 Comparison of nutritional deficiencies

The major nutrient deficiencies as diagnosed by DRIS and sufficiency range diagnostic approaches at different locations of Jammu region are presented in table 24 and 25. Data from table 24 and 25 reveals that DRIS diagnostic approach identified leaf available sulphur as major relative deficient in 30.0 per cent orchards followed by available phosphorus in 18.0 per cent orchards, available calcium in 14.0 per cent, available iron in 12.0 per cent, available nitrogen in 10.0 per cent, available potassium in 8 per cent, available magnesium, available zinc and available copper in 2 per cent orchards respectively, and available manganese in none orchard.

The highest percentage of orchards identified as having major relative deficiency of available sulphur was observed at Samba with 50 per cent followed by Akhnoor in 14 per cent. Leaf phosphorus as major relative deficiency was observed at Samba in 18 per cent followed by Akhnoor in 17 per cent. 25 per cent orchards at

Akhnoor were found to have leaf available calcium as major relative deficiency. Leaf iron as major relative deficiency was observed at Akhnoor in 14 per cent orchards followed by Samba in 9 per cent orchards. 18 per cent orchards at Samba were found as having deficiency for leaf nitrogen followed by 3 per cent orchards at Akhnoor. Leaf available potassium was found as major relative deficient in 10 per cent orchards at Akhnoor followed by 4 per cent in Samba. At Akhnoor leaf available magnesium, zinc and available copper were identified as major relative deficient in 3 per cent orchards.

Diagnosis by sufficiency range approach for nutrient deficiencies in mango orchards identified 20 per cent orchards as having deficiencies for leaf iron followed by leaf available sulphur in 18 per cent, available nitrogen in 16 per cent, available manganese in 14 per cent, available zinc in 18 per cent and available phosphorus in 2 per cent orchards.

The highest percentage of orchards showing available iron deficiency was observed at Samba with 27 per cent orchards followed by 14 per cent orchards at Akhnoor. 27 per cent orchards at Samba were found as having deficiency for leaf available sulphur followed by 10 per cent orchards at Akhnoor. Leaf available nitrogen was diagnosed as deficient in 22 per cent orchards at Samba followed by 10 per cent in Akhnoor. At Samba, 18 percent orchards `were identified as having deficiency for leaf available manganese followed by 10 per cent at Akhnoor.

Leaf copper was diagnosed as deficient in 18 per cent orchards at Samba followed by 7 per cent orchards at Akhnoor. Leaf zinc was observed as deficiency in 13 per cent orchards at Samba followed by 3 per cent orchards at Akhnoor. At Akhnoor leaf available phosphorus was identified as deficient in 3 per cent orchards.

4.7.5.2 Comparison of nutritional excess

Diagnosis of nutrient excesses in mango orchards using DRIS diagnosis approach (Table 24 and 25) indicated that leaf available copper diagnosed excess in 40 per cent followed by available calcium and available sulphur in 18 per cent and 16 per cent, phosphorus and zinc in 6 per cent, potassium, iron and manganese in 4 per cent and nitrogen in 2 per cent, respectively. 40 per cent orchards were identified as having major relative excesses for available copper at Samba location followed by 39 per cent at Akhnoor. 36 per cent orchards were observed as having major relative excesses for available calcium followed by 3 per cent in Akhnoor. Leaf available sulphur was identified as major relative excesses at Akhnoor in 21 per cent orchards followed by 9 per cent in Samba. 7 per cent orchards were identified as having major relative excesses for available phosphorus and available zinc at Akhnoor followed by 4 per cent orchards for available phosphorus and available zinc at Samba.

Leaf available potassium and leaf available iron as major relative excesses were observed in 7 per cent orchards at Akhnoor. Leaf available nitrogen as major relative excesses was observed in 3 per cent orchards at Akhnoor. Diagnosis by sufficiency range approach reveals that among two locations of mango, none of the orchard exhibited excess of leaf available nitrogen, available phosphorous, available potassium, available calcium, available magnesium, available sulphur, available copper, available manganese, available iron and available zinc.

4.8 Distribution of nutrient imbalances indices and fruit yield at two different locations

Data presented in table 26 and Fig. 7 exhibits the ranges means and coefficient of variation of Nutrient Imbalances Indices (NII) and fruit yields (kg/tree) in mango orchards at two locations. Data shows that fruit yield recorded in mango orchards at two locations ranged from 34.92 to 84.69 kg/tree and 30.5 to 76.28 kg/tree with mean values of 61.09 and 50.31 kg/tree at Akhnoor and Samba, respectively. Nutrient imbalances indices were observed in the range of 19.95 to 305.35 and 29.00 to 344.80 with corresponding mean values of 94.76 and 75.47 at Akhnoor and Samba, respectively.

The highest Nutrient Imbalance Index (NII) was recorded at Samba with 75.47 per cent coefficient of variation, respectively and the highest coefficient of variation for yield was recorded at Akhnoor with 25.91 per cent of variation respectively.

Lowest mean Nutrient Imbalance Index (NII), 82.87 was observed at Akhnoor with yield of 61.09 Kg/tree. The data reveal that higher yields are generally associated with lower nutrient imbalances indices.

4.9 Leaf nutrient standard for mango

The optimum ranges have been established for plant nutrients based on the mean nutrient concentration and standard deviation (SD) from high yielding population. The nutrients were classified as deficient, low, optimum, high and excessive based on the principle of DRIS (Bhargava and Chadha, 1993) and presented in table 27. The optimum nitrogen ranged from 1.95 to 2.29 per cent. The leaf nitrogen content less than 1.77 per cent and more than 2.47 per cent was considered as deficient and excess, respectively. The optimum phosphorous ranged from 0.15 to 0.23 per cent and leaf potassium ranged from 0.25 to 0.43 per cent. The leaf phosphorous content of less than 0.11 per cent and more than 0.27 per cent is considered as deficient and excess. The leaf potassium content of less than 0.15 per cent and more than 0.53 per cent is considered as deficient and excess.

The optimum calcium concentration ranged from 2.05 to 2.37 per cent and calcium content of less than 1.89 and more than 2.53 per cent is grouped under deficient and excess category. The optimum magnesium ranged from 0.53 to 0.93 per cent and the sulphur content ranged from 0.16 to 0.26 per cent. The leaf magnesium content of less than 0.33 per cent and more than 1.13 per cent and leaf sulphur content of less than 0.1 per cent and more than 0.32 per cent were considered as deficient and excess, respectively. The optimum zinc ranged from 19.6 to 27.04 ppm and optimum iron ranged from 194.65 to 303.37 ppm. The leaf zinc content less than 15.88 and more than 30.76 ppm considered as deficient and excess, respectively. The leaf iron content less than 140.29 and more than 357.53 ppm considered as deficient and excess. The optimum copper concentration ranged from 16.78 to 22.48 ppm and copper content of less than 13.92 and more than 25.34 ppm is grouped under deficient and excess category. The optimum available manganese leaf concentration ranged from 122.43 to 178.53 ppm and manganese content of less than 94.37 and more than 206.59 ppm is grouped under deficient and excess category (Table 21). The leaf nutrient status indicated that the mean nutrient content of nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, manganese, iron and zinc were found to be higher in high yielding orchards these have received good amount of fertilizer and management practices. The yield in the high yielding population varied from 50.30 to 84.69 kg/tree where as in the low yielding population the yield varied from 30.50 to 49.64 kg/tree.

Table 26. Distribution of Nutrient Imbalance Index (NII) and fruit yield at different locations

Location	Nutrient imbalance Index(NII)			Fruit yield (kg/tree)		
	Range	Mean	C.V	Range	Mean	c.v
Akhnoor	19.95-305. 35	82.87	94.76	34.92-84.69	61.09	25.91
Samba	29.00- 344.80	127.52	75.47	30.5-76.28	50.31	22.24

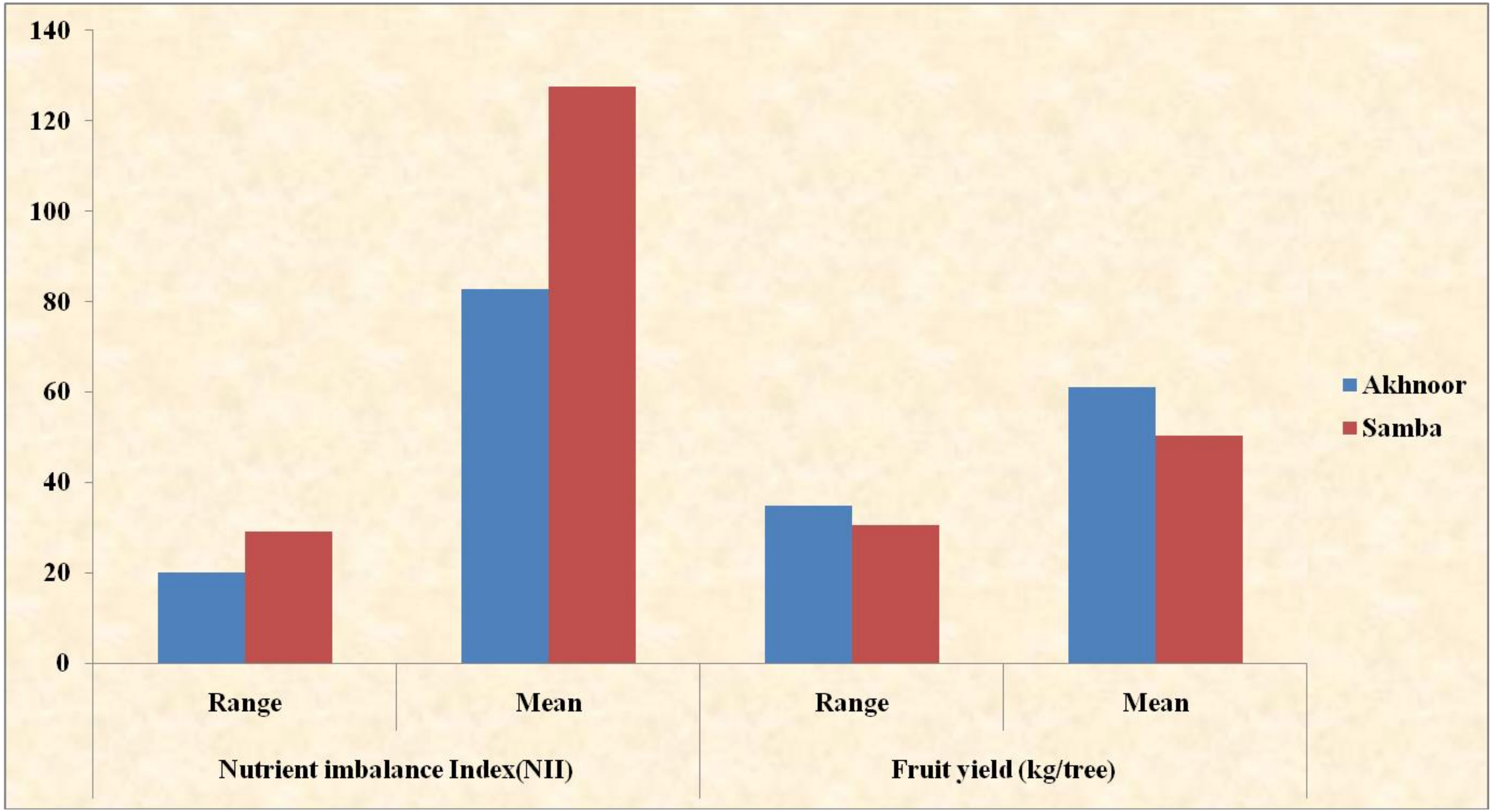

Fig. 7. Distribution of NII and fruit yield (kg/ tree) at different locations.

4.9.1 Classification of mango orchards (%) at different location based on the leaf nutrients standards

The classification of the individual mango orchards with the established norms is presented in Table 28. The results indicated that nearly 89 per cent of the orchards were optimum with respect to nitrogen content in leaves and 7 per cent of the orchards were low in nitrogen content. The leaf phosphorous was found to be optimum in 75 per cent of the orchards, 14 per cent low and 7 per cent in high. The leaf potassium content was optimum in 78 per cent of the orchards while it was low in 17 per cent and high in 3 per cent of the orchards. The leaf sulphur content was optimum in 71 per cent, low in 7 per cent and high in 10 per cent of the orchards. The leaf calcium content was optimum in 67 per cent of the orchards and 10 per cent of the orchards in both low and high.

The leaf magnesium was optimum in 67 per cent of the orchards, low in 25 per cent and high in 7 of the orchards. Zinc was optimum in 78 per cent of the orchards, low in 10 and 7 percent of the orchards in high while iron and copper both were optimum in 71 per cent of the orchards, iron low and high in 7 per cent while copper low in 7 per cent and high in 14 per cent. Manganese was optimum in 75 per cent of the orchards, while low and high in 7 per cent of the orchards in Akhnoor region respectively.

In Samba, the optimum leaf nitrogen content nearly 45 per cent and 31 per cent orchards were low. The leaf phosphorous was found to be optimum in 50 per cent of the orchards and rest of 50 per cent of the orchards were low. The leaf potassium content was optimum in 45 per cent of the orchards while it was low in 54. The leaf sulphur content was both optimum and low in 36 per cent of the orchards. The leaf calcium content was optimum in 36 per cent and low in 50 per cent of the orchards. The leaf magnesium content was optimum in 45 per cent of the orchards and 54 per cent of the orchards were low. Similarly, the leaf zinc was optimum in 45 per cent and low in 40 per cent of the orchards. The leaf iron content was optimum in 50 per cent and 22 per cent of the orchards were in low category. Cu content was optimum in 54 per cent and low in 22 per cent of the orchards. Manganese was optimum in 50 per cent of the orchards, while low in 31 per cent of the orchards.

In Jammu region the data presented that nearly 70 per cent of the orchards were optimum with respect to nitrogen content in leaves, 18 per cent of the orchards were low. The leaf phosphorous was found to be optimum in 64 per cent of the orchards, 30 per cent in low and 4 per cent in high. Similarly, the leaf potassium content was optimum in 64 per cent, and low in 34 per cent and high in 2 per cent. The leaf sulphur content was optimum in 56 per cent and low in 20 per cent and high in 9 per cent of the orchards. The leaf calcium content was optimum in 54 per cent and low in 28 per cent and high in 9 per cent of the orchards. The leaf magnesium content was optimum in 58 per cent of the orchards, 38 per cent of the orchards were low and 4 per cent of the orchards were high. The leaf zinc was optimum in 64 per cent and low in 24 per cent and high in 4 per cent of the orchards. Similarly the leaf iron, copper and manganese were optimum in 64 per cent of the orchards whereas this leaf content were low in 14, 14 and 18 per cent and high in 4, 10 and 4 per cent of the orchard in Jammu region, respectively.

Table 27. Leaf nutrient standards for mango

S.NO.	Nutrient	Deficient	Low	Optimum	High	Excessive
1	N (%)	<1.77	1.95-1.77	1.95-2.29	2.29-2.47	>2.47
2	P (%)	<0.11	0.15-0.11	0.15-0.23	0.23-0.27	>0.27
3	K (%)	<0.15	0.25-0.15	0.25-0.43	0.43-0.53	>0.53
4	S (%)	<0.10	0.16-0.10	0.16-0.26	0.26-0.32	>0.32
5	Ca (%)	<1.89	2.05-1.89	2.05-2.37	2.37-2.53	>2.53
6	Mg (%)	<0.33	0.53-0.33	0.53-0.93	0.93-1.13	>1.13
7	Zn (%)	<15.88	19.6-15.88	19.6-27.04	27.04-30.76	>30.76
8	Fe (%)	<140.29	194.65-140.29	194.65-303.37	303.37-357.73	>357.73
9	Cu (%)	<13.92	16.78-13.92	16.78-22.48	22.48-25.34	>25.34
10	Mn (%)	<94.37	122.43-94.37	122.43-178.53	178.53-206.59	>206.59

Table 28 Classification of mango orchards (%) at different location based on leaf nutrients standard.

Location		N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn
Akhnoor	Deficient	10	3	0	10	10	0	3	14	7	10
	Low	7	14	17	7	10	25	10	7	7	7
	Optimum	89	75	78	71	67	67	78	71	71	75
	High	0	7	3	10	10	7	7	7	14	7
	Excess	0	0	0	0	0	0	0	0	0	0
Samba	Deficient	22	0	0	27	13	0	13	27	18	18
	Low	31	50	54	36	50	54	40	22	22	31
	Optimum	45	50	45	36	36	45	45	50	54	50
	High	0	0	0	0	0	0	0	0	0	0
	Excess	0	0	0	0	0	0	0	0	0	0
Overall	Deficient	16	2	0	18	12	0	8	20	12	14
	Low	18	30	34	20	28	38	24	14	14	18
	Optimum	70	64	64	56	54	58	64	64	64	64
	High	0	4	2	9	9	4	4	4	10	4
	Excess	0	0	0	0	0	0	0	0	0	0

Chapter-5

Discussion

CHAPTER -5

DISCUSSION

Assessment of the nutritional status of fruit trees is of great importance for determining the quantity, method and time of application of nutrients for improving the yield and quality of fruits. DRIS approach takes into account the concentration of nutrients at appropriate plant growth stages and their inter-relationship with yield. The nutrient diagnostic norms for a crop, at a given stage, developed in this approach serve as a standard nutrient guide for diagnosis of nutrient disorders are accordingly employed. Optimization of limiting factors of crop plant growth, creates rather balanced conditions which are likely to increase the chances of obtaining higher yields and quality of the fruit crop, it is the system that provides the possibility of bringing to balance all the elements involved in nutrition together and evaluating them simultaneously, with targeted yield level being part of the process. In the present investigation, DRIS approach was employed for interpreting leaf and soil nutrients analysis in relation to fruit yield and quality to establish preliminary DRIS norms in mango fruit.

5.1 Soil reaction, electrical conductivity and organic carbon.

The results obtained on soil reaction, electrical conductivity and organic carbon contents in soil samples of different mango orchards at different locations are explained in chapter 4, under sub-head 4.1.1 to 4.1.3.

It was observed that the soil pH increased with increasing soil depth. The pH values were found to increase with depth, possibly due to leaching of bases. The lower pH values in the surface soil might be due to the release of organic acid during decomposition of organic matter and these acids might have brought down the pH in the surface soils. The difference in the nature of parent material and degree of weathering is also responsible for variation in soil pH of different layers. Sarkar and Sahoo (2000) and Patil *et al.* (2008) were of same opinion and found that the pH value increased with depth as soil alkalinity increases with depth due to deposition of basic salts by irrigation and eluviations. Sharma *et al.* (2009) observed that the soils were neutral with pH varying between 6.76 and 7.67. Sharma *et al.* (2018) who found that pH range between 6.12 to 7.10 and noticed that mild variation in pH of the different orchard soils. These findings are in agreement with the findings of Sharma *et al*., (2018), who reported that the sub- surface soils contain higher pH values as compared to surface soils in mango orchards of Kangra district of Himachal Pradesh.

The electrical conductivity in the surface of soil varied from 0.05 to 0.27 dS m^{-1} with mean value 0.15dS m^{-1} and in the sub-surface layers 30-60 cm and 60-90 cm values varied from 0.04-0.25 dS m^{-1} and 0.03-0.24 dS m^{-1} with mean values 0.13 dS m^{-1} and 0.12 dS m^{-1}.The results are in agreement with those obtained by Bindroo (1998) who reported that electrical conductivity of citrus soils of Jammu region varied from 0.05-0.32 dS m^{-1}. Verma and Tripathi (2007) found that the soils of mid-Shivalik hills in Himachal Pradesh are very low in soluble salt concentration with electrical conductivity values ranging from 0.01 to 0.15 dSm^{-1}. These soils are free from soluble salts, hence responsive to fertilizer application. The low value of electrical conductivity indicates that the accumulation of the salts in these soils was less. Similar types of findings have been reported by Ahlawat *et al*. (1986). The forest and pasture land has lower EC than the other land use systems. Highest electrical conductivity values were found in wasteland agriculture land use systems. The accumulation of soluble salts in mountainous regions is unlikely because of the climatic conditions of the regions, e.g. heavy rainfall that cause leaching of all the salts from the surface to sub-surface layers. These observations are quite consistent with findings of Kher and Singh (1993) and Jalali *et al*. (1989).

The organic carbon content in surface soil varied from 0.21 to 2.30 per cent with mean value of 0.99 per cent. In sub-surfaces of the soil the values varied from 0.18 to 2.25 per cent and 0.15 to 0.28 per cent with mean values of 0.93 per cent and 0.89 per cent, respectively. The result are in close conformity with the findings of Sharma *et al*.(2009) who observed that majority of the soils were low in organic matter content with the organic carbon content for 92 per cent of the soils varying between 0.31 to 0.55 per cent. The organic carbon was found to decrease with increase in soil depth. The overall status shows that the soils were low to medium in organic carbon. This may be due to the management practices and variable addition of farm yard manure. Lesser amounts are found in more hotter and dry areas. Variable distribution and land management practices can result in decrease in soil organic matter levels. The results obtained are in accordance with the findings of Kumar *et al*. (2012) who reported that organic carbon contents in most of the soil samples were low in mango orchards. The organic carbon content decreased with depth in all soil profiles. These findings are supported by Chakravarthy and Barua (1983), and Bindroo (1998) who noticed that lower horizons had mostly low organic matter content. The extremely low organic carbon content of the soils could be attributed to occasional addition of organic materials, lack of natural vegetation and poor moisture retention capacity of soils coupled with high temperature enhanced oxidation of organic matter content. These results are in close agreement with the findings of Kainthaliya and Bhatt (1991).

5.2 Soil nutrients

The data related to soil nutrients such as nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, zinc, iron, copper and manganese are presented in chapter 4 under sub heads 4.2.1 to 4.2.10. The overall available nitrogen content in mango orchard soils ranged from 107.10 to 298.26 kg/ha with mean value of 251.90 kg/ha at 0-30 cm depth, at soil depth 30-60 cm the nitrogen content ranged from 75.60 to 282.63 kg/ha with mean value 230.38 kg/ha. At 60-90 cm soil depth the available nitrogen ranged from 57.80 to 280.15 kg/ha with mean value of 204.65 kg/ha. The available nitrogen was found to decrease with soil depth. This decrease of available nitrogen with depth was ascribed to decrease of organic carbon with depth. The semiarid conditions of the area might have favoured rapid oxidation and lesser accumulation of organic matter releasing more NO_3-N which could have been lost by leaching (Finck and Venkateswarlu, 1982). The result are in close conformity with the findings of Sharma *et al.* (2009), who reported that the soils were low in available nitrogen with the test values ranging from 169 to 265 kg/ha. The poor nitrogen status of soils has also been observed earlier in Bhalwal block falling within the Kandi areas of Jammu (Sumbria *et al.* 1989) which is in conformity with the findings of Bindroo (1998), who in a survey of citrus orchard soils of Jammu region were low in available nitrogen and its contents were higher in surface layers. Sharma and Mahajan (1990) also recorded a decreasing trend in the content of available nitrogen, phosphorous and potassium with soil depth, which was attributed to lesser biomass addition in lower layers. On surface layers Samra and Arora (1997) reported 30 to 40 per cent deficiency of available nitrogen in crops. Kumar *et al*. (2012) revealed that the soils of Malihabad region of mango orchards were deficient in available nitrogen which needs nitrogenous fertilizer application at the recommended rates for improving the productivity of mango. The higher content of available nitrogen in surface soil might be due to their organic carbon content. Fertility status with respect to available nitrogen was dependent upon the amount of organic matter added to the soil. These results are in accordance with the finding of Singh and Ahuja (1990), Yadav and Kumar (1999), Khan and Begum (2007) and Kumar *et al.,* (2010).

Available soil phosphorus in different orchards was found to be in the range of 7.60 to 22.90 kg/ha with a mean value of 18.15 kg/ha at 0-30 cm soil depth. Available phosphorus in the 30-60 cm soil depth ranged from 6.90 to 20.00 kg/ha with mean value of 14.13 kg/ha. Phosphorous content decreased with increase in depth in almost all the orchards under study. Phosphorus distribution did not follow any systematic pattern as in case of mango and guava, it decreased with depth. A decrease in available phosphorous with increase in soil depth has been reported by Sood et *al*. (1991) and Dongale (1993).

Sharma *et al*. (2009) reported that available phosphorus content of the soils varied between 9.0 to 14.3 kg/ha, with 67 per cent of the soils are low in P content. The available phosphorus content of the soil was positively and significantly correlated with the organic carbon content of the soils. The mineralization of organic phosphorus contributes to the available phosphorus fraction (Pinerio and Navarro, 2001). Also the farmers in the *kandi* areas mainly depend upon the farm yard manure to apply nutrients for the growing crops. The results obtained in the present investigation are similar to the finding of Raina (1988) who found medium to high levels of phosphorus in citrus growing soils of Poanta area of Himachal Pradesh. Kumar *et al*., (2012) reported that the soils of Malihabad region of mango orchards were medium to high in available phosphorus. The higher levels of phosphorus in many soils may be ascribed to the inherent status of phosphorus in soils, as well as better phosphorus management practices being adopted by the farmers of that region.

Soil potassium varied from 95.10 to 224.23 kg/ha with mean value of 156.23 kg/ha at 0-30 cm soil depth. At 30 to 60 cm soil depth potassium ranged from 90.00 to 217.19 kg/ha with a mean value of 144.59 kg/ha. At 60-90 cm the soil potassium ranged from 79.34 to 210.00 kg/ha with mean value of 133.71 kg/ha The available potassium was found to decrease with increase in soil depth. A decrease in potassium content in the sub-surface layers has also been reported by Singh (1987) and Sharma (1988). The higher available potassium could be ascribed to more weathering of potassium bearing minerals, alternate wetting and drying cycles and release of potassium from decomposing organic matter added to the surface through natural vegetation. These results were in agreement with the findings of Munaswamy *et al.* (1989) and Hirekurabar *et al.* (2000).The high content of available potassium in the soils may be partly due to the nature of parent material, which according to Pandey (1966) has at one time acquired biotite and quartz mineral assemblage. These findings closely resembled with the findings of Gupta *et al.* (1987) and Gupta and Khanna (1994).The findings of Sharma (1990) also support the results who reported high available potassium content in orchard soils of district Mandi of Himachal Pradesh.

Further, Sharma *et al*. (2009) reported that the available potassium ranged from low (77kg/ha) to medium (144kg/ha), with a mean value of 110.8 kg/ha of soil. Sharma *et al*. (2018) who found that the mean values for available potassium content in mango, citrus and guava orchards were 61.1, 64.8 and 66.2 mg/kg of soil. Bopaiah and Srivastava (1984) were of same opinion and reported that the available nitrogen, phosphorus and potassium content were lower in the second and third layers than in top layer of Dashehari mango orchards soils. The higher contents in the soils of Udeywalla and Karan Bagh at Jammu can be attributed to application of potassium in these orchards, while lower amounts in Akhnoor and Laduwal could be because these soils are degraded and subjected to erosion.

The sulphur content in surface soil 0-30 cm ranged from 12.60 to 19.74 kg ha^{-1} with mean value 16.10 kg ha^{-1} and sub surfaces 30-60 cm and 60-90cm the values varied from 10.40 to 17.90 kg ha^{-1} and 9.80 to 16.95 kg ha^{-1} with mean values 14.95 kg ha^{-1} and 13.97 kg ha^{-1}. The higher available sulphur in these soils might be due to the continuous application of fertilizers like single super phosphate. These results were in confirmation with those reported by Venkatesu *et al.* (2002). The higher content of sulphur in the surface soils was attributed to the greater plant and microbial activities and subsequent higher organic matter accumulation. Similar results were reported by Gupta *et al.* (2004) in citrus orchard soils of Jammu region.

The findings of Tripathi and Singh (1992) support the results who reported the decreasing trend of sulphur with increasing soil depth. Adequate supplies of sulphur have also been advocated by Singh (1987), Sharma (1988) in different regions of Himachal Pradesh. The medium or adequate content of available sulphur in soils of Himachal Pradesh may be due to the high content of organic matter and the nature of parent material which is gypsiferrous and ferruginous limestone (Wadia,1966).

Bindroo (1998) and Singh and Sharma (1983) reported that available sulphur in soil profiles decreased with depth. Lower amounts of available sulphur in Raya, Sanyal, Basholi and Akhnoor in lower depths of soil could be due to lower amounts of organic matter in these soils. Similar results were reported by Gupta *et al.* (2004) in citrus orchard soils of Jammu region.

The available calcium content from surface soil 0-30 cm ranged from 4.02-6.35 [c mol (p+) kg $^{-1}$ with mean value 5.66 c mol (p+) kg $^{-1}$. Available calcium content from sub surface soils varied from 4.00 to 6.32 c mol (p+) kg $^{-1}$ and 4.00 to 6.29 c mol (p+) kg $^{-1}$ with mean values 5.63c mol (p+) kg $^{-1}$ and 5.60 c mol (p+) kg $^{-1}$. The available calcium content decreased with an increase in soil depth. Nair and Chamuah (1988) and Bala and Sahu (1993) have also reported calcium as dominant cation in the soils of pine forest of Himachal Pradesh. Similarly, Sharma *et al.*, (2002) reported that soils of Fatehpur block in Himachal Pradesh were sufficient in calcium. The higher values of available calcium in soils may be due to high content of calcium carbonate and neutral pH. Further, higher values may also be attributed to the nutrient management practices followed by the farmers of the area and also to the parent material.

It is evident that the soil magnesium from surface layer 0-30 cm varied from 2.18 to 3.32 cmol (p+) kg^{-1} and from the sub-surface soil 30-60 cm and 60-90 cm it varied from 2.16 to 3.28 cmol (p+) kg^{-1} and 2.14 to 3.28 cmol (p+) kg^{-1}. The overall status of available magnesium was found to be high in the mango growing soils of Jammu region. The available magnesium content decreased with an increase in soil depth. Mandal *et al*. (1990) attributed high magnesium content to the organic carbon and calcium carbonate ($CaCO_3$) content in the soils of upper hill forests of eastern Himalayan soils. Similar findings have been reported by Kaistha and Gupta, (1993) for the hill soils of Himachal Pradesh Similarly, Sharma *et al*. (2002) reported that soils of Fatehpur block in Himachal Pradesh were sufficient in magnesium.

The soil zinc from surface soil 0-30 cm varied from 0.52 to 1.04 ppm with mean value 0.76 ppm and from the sub- surface soil 30-60 cm and 60-90 cm it varied from 0.50 to 0.97 ppm and 0.48 to 0.95 ppm with mean values 0.74 to 0.72 ppm, respectively. Zinc was found to decrease with increase in soil depth. Furthermore, the surface soils were sufficient in available zinc whereas, the sub-surface soils were deficient in available zinc. Similar views were expressed by Thangasamy *et al.* (2005)

soils of Chittoor district in Andhra Pradesh. Gupta *et al.* (1989) reported wide spread zinc deficiency in Mandarin growing areas of Nepal. The zinc content decreased with increase in depth in most of soil profiles. Surface layers were richer in DTPA-Zn than the sub-surface layers, the continuous leaf fall and its decay may be accounted for it. These findings are in agreement with those of Follet and Lindsay (1970) and Jalali *et al.* (1989) who reported a decrease in DTPA-extractable zinc with depth of soil profiles. The results get strength from the findings of Tripathi *et al*. (1994) who found zinc to vary from 0.10 to 2.80 ppm in soils and its content decreased with increase in soil depth. The high content of available zinc in surface layer may be attributed to its more favorable pH and higher organic carbon content.

Iron content in surface soil 0-30 cm ranged from 11.48 to 21.75 ppm and from the sub-surface soil 30-60 cm and 60-90 cm it varied from 11.10 to 20.94 ppm and 10.99 to 20.75 ppm, respectively. The surface soils registered significantly higher available iron content as compared to the sub-surface soils probably due to the higher organic matter content in the surface soils further, this decrease in the available iron with depth might be also due to absorption of iron from lower layers and their deposition in surface layer by leaf shedding. These results were in accordance with the findings of Reddy and Rao (1991) in sweet orange orchards of Rayalaseema region in Andhra Pradesh and Ratnam *et al.* (2001) in sapota growing soils of Andhra Pradesh.

The soil copper content in mango orchard surface soil 0-30 cm depth varied from 0.9 to 1.65 ppm with 1.12 ppm mean value, and the sub- surface soils 30-60 cm and 60-90 cm it varied from 0.80 to 1.63 ppm and 0.72 to 1.59 ppm with mean values 1.08 ppm and 1.05 ppm. Copper was also found to decrease with increase in soil depth. The decreasing trend of available copper with depth was due to the fact that the pattern of distribution of available copper was probably under the influence of vegetation and its translocation to the surface immediately from the subsoil and the latter had the lowest amount of copper. Similar trend of decrease in available copper with depth was also reported by Gupta *et al.* (2004) in citrus orchards of Jammu region. These results are in agreement with Gupta *et al.,* (1987) who reported copper content well above the critical limits for soils of Rajouri district of Jammu region. Further, Bindroo (1998) and Raina (1988) reported that citrus soils of Jammu and Sirmour district of Himachal Pradesh were adequate in available copper. Further, Fida *et al.* (2011) observed that the available micronutrients ranged in surface soil viz., Cu (2.44 to 8.46 µg/g), with a mean value of 5.61 µg/g.

It is evident from the data in the Table 5 that the soil manganese content from the surface soil 0-30 cm ranged from 4.15 to 22.25 ppm with mean value 16.48 ppm and from the sub- surface soil 30-60 cm and 60-90 cm the values varied from 4.00 to 20.98 ppm and 3.92 to 20. 89 ppm with mean values 16.08 and 15.89 ppm. The higher available manganese in surface soils was attributed to leaf residues and humus accumulation at the surface layer and also due to the increase in pH at lower depths.

These findings are in agreement with findings of Ratnam *et al.* (2001). Similar conclusions were also drawn by Sailaja (1999) and Reddy *et al.* (2002) in mango orchards of Andhra Pradesh. Bindroo (1998) reported that available manganese content decreased slightly with increase in depth, though the decline in the manganese content was not sharp. These findings find support of Rai (1969) who found that in the case of black soils the distribution of actual manganese was either uniform or slowly declined with depth.

5.2.1 Soil nutrients status of high and low yielding population.

The entire population was divided into two groups as high and low yielding based on yield performance (Beaufils, 1973) and the nutrient concentrations were compared between the two. It was observed that the soil available nitrogen, available phosphorus, available potassium, available sulphur, available zinc, available iron, available copper and available manganese content were higher in high yielding orchards. The presence of higher concentration of these essential elements in high yielding population might have governed the yield and growth attributes to a greater extent. The presence of higher concentration of essential elements in high yielding population was also reported by Hundal and Arora (2001), Raghupathi *et al.* (2004). Similarly, Reddy *et al.* (2001) showed that the high yielding mango trees in peninsular India had high soil nitrogen content than low yielding varieties. Reddy *et al*. (2003) reported that the contents of nitrogen, phosphorus and potassium in soil and leaf of high yielding trees were found to be higher than low yielding trees in case of Alphonso mango orchards of Andhra Pradesh. Higher nitrogen, phosphorus and potassium contents in leaves and soils of high yielding trees than low yielding trees were reported in case of Alphonso, Totapuri and Banaganpalli varieties of mango (Anonymous, 2012). Khokhar *et al*. (2012) also reported higher soil available nitrogen, available phosphorus, available potassium, available zinc, available iron, and available copper and available manganese in higher yielding orchard as compared to low yielding orchards.

The soil nutrient status indicated that the mean nutrient content of available nitrogen, available phosphorus, available potassium, available sulphur, available zinc, available iron, and available manganese were found to be higher in high yielding orchards compared to low yielding orchards due to better fertilizer application and management practices.

5.3 Leaf nutrients

The results related to leaf nutrients nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper and manganese are presented in chapter 4 under subheads 4.3.1.1 to 4.3.10. The overall nitrogen content varied between 1.10 to 2.25 per cent with mean value 1.97 per cent. The similar results were observed by Reddy *et al*. (2013) who reported leaf nutrient range of 1.80 to 2.50. The results are in also accordance with Singh and khan (1990). Similarly Sharma *et al*., (2018) who reported that the nitrogen concentration in mango leaves varied from 1.12 to 2.14 per cent with mean value 1.61 per cent. Similar results have been reported by Sharma and Bhandari (1995) in apple orchards of Himachal Pradesh where in the leaf nitrogen status was found to be sufficient. Similar results have been also reported by Hundal and Arora (1993) in litchi orchards of Punjab. Bhargava and Raghupathi (1993) suggested 0.77 to 0.99 per cent available nitrogen in leaves as critical limit for mango leaves and according to this criterion 33 per cent orchards were low in this element.

It is evident from the data and that the overall phosphorus content of mango leaves ranged from 0.09 to 0.25 per cent with mean value 0.17 per cent. The results obtained in present investigation are in consonance with findings of Sharma *et al*., (2018) who observed that the mean values of phosphorus content in mango leaves were 0.20 per cent. Moreover, Bhatnagar *et al*. (2001) reported that the phosphorus content varied from 0.29 to 0.88 per cent with a mean value 0f 0.46 per cent. Samra and Arora (1997) reported a value of 0.09 to 0.14 in unfertilized mango orchards. Further, Bopaiah and Srivastava (1984) reported a mean leaf concentration of 0.31 and 0.12 in fruiting non fruiting trees, respectively. Similar range of phosphorus was reported by Haynes (1990), Singh and Bhandari (1992) and Najar (2002).

It is revealed from the data that the overall potassium content of mango leaves varied from 0.19 to 0.45 per cent with mean value 0.30 per cent. The results are in close conformity with the findings of Sharma *et al*. (2018) who reported that the potassium concentration of mango leaves varied from 0.35 to 0.94 per cent with mean value 0.59 per cent. Similarly, Naik and Bhat (2018) reported that the potassium content in mango leaves varied from 0.63 to 0.86 per cent with mean value 0.76 per cent, respectively. Similar values for leaf potassium were reported earlier (Samra and Arora, 1997), Bopaiah and Srivastava, 1984 and Chowdhary *et al.* 1985) for mango leaves.

It is evident from the data that the sulphur content of mango leaves varied from 0.04 to 0.29 per cent with mean value 0.18 per cent. The results obtained in present investigation are in consonance with findings of Naik and Bhat, (2018) who reported that the concentration of mango leaves varied from 0.08 to 0.17 per cent with mean value of 0.17 per cent. Sharma *et al*. (2018) reported that the sulphur content of mango leaves varied from 0.24 to 0.65 per cent with mean value 0.45 per cent, respectively. Samra *et al.* (1978) suggested a critical value of 0.12 per cent for mango leaves and accordingly 44 per cent leaves were low in this nutrient. A wide spread deficiency of sulphur in Indian soils have been reported but its deficiency in fruit plants has, however, not been widely seen in the field (Randhawa and Srivastava, 1986). Samra *et al.* (1978) found higher amounts of sulphur in Dashehari leaves as compared to other cultivars.

It is revealed from the data that the overall calcium content of mango leaves ranged from 1.8 to 2.45 per cent with mean value 2.11 per cent. The result obtained in present investigation are in consonance with findings of Naik and Bhat, (2018) who reported that the calcium content of mango leaves varied from 1.41 to 3.54 per cent with mean value 2.21 per cent.

It is observed from the data that the overall manganese content of mango leaves varied from 0.42 to 1.01 per cent with mean value 0.64 per cent. The results obtained in present investigation are in consonance with findings of Sharma *et al*. (2018) who reported that the available manganese content in mango leaves varied from 0.42 to 1.48 per cent with mean value 0.85 per cent. Similarly, Naik and Bhat, (2018) observed that the magnesium content in mango leaves varied from 0.13 to 0.79 per cent with mean value 0.32 per cent. None of the samples of mango were found in the deficient range as per criteria proposed by Bhargava and Ragupathi(1993), Khanduja and Garg (1984) and De plesis *et al.* (1973).

It is explicit from the data presented in Table 3 that the overall zinc content of mango leaves varied between 10.6 to 28.5 ppm with mean value 21.22 ppm .The results are in close conformity with the findings of Naik and Bhat, (2018) who observed that the zinc content in leaves varied from 12.0 to 33.5 mg/kg^{-1} with mean value 21.0 mg/kg^{-1}. Similarly Sharma *et al*. (2018) reported that the zinc content of mango leaves ranged from 17.00 to 48.50 ppm with mean value 31.02 ppm. Similarly Singh (2001) observed that the zinc content in mango leaves varied from 10 to 39 ppm with mean value 19.50 ppm.

It is cleared from the data that the overall iron content of mango leaves varied between 101.2 to 310.5 ppm with mean value 209.88 ppm. Similarly Sharma *et al*., (2018) observed that the iron content in the mango orchard ranged from 192.70 to 338.40 ppm with mean value of 259.38 ppm. Similarly Naik and Bhat, (2018) reported that the iron content in the mango leaves varied from 71.0 to 248 mg/kg^{-1} with mean value of 121.5 mg/kg^{-1}.Similarly Singh (2001) observed that the iron content in the mango leaves at flowering stage ranged from 42 to 499 ppm with mean value of 170 ppm.

It is apparent from the data that the overall copper content of mango leaves varied between 10.5 to 24.7 ppm with mean value 18.52 ppm. The results are in close conformity with the findings of Sharma *et al*. (2018) who observed that the copper content in mango leaves varied from 14.20 to 42.80 ppm with mean value of 22.03 ppm. Similarly, Naik and Bhat, (2018) observed that the copper concentration in mango leaves varied from 13.2 to 36.4 mg/kg^{-1} with mean value of 23.2 mg/kg^{-1}.Similarly Singh (2001) reported the copper content of mango leaves ranged from 9 to 25 ppm with mean value of 13.5 ppm.

It is evident from the data that the overall manganese content of mango leaves ranged between 69.9 to 193.9 ppm with mean value 132.36 ppm. Similarly Singh (2001) reported the manganese content of mango leaves ranged from 40 to 142 ppm with mean value of 100 ppm. Sharma *et al*. (2018) observed that the manganese content ranged from 71.40 to 198.20 ppm with mean value of 131.73 ppm. Similarly

Naik and Bhat, (2018) who reported that the manganese content in mango leaves ranged from 43.8 to 403.6 mg/kg^{-1} with a mean value of 175.6 mg/kg^{-1}.

5.3.1 Leaf nutrients status of high and low yielding population

The entire population was divided into two groups as high and low yielding based on yield performance (Beaufils, 1973) and the nutrient concentrations were compared between the two. It was observed that the leaf nitrogen, phosphorus, potassium, calcium, available magnesium, sulphur, zinc, iron, copper and manganese content were high in high yielding orchards. The presence of higher concentration of these essential elements in high yielding population might have governed the yield and growth attributes to a greater extent. The presence of higher concentration of essential elements in high yielding population was also reported by Hundal and Arora (2001), Raghupathi *et al.* (2004) . Similarly, Bopaiah *et al*. (1988) also observed that the leaf samples of high yielding trees had higher content of available nitrogen, available phosphorus, available potassium, available iron available manganese and available copper than low yielding trees. Hundal *et al*. (2005) stated that leaves and fruits of high yielding trees had higher contents of nitrogen, phosphorus, potassium, zinc, iron, copper, manganese and boron than that in low yielding trees. Higher nitrogen, phosphorus and potassium contents in case of Alphonso, Totapuri and Banganpalli varieties of mango Anonymous, 2012, Ray and Mukherjee 1982 observed that in Fazli, Himsagar and Langra varieties of mango leaves of higher yielding trees had higher contents of total nitrogen, phosphorus and potassium than low yielding trees. Gimenez *et al*. (2000) found that low yielding orchards recorded relatively high mean Boron (17.8 ppm) and zinc (4.83 ppm) as compared to high yielding orchards recorded high mean Boron (12.67 ppm and 3.42 ppm, respectively) while manganese, (35.8 ppm) and copper (16.42 ppm) content was relatively higher than low yielding orchards (34.3 and 15.3 ppm respectively). Similarly Khokhar *et al*. (2012) who reported that the leaf available nitrogen, available magnesium, available copper, available iron and available zinc were higher in higher yielding orchard than low yielding orchard.

The leaf nutrient status indicated that the mean nutrient content of available nitrogen, available phosphorus, available potassium, available calcium, available sulphur, available magnesium, available zinc, available iron, available copper and available manganese were found to be higher in high yielding orchards as compared to low yielding orchard due to high yielding orchards have received good amount of fertilizer and management practices.

5.4. Fruit characteristics

5.4.1. Physical characteristics

The result with respect to fruit weight, length, diameter, volume, specific gravity, fresh pulp weight, dry pulp weight, stone weight and pulp: Stone ratios are presented in chapter 4 and section 4.4.1 to 4.4.10. A perusal of data indicated that fruit weight varied from 139.98 to 171.03g with mean value of 157.15 g. These findings are in agreement with those Pawar and Singh (2018) who reported that fruit weight varied from 164.86 to 221.98 g. The increase in fruit weight might be due to increased cell division and expansion. Appreciable improvement in fruit weight, fruit length and fruit diameter by sea weed sap application has also been reported by Chawdhury *et al.* (2007), Karim and Rahim (2008) and Ahmed *et al.* (2014) in mango.

It is apparent from the data that the fruit length and diameter, volume and specific gravity varied from 9.05 to 10.45 cm, 5.00 to 6.17 cm and 138.90 to 170.00 cm^3 with the mean value of 9.91cm, 5.66 cm, 156.10 cm^3 and 1.006 to 1.008, respectively. These results are in accordance with the findings of Rani *et al*. 2017 who observed that the fruit length, diameter and volume might be due to the application of the combined benefit of foliar application of different nutrient application also due to the fact that potassium plays a role to transfer of photosynthates to the fruits. The variation in fruit length, diameter and volume may be attributed to variation in soil nutrient status, pattern of fertilizer application, crop load of tree and climatic conditions. These parameters are influenced by cell division, cell elongation and enlargement which depend upon the availability of gibberellins, the synthesis of which is influenced by nitrogen (Faust, 1989). Better nourished plants produce superior fruit size. Singh and Pathak (2018) reported that the specific gravity varied from 1.013 to 1.074. Similar data was observed by Hoda *et al.* (2003) Abourayya *et al*. (2011) and Sarkar *et al.* (2001) According to them the specific gravity of the fruit is governed not only by physical growth but also by its internal compositions.

From the data it is evident that average pulp weight, stone weight and pulp: stone ratio of mango varied from 87.05 to 109.80 g , 26.32 to 31.10g , 3.23 to 3.55

per fruit with mean value of 97.45 g, 28.68 g and 3.40 per fruit. These results are in close conformity with the findings of Bakshi *et al*. (2013) who revealed that the pulp weight, stone weight and pulp stone ratio varied from 31.30 to 117.15g, 12.26 to 35.60 g and 1.69 to 3.90 in different cultivars of mango. These results are contradictory to Syamal and Mishra (1987). The similar results were obtained with the findings of Singh *et al*. 2017 who recorded that pulp: stone ratio varied from 1.69 to 10.60. More variation was found in pulp: stone ratio compared to other parameters. The pulp stone ratio is an ideal parameter for judging the fruit quality from the consumer's point of view. Mitra and Mitra (2001) also found variation for pulp: stone ratio in mango varieties and concluded that a high pulp: stone ratio indicates the suitability of the cultivars for fruit processing.

5.4.2. Chemical Characteristics

The result with respect to chemical characteristics of mango fruit are presented in chapter 4 under sub- heads 4.4.2.1. to 4.4.2.7.It is obvious from the data that average total soluble solids, titrable acidity, TSS: acid ratio and ascorbic acid of mango varied from 17.11 Brix^0 to 20.17 Brix^0, 0.21 to 0.28 per cent, 66.55 to 82.19 and 35.59 to 41.82 mg/100 g pulp with mean value of 17.69 Brix^0, 0.24 per cent, 72.82, 39.23 mg/100 g pulp. These findings are in agreement with those of Bakshi *et al*.,(2013) who reported the range of total soluble solids 16.25 to 20.15 Brix^0, titrable acidity 0.20 to 0.36 per cent, 63.28 to 96.92 among different cultivar of mango. The similar results were reported by Hoda *et al*. (2003). They found that the time of harvest and prevailing agro-climatic conditions affect the variation in acidity of mango fruit. These values are in line with the reports by Singh and Maurya (1986). Hada and Singh (2018) observed that the higher level of ascorbic acid might be due to the perpetual synthesis of glucose 6- phosphate during the growth and development of fruits, which is considered to be the precursor of ascorbic acid. The increase in ascorbic acid content is probably due to the catalytic influence of growth substances on the biosynthesis of ascorbic acid from sugars.

The observation of results showed that total sugar content, reducing sugars and non- reducing sugars ranged from 12.43 to 15.07 per cent, 2.95 to 3.98 per cent and 9.63 to 11.29 per cent with mean value of 13.76 per cent, 3.48 per cent and 10.45 per cent, respectively. These findings are in agreement with those of Bakshi *et al*. (2013) who reported range of total sugars 13.13 to 16.63 per cent, reducing sugars 4.28 to

5.02 per cent and non – reducing sugars 8.47 to 10.99 per cent among different cultivar of mango. Similar results were obtained by Singh and Pathak (2018). The increased sugar contents might be due to the presence of potassium and boron which plays a very important role in the translocation of sugars from other parts into developing fruits under the study of Rani *et al*. (2017). Similar findings were also observed by Sarker and Rahim (2013) who reported that total sugars and reducing sugars of mango fruit were significantly influenced by the foliar nutrition of mango trees with the foliar application of potassium.

5.5 Relationship of soil nutrients with soil properties, leaf nutrients and fruit characteristics.

5.5.1 Relationship of soil properties with soil nutrients

In the present investigation, the relationship between soil nutrients, the soil pH of the surface layer 0-30 cm was significantly and positively correlated with available magnesium and available copper. For the sub- surface layer 30-60 cm the soil pH was found to be positively and significantly correlated with available copper. A positive and significant correlation of Electrical Conductivity with available soil calcium, magnesium and copper For the sub- surface layer 30- 60 cm layer, electrical conductivity was found to be significantly and positively correlated with available calcium, magnesium and copper and for the sub- surface layer 60-90 cm the available calcium, available magnesium and copper.The organic carbon content in the surface soil 0-30 cm was found to be significantly and positively correlated with available soil nitrogen, phosphorus, calcium, magnesium, zinc, copper and manganese. For the sub- surface layer 30-60 cm layer it was found to be positively and significantly correlated with available nitrogen, phosphorus, calcium, magnesium and copper. The organic carbon content positively and significantly correlated with available nitrogen, available phosphorus, available calcium, available magnesium and available copper.

Soil pH is considered as the driver of soil fertility because of its direct impact on nutrient availability and plant growth. It has been reported that solubility and availability of nutrient ions are pH dependent and the micronutrient availability decreases 100- fold with each unit increase in pH (Tisdale *et al*. 1995). Negative relationship of pH with available micronutrients cations has been reported by Rai *et al*. (1972) and Bhandari and Randhawa (1985). Verma and Tripathi (1982) reported that the soil pH had negative co-relation with total Fe in soils of Kangra valley. Katyal and Aggarwal (1982) have also depicted an inverse relationship of soil pH with available micronutrient cations viz., Fe, Mn and Cu and Mn. Mishra *et al*. (1990) observed a positive relationship of soil pH with available P in foot hills of Himalayas.

The relationship obtained for electrical conductivity is supported by the findings of Ramana Murthy and Srivastava (1994) who observed a positive and significant correlation of EC with available phosphorus. Trivedi *et al*. (2010) also found a negative and highly significant relation of EC with available phosphorus in the soils of Madhya Pradesh. With regard to correlation between soil physico-chemical characteristics and available soil nutrients, soil pH was significantly and negatively correlated with soil phosphorus, copper, iron and manganese whereas it was significantly and positively correlated with calcium and magnesium (Sailaja, 1999). The EC of the soil at three depths were positively and significantly associated with available copper, iron and manganese (Sreenivasula Reddy, 2002).

5.5.2 Relationship of soil properties with macro and micro leaf nutrients of mango orchards at Akhnoor region

The correlation of soil pH, electrical conductivity and organic carbon with leaf available nitrogen, available phosphorus, available potassium, available calcium, available magnesium, available sulphur, available zinc, available iron, and available copper and available manganese were found non- significant from the surface and sub- surfaces of the soil depth.

Soil pH is considered as the driver of soil fertility because of its direct impact on nutrient availability and plant growth. It has been reported that solubility and availability of nutrient ions are pH dependent and the micronutrient availability decreases 100- fold with each unit increase in pH (Tisdale *et al*. 1995). Negative relationship of pH with available micronutrients cations has been reported by Rai *et al*. (1972) and Bhandari and Randhawa (1985). Verma and Tripathi (1982) reported that the soil pH had negative co-relation with total iron in soils of Kangra valley. Katyal and Aggarwal (1982) have also depicted an inverse relationship of soil pH with available micronutrient cations viz. iron, manganese and copper Mishra *et al*. (1990) observed a positive relationship of soil pH with available phosphorous in foot hills of Himalayas.

The relationship obtained for electrical conductivity are supported by the findings of Trivedi *et al.* (2010) who observed a negative and highly significant relation of electrical conductivity with available phosphorous in the soils of Madhya Pradesh.

5.5.3 Relationship of soil properties with soil nutrients of mango orchards of Jammu region at different depth layers

The results obtained in the present study revealed that the correlation of available phosphorus with leaf nitrogen exhibited negative but significant from sub-surface layers, 30-60 and 60-90cm, whereas it was non significant at soil surface layer 0-30 cm. Relationship of soil available potassium with leaf phosphorus and leaf manganese were found to be negative but significant, whereas it was found non significant at soil depth 0-30, 60-90 cm. The correlation of soil magnesium with leaf nitrogen and leaf sulphur showed negative but significant from soil surface layer. From the sub-surface layer 60-90 cm leaf magnesium showed significant relationship with leaf nitrogen, leaf sulphur and leaf iron. A negative but significant correlation of soil available zinc with leaf copper were found from the surface and sub- surfaces of the soil. According to Anderson and Albrigo (1977) more significant correlation coefficient occurred with surface soils in micronutrient element as compared to sub-surface soils. Sharma and Bhandari (1992) and Awasthi *et al*. (1998) also reported significant and positive correlation among leaf and soil samples. Awasthi *et al*. (1999) found negative and significant correlation between leaf N and soil K of peach orchards in Sirmour.

5.6 Relationship of leaf nutrients with fruit characteristics.

5.6.1 Relationship of leaf nutrients with physical characteristics

A positive and significant correlation of fruit weight with all leaf nutrients viz., N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn was obtained in our study. The relationship between fruit length and leaf N found to be positive and significant, whereas, leaf Cu and Mn showed non-significant relationship. The correlation of fruit diameter with N showed positive and significant. Fruit volume showed positive and significant correlation with leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn, respectively. A negative but significant correlation of specific gravity with leaf N, P , S, Ca , Mg, Zn and Fe whereas leaf K, Cu and Mn showed non- significant relationship. Pulp weight found to be highly positive and significant correlation of leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn respectively. Stone weight exhibited positive and significant relationship with N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn, respectively. Pulp: stone ratio showed positive and significant correlation with leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn respectively. The relationship between fruit yield and leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn were found to be positive and significant at Akhnoor.

The relationship of fruit yield were found to be positive and significant with leaf zinc while as negative and non- significant correlation of fruit weight, fruit length, fruit diameter, fruit volume, specific gravity, pulp weight, stone weight and pulp : stone ratio with all leaf nutrients viz. N, P, K, S, CA, Mg, Zn, Fe, cu and Mn at Samba. The results are in close conformity with the findings of Kumar and Chandel (2004) who found that nitrogen, content in leaves was significantly and positively correlated with fruit length, fruit weight and fruit yield. This may be attributed to the fact that nitrogen plays an active role in cell division and cell elongation thus improves the growth parameters and yield. Moreover, Li *et al*. (2017) who reported that leaf potassium and leaf iron were positive and significant correlation with fruit weight, fruit shape, and index and fruit peel thickness. Kumar *et al*. (2009) found that zinc positively correlated with fruit weight.

5.6.2 Relationship of leaf nutrients with chemical characteristics

The relationship between total soluble solids and leaf nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, zinc, iron, copper and manganese were found to be highly significant as depicted in table 15. A positive and highly significant correlation between titratable acidity and leaf nitrogen, phosphorus, sulphur, calcium, magnesium , zinc, iron, copper and manganese whereas, non significant relationship of titratable acidity with leaf potassium. TSS: acidity shows positive but non- significant relationship with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese. TSS: acidity showed negative and non significant correlation with leaf sulphur. A positive and highly significant correlation of ascorbic acid with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese. Highly significant and positive correlation of total sugar observed with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese and total sugar found to be non-significant with leaf Cu. Reducing sugar found to be positive and highly significant relationship with nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese. A positive and significant relationship of non- reducing sugar with leaf nitrogen, phosphorus, sulphur, calcium, magnesium , zinc, iron, copper and manganese. Non reducing sugar exhibited non significant relationship with leaf copper at Akhnoor.

The correlation of total soluble solids, titratable acidity, TSS: acidity, ascorbic acid, total sugars, reducing sugar and non-reducing sugar with leaf nitrogen, phosphorus, sulphur, calcium, magnesium , zinc, iron, copper and manganese showed non- significant relationship at Samba These result are in agreement with the findings of Li *et al.* (2017) who found that leaf potassium and iron were positive and significant correlation with total soluble solids, total soluble solids :acidity, total sugar and vitamin –C. It has also been suggested that most of the nutrients in citrus leaves were negatively correlated with vitamin C content (Xu *et al*. 2012). Similarly, Dar *et al*. (2015) who reported that leaf nitrogen, phosphorus, potassium, zinc, iron, copper and manganese were found to be positive and significant correlation with total soluble solids and total sugars. Khayyat *et al*. (2007) reported that boron, iron, zinc content and titratable acidity were significantly negatively correlated, it indicated that it could increase sugar and reduce acid content with increasing boron, iron, and zinc content . Xu *et al*. (2012) that most of the nutrients in citrus leaves were negatively correlated with the soluble solids of fruit quality, and positively correlated with vitamin C content. Kumar *et al*. (2009) studied the zinc availability in pomegranate cv. Ganesh growing orchards of Rajasthan and found positively correlated with fruit quality.

5.7 DRIS ratio norms for mango

DRIS method uses nutrient ratios instead of absolute and/or individual nutrient concentrations. DRIS norms were calculated using leaf available nitrogen, available phosphorus, available potassium, available calcium, available magnesium, available sulphur, available zinc, available iron, available copper and available manganese contents and yield observations (Table 16). In all, 55 nutrient expressions producing highest variance ratios were selected as DRIS norms expression (Table 29). The mean values of selected expressions in the high yielding sub-populations were selected as the norm values which were then compared with norms derived from mean of the sufficiency ranges (Tables 20). The nutrients pairs involving N/P, N×K, N/S, Ca/N, N×Mg, Zn/N, N/Fe, Cu/N, N/Mn, P×K, P/S, Ca/P, Mg/P, Zn/P, P/Fe, Cu/P, P×Mn, K/S, Ca/K, K× Mg, Zn/K, K/Fe, Cu/K, K× Mn, Ca/S, Mg/S, Zn/S, Fe/S, Cu/S, Mn/S, Ca/Mg, Ca/Zn, Ca/Fe, Ca/Cu, Ca/Mn, Zn/Mg, Mg/Fe, Cu/Mg, Mg/Mn, Zn/Fe, Cu/Zn, Zn/Mn, Cu/Fe, Mn/Fe, Cu/Mn with corresponding mean values of 11.074, 0.005,10.248, 1.045, 1.559, 0.001, 86.679, 0.001, 142.609, 0.006, 0.930, 11.553, 3.783, 0.012, 7.898, 0.010, 0.003, 1.626, 6.736, 0.253, 0.007, 13.784, 0.006, 0.005, 10.691, 3.457, 0.011, 0.119, 0.009, 0.072, 3.125, 955.608, 90.283, 1133.510, 148.785, 0.003, 48.726, 0.095, 0.849, 0.157, 0.080, 0.613, 0.132, respectively, highest variance ratios among the particular nutrient pairs, were selected as DRIS norms. These values are quite comparable with those of Naik and Bhat, (2018) who reported the norm values of 9.54, 1.58, 6.03, 1.93, 3.06, 7.77, 16.4, 155.5, 25.9, 8.61 and 10.7 for nutrient expression N/P, N/K, K/P, Ca/N, Ca/K, Ca/Mg, Zn/N, Zn/P, Zn/K, Zn/Ca and B/N. Raghupathi *et al*. (2004) found that DRIS norms values of 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) have shown lower co-efficient of variation values compared to others and were critical from the crop performance point of view. These values are quite comparable with those of Das (2004) who has reported the norm value of 1.20, 1.23, 0.10, 0.39, 0.38, 0.07, 3.01, 0.55, 5.59 and 0.149 for nutrient expressions N/K, N/Ca, P/N, P x K, P x Ca, P x Mg, K x Ca, K x Mg, Ca/Mg and Mg/N, respectively. Similarly, the norm values 1.30, 1.30, 0.09, 0.29, 0.30, 0.06, 2.80, 0.53, 5.40 and 0.16 reported by Singh *et al.* (2000) for nutrient expression N/K, N/Ca, P/N, P x K, P x Ca, P x Mg, K x Ca, K x Mg, Ca/Mg and Mg/N, respectively are also in agreement with those obtained in the current studies. Besides the above expressions, norm expressions N/Fe, N/Mn, N/B, P/Fe, P/B, K/Fe, K/Zn, K/Cu, K x B, Ca/Fe, Ca/Cu, Ca/Mn, Ca x B, Mg/Zn, Mg/Mn, Mg x B, S/Fe, S x Zn, Fe/Mg, Zn/N, Zn/P, Zn/Ca, Zn/Fe, Zn/Mn, Zn/B, Cu/Zn, Cu/B, Mn/P, Mn/K, Mn/S, B/Fe and B/Mn with corresponding norm values of 0.01, 0.025, 0.07, 0.001, 0.006, 0.01, 0.04, 0.16, 55.38, 0.01, 0.17, 0.02, 50.43, 0.01, 0.003, 10.40, 0.001, 7.56, 568.44, 17.91, 209.78, 24.55, 0.25, 0.44, 1.16, 0.29, 0.31, 518.60, 63.73, 518.68, 0.22 and 0.39, respectively also produced significant variance ratios and were selected as DRIS norms.

DRIS norms can be derived from the means of published sufficiency ranges. The variations in some of the norm values from the means of published sufficiency ranges could be attributed to variation in management, cultural, manurial and agro climatic conditions rather than changes in the physiological processes within the plant system (Kenworthy, 1961).

5.7.1 Diagnosis of leaf nutrient status of mango orchards using DRIS Diagnostic Approach and Sufficiency Range Approach

DRIS norms for nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper and manganese derived in the current study were used to calculate the DRIS indices for nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper and manganese. DRIS diagnostic approach and sufficiency range approach (Shear and Faust, 1980) were used to work out DRIS order of nutrient requirements, orchards having positive and negative indices and nutrient deficiencies and excesses (Table 18, 19 and 20).

DRIS diagnostic approach diagnosed foliar nitrogen as the major relative deficient in 10 per cent orchards. Negative indices for nitrogen were observed in 60.0 per cent orchards indicating nutrient status as sufficient to deficient in different orchards. However, sufficiency range approach identified 16 per cent of the orchards as deficient in foliar nitrogen.

DRIS approach identified foliar phosphorus as the major relative deficiency in 18 per cent orchards. Negative DRIS indices for phosphorus were observed in 62 per cent orchards. Major relative excesses in phosphorus were observed only in 6 per cent orchards where as sufficiency range approach identified 2 per cent orchards as deficient.

Leaf potassium was identified as major relative deficiency in 8 per cent orchards. Positive DRIS indices for potassium were identified in 28 per cent orchards. However Sufficiency range approach identified none of the orchards as deficient or excess in foliar potassium.

DRIS approach diagnosed foliar sulphur as the major relative deficient in 30 per cent orchards with 62 per cent orchards were diagnosed to have negative DRIS indices for sulphur where as sufficiency range approach identified 18 per cent orchards as deficient for leaf sulphur.

Diagnosis of leaf calcium status by DRIS approach identified 18.0 per cent having calcium as the major relative excess. In all 66.0 per cent orchards were diagnosed to have positive DRIS indices for calcium which give an indication of widespread foliar calcium in sufficiency in different orchards. Whereas, sufficiency range approach identified 12 per cent orchards as deficient in leaf calcium.

Foliar magnesium was diagnosed as the major relative deficient in 2.00 and 78.00 per cent orchards with positive DRIS indices for magnesium. On the other hand, sufficiency range approach identified none of the orchard as deficient or excess.

DRIS diagnostic approach diagnosed foliar zinc as the major relative excess in 6 per cent orchards with positive DRIS indices for zinc was observed in 60 per cent orchards indicating nutrient status as sufficient to excess in different orchards. However, sufficiency range approach identified 8 per cent of the orchards as deficient in foliar zinc.

DRIS diagnostic approach revealed iron as the major relative deficiency in 12 per cent orchards. However, sufficiency range approach could diagnose only 20 per cent orchards deficient in leaf iron.

Leaf copper was identified as major relative excess in 40 per cent orchards. Positive DRIS indices for copper were identified in 82 per cent orchards. Sufficiency range approach identified 12 per cent any orchards as deficient in leaf copper.

DRIS approach diagnosed foliar manganese as the major relative excess in 4 per cent orchards with 58 per cent positive indices. DRIS indices for manganese which provide an indication of relative degree of leaf manganese sufficiency to excess in different orchards whereas sufficiency range approach identified 14 per cent of the orchards as deficient for leaf manganese.

The result presented in chapter 4 and section 4.9.3 reveal that DRIS diagnostic approach identified relative nutrient deficiencies and excesses in all the orchards while sufficiency range approach diagnosed deficiencies and excesses in 19 orchards. Quite comparable major deficiencies and excesses between DRIS and sufficiency approach were observed, except few exceptions. Data in Table 20 presented the superiority of the DRIS approach over the sufficiency range approach. DRIS approach indicated not only the most limiting nutrient, but the order in which other nutrients would likely become limiting. The major advantage of DRIS approach lies in its ability to minimize the effect of leaf age on diagnosis (Angeles *et al*. 1990).

The DRIS approach diagnosed sulphur as the major relative deficiency in 30 per cent orchards followed by phosphorus in 18 per cent, calcium in 14 per cent, iron 12 per cent, nitrogen 10 per cent, potassium in 8 per cent, magnesium, zinc and copper in 2 per cent. On the other hand sufficiency range approach observed iron as the major relative deficiency in 20 per cent orchards followed by sulphur in 18 per cent, nitrogen in 16 per cent, manganese in 14 per cent, and zinc in 18 per cent and phosphorus in 2 per cent (Table 20).

DRIS approach observed only relative nutrient deficiencies and excesses and not the absolute one as it provides relative measure of the nutrient status (Beverly *et al*., 1984). Therefore, best comparison between these two approaches is not possible. DRIS approach also measure the degree of nutrient balance within the plant system in the form of nutrient imbalance index (NII), which on the other hand is not possible by sufficiency range approach. Superiority of DRIS approach has also been reported by Beverely *et al*. (1984), Parent and Granger (1989), Angeles *et al*. (1993) and Singh (1966).

5.8 Distribution of nutrient imbalance indices and fruit yield at different locations

Data reveals that fruit yield recorded in mango orchards at different locations recorded ranged from 34.92 to 84.69 and 30.5 to 76.28 kg/tree with mean values 61.09 and 50.31 kg/tree at Akhnoor and Samba respectively. Nutrient Imbalance Indices (NII) was observed in the range of 19.05 to 305.35 and 29.00 to 344.80 with corresponding mean values of 82.37 and 127.52 at Akhnoor and Samba, respectively.

The highest variation in NII was recorded at Akhnoor with 94.76 per cent coefficient of variation, followed by Samba with 75.47 per cent coefficient of variation respectively and the highest coefficient of variation for yield was also recorded in Akhnoor with 25.91 per cent of variation followed by Samba with 22.24 per cent of variation respectively. The above findings are in close agreement with those of Singh *et al.* (2000) and Das (2004) who also reported relative excess or deficiencies for different nutrient elements in different apple orchards of Himachal Pradesh. Compared to the sufficiency range approach, the DRIS diagnostic approach could diagnose major relative deficiencies or excess in almost all the cases. In addition to this, the DRIS indices are simpler to interpret as compared to the sufficiency range approach and provide a measure of nutrient balance (Sumner, 1986 and Szucs *et al*. 1990). DRIS approach is as effective as sufficiency range approach, with the additional advantage of establishing a nutrient deficiency or excess ranking according to its importance and a strong relation among them. Although the DRIS approach diagnosed different nutrients as relatively most insufficient or excess but may not be deficient or excess in strict sense, as the DRIS indices are relative and not absolute measures of the nutrient status which identify the order of limitation or requirements, even if all nutrients are present in sufficient or deficient concentrations (Beverly *et al.* 1984). However, the DRIS approach quantifies the plant nutrient balance and measures the degree of nutrient balance within the plant system in the form of Nutrient Imbalance Index (NII), which is not possible with the use of sufficiency range approach and thus, it is the major advantage of DRIS over sufficiency range approach. The superiority of DRIS approach over sufficiency range approach has been reported by Davee *et al.* (1986), Walworth and Sumner (1987), Parent and Granger (1989), Szucs *et al.* (1990) and Angeles *et al.* (1993). Thus DRIS norms derived in the present studies have shown better precision as diagnostic tool for assessing nutrient status of mango orchards.

5.9 Leaf nutrient standard for mango

By using mean and standard deviation, five nutrient ranges/standards were derived as deficient, low, optimum, high and excess for each nutrient. The optimum leaf nutrient norms developed based on the mean leaf nutrient concentrations in high yielding population are presented in chapter 4 under sub-heads 4.11.

The optimum nitrogen ranged from 1.95 to 2.29 per cent indicating that a minimum of 1.95 per cent nitrogen should be maintained in the leaf for better growth and production in mango. The leaf nitrogen content of less than 1.77 per cent and more than 2.47 per cent is considered as deficient and excess respectively. This indicated a wide variation in leaf nitrogen content that existed without having much effect on yield. Raghupathi and Bhargava (1998, 1999a) also reported similar results in pomegranate and mango. The optimum leaf phosphorous ranged from 0.15 to 0.23 per cent which was in general much lower compared other fruit crops. Since the relative amounts of nutrients required by plants are reflected in the leaf composition, the low phosphorous content in mango leaves indicated that the phosphorous requirement of mango is far lower than that of other fruit crops such as papaya

(Anjaneyulu, 2007). The optimum potassium concentration ranged from 0.25 to 0.43 per cent reflecting a wide variation. Potassium is considered deficient when it is less than 0.15 per cent and excess when it is more than 0.53 per cent. If the concentration of potassium is above the upper limit/excess is bound to induce physiological disturbance in relation to magnesium and calcium. As reported in case of potassium and phosphorous requirement of sapota orchards were much less compared to fruit crops like papaya and banana (Bhargava, 2002).

The optimum calcium concentration ranged from 2.05-2.37 per cent. Calcium content of less than 1.89 per cent is classified as deficient and more than 2.53 per cent as excess category. Calcium content in mango leaves was higher compared to primary nutrients, which indicated high root activity and adequate absorption of calcium from a soil rich in calcium content. The physiological role of calcium in vital functions of a plant is well established. Bhargava and Raghupathi (1997) noticed higher calcium content in grape petiole during bud differentiation stage. Similarly, Anjaneyulu (2007) reported higher Calcium content in papaya crop, which has a continuous flowering habit. Therefore, it appears that the calcium concentration in mango is governed by new flushes and flowering pattern to a large extent. The optimum leaf magnesium norms for mango were 0.53 to 0.93 per cent. Raghupathi and Bhargava (1998, 1999a) noticed a similar range for magnesium in pomegranate grown in Bijapur district of Karnataka. The optimum sulphur concentration ranged from 0.16 to 0.26 per cent.

In the present study, among the micronutrients a wide optimum range was noticed for leaf iron and manganese content. The optimum iron and manganese concentrations ranged from 194.65 to 303.37 ppm and 122.43 to 178.53 ppm, respectively. The wide range observed might be mainly due to large variation in the available iron and manganese contents in the surveyed orchards (Raghupathi and Bhargava, 1999a). The optimum zinc and copper concentrations ranged from 19.6 to 27.04 and 16.78 to 22.48 ppm, respectively.

The data presented that nearly 70, 64, 64, 56,54, 58, 64, 64, 64 and 64 per cent were found to be sufficient whereas 18, 30, 34, 20, 28, 38, 24, 14, 14 and 18 per cent were low and 16, 2, 0, 18, 12, 0, 8, 20, 12, 14 per cent deficient in nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper and manganese, respectively. These findings are in agreement with those of Hundal *et al.*

(2005) found that 16, 15, 12, 17, 16, 19, 18, 12 and 20 per cent of the leaf samples were deficient in nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper and manganese, respectively. Similarly, Nayak *et al*. (2011) reported that on the basis of the sufficiency ranges 33, 51, 47, and 46 per cent samples were found sufficient whereas 34, 22, 18 and 27 per cent of samples were low and 26, 8, 1 and 17 per cent deficient in nitrogen, phosphorus, potassium and zinc, respectively.

Chapter-6

Summary and Conclusions

CHAPTER -6

SUMMARY AND CONCLUSION

The present investigation entitled **"Standardization of Diagnosis and Recommendation of Integrated System of mango cultivar Dashehari under Jammu sub tropics"** was carried out in Jammu region during the year 2016-17 and 2017-18. The salient findings and conclusion drawn are summarized below.

6.1 Soil properties

6.1.1

In the surface and sub-surfaces depth, pH varied from 6.24 to 7.8, 6.30 to 7.82 and 6.33 to 7.83 with mean values of 6.97, 7.02, and 7.05.

6.1.2

The EC ranged from 0.05 to 0.27, 0.04 to 0.25 and 0.03 to 0.24 dS m^{-1} with mean values 0.15, 0.13 and 0.12 dS m^{-1} in the surface and sub-surface depths.

6.1.3

The respective contents of organic carbon in surface and sub- surfaces depth ranged from 0.21 to 2.30, 0.18 to 2.25 and 0.15 to 0.28 per cent with mean values of 0.99, 0.93 and 0.89 per cent.

The soil pH was nearly neutral in reaction and showed an increasing trend with depth, while EC and Organic contents decreased with the increase in soil depth.

6.2 Soil nutrient status

6.2.1 Nitrogen

Available N content ranged from 107.10 to 298.26, 75.60 to 282.63 and 57.80 to 280.15 kg ha^{-1} with mean values 251.90, 230.38 and 204.65 kg ha^{-1} in surface and sub- surfaces depth, respectively.

6.2.2 Phosphorus

In surface soils, available P contents ranged from 7.60 to 22.90kg ha^{-1} with a mean value of 18.15 kg ha^{-1}, whereas, in sub- surfaces soil, it ranged from 6.90 to 20.00 and 6.20 to 18.42 kg^{-1} with mean values of 16.00 and 14.13 kg ha^{-1}.

6.2.3 Potassium

In surface depth, available K content ranged from 95.10 to 224.23 kg ha $^{-1}$ with the mean value of 156.23 kg ha^{-1} and in sub- surfaces depth, it ranged from 90.00 to 217.19 and 79.34 to 210.00 kg ha^{-1} with mean values of 144.59 and 133.71 kg ha^{-1}.

6.2.4 Sulphur

The S content in the surface and sub- surfaces depth ranged from 12.60 to 19.74, 10.40 to 17.90 and 9.80 to 16.95 kg ha^{-1} with mean values of 16.10, 14.95 and 13.97 kg ha^{-1}.

6.2.5 Calcium

Ca content ranged from 4.02 to 6.35, 4.00 to 6.35 and 4.00 to 6.32 [c mol (p+) kg $^{-1}$] with the mean values of 5.66, 5.63 and 5.60 [c mol (p+) kg $^{-1}$], respectively in the surface and sub- surfaces depth.

6.2.6 Magnesium

In the surface and sub- surface depth Mg content ranged from 2.18 to 3.32, 2.16 to 3.28 and 2.14 to 3.28 [c mol (p+) kg $^{-1}$] with mean values of 2.83, 2.81 and 2.76 [c mol (p+) kg $^{-1}$], respectively.

6.2.7 Zinc

Zn content of the soil ranged from 0.52 to 1.04 ppm with mean value of 0.76 ppm from the surface depth and 0.50 to 0.97 and 0.48 to 0.95 with mean values of 0.74 and 0.72 ppm from sub- surfaces depth of soil.

6.2.8 Iron

Fe ranged from 11.48 to 21.75 with mean value of 17.71 ppm from the surface soil, it ranged from 11.10 to 20.94 and 10.99 to 20.75 ppm with mean values of 17.11 and 16.58 ppm.

6.2.9 Copper

Cu contents of the soils ranged from 0.90 to 1.65 with mean value of 1.12 ppm from surface soil and from the sub- surface soil it ranged from 0.80 to 1.63 and 0.72 to 1.59 ppm with mean values of 1.08 and 1.05 ppm.

6.2.10 Manganese

Mn content varied from 4.15 to 22.25, 4.00 to 20.98 and 3.92 to 20.89 ppm with mean values of 16.48, 16.08 and 15.89 ppm in the surface and sub- surfaces depths, respectively.

6.2.11

The soil nutrient status indicated that the mean nutrient content of N, P, K, S, Zn, Fe, Cu and Mn were found to be higher in high yielding orchards as compared to low yielding orchard.

6.3 Leaf nutrients status

Leaf nutrients in different mango orchard viz., N, P, K, S, Ca, Mg, Zn, Fe, Cu, Mn varied from 1.10 to 2.25 per cent, 0.09 to 0.25 per cent, 0.19 to 0.45 per cent, 0.04 to 0.29 per cent, 1.8 to 2.45 per cent 0.42 to 1.01per cent, 10.6 to 28.5 ppm, 101.2 to 310.5 ppm, 10.5 to 24.7 ppm and 69.9 to 193.9 ppm, respectively with mean values of 1.97 per cent,0.17 per cent,0.30 per cent, 0.18 per cent, 2.11 per cent, 0.64 per cent, 21.22 ppm, 209.88 ppm, 18.52 ppm and 132.36 ppm, respectively. The leaf nutrient status indicated that the mean nutrient content of N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn were found to be higher in high yielding orchards as compared to low yielding orchards.

6.4 Fruiting characteristics

6.4.1 Physical characteristics

The fruit weight, length, diameter, volume, specific gravity, fresh pulp weight**,** dry pulp weight, stone weight, pulp stone ratio and yield varied from 139.98 to 171.03 g, 9.05 to10.45 cm, 138.90 to 170 cm^3, 1.006 to 1.008, 87.05 to 109.80 g, 4.83 to 6.97 g, 26.32 to 31.10 g, 3.23 to 3.55 and 30.50 to 84.69 kg/ plant, respectively with mean values of 157.15 g, 9.91cm, 5.66 cm, 156.10 cm^3, 1.007, 97.45 g, 5.65 g, 26.68 g, 3.40 and 55.55 kg/plant, respectively.

6.4.2 Chemical characteristics

Total soluble solids, titrable acidity, T.S.S: acidity, ascorbic acid, total sugars content, reducing sugar and non – reducing sugar of mango fruit varied from 17.11 to 20.17 $Brix^0$, 0.21 to 0.28 per cent, 66.55 to 82.19, 35.59 to 41.82 mg/100 g, 12.43 to 15.07 per cent, 2.95 to 3.98 per cent, 9.63 to 11.29 per cent with mean values of 17.69 Brix^0, 0.24 per cent, 72.82 , 39.23 mg/100 g, 13.76 per cent, 3.48 per cent and 10.45 per cent, respectively.

6.5 Relationship of soil nutrients with soil properties, leaf nutrients and fruit Characteristics

The soil pH of the surface layer 0-30 cm was significantly and positively correlated with available magnesium and available copper. For the sub- surface layer 30-60 cm the soil pH was found to be positively and significantly correlated with available copper.

The electrical conductivity of the surface layers 0-30, 30-60 and 60-90 cm was significantly and positively correlated with available soil calcium, magnesium and copper.

The organic carbon content in the surface soil 0-30 cm was found to be significantly and positively correlated with available soil nitrogen, phosphorus, calcium, magnesium, zinc, copper and manganese. For the sub- surface layer 30-60 cm layer it was found to be positively and significantly correlated with available nitrogen, phosphorus, calcium, magnesium and copper. The organic carbon content positively and significantly correlated with available nitrogen, available phosphorus, available calcium, available magnesium and available copper.

The correlation of available phosphorus with leaf nitrogen exhibited negative but significant from sub- surface layers, 30-60 and 60-90cm. Relationship of soil available potassium with leaf phosphorus and leaf manganese were found to be negative but significant. The correlation of soil magnesium with leaf nitrogen and leaf sulphur showed negative but significant from soil surface layer. From the sub-surface layer 60-90 cm leaf magnesium showed significant relationship with leaf nitrogen, leaf sulphur and leaf iron. A negative but significant correlation of soil available zinc with leaf copper were found from the surface and sub- surfaces of the soil.

6.6 Relationship of leaf nutrients with fruit characteristics

The relationship between fruit length and leaf N was found to be positive and significant, whereas, leaf Cu and Mn showed non-significant relationship. The correlation of fruit diameter with N was positive and significant.

Fruit volume showed positive and significant correlation with leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn.

A negative but significant correlation of specific gravity was found with leaf N, P, S, Ca, Mg, Zn and Fe whereas leaf K, Cu and Mn showed non-significant relationship.

Pulp weight was found to be highly positive and significant correlation of leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn.

Stone weight exhibited positive and significant relationship with N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn. Pulp: stone ratio showed positive and significant correlation with leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn.

The relationship between fruit yield and leaf N, P, K, S, Ca, Mg, Zn, Fe, Cu and Mn were found to be positive and significant at Akhnoor.

The relationship of fruit yield were found to be positive and significant with leaf zinc while as negative and non- significant correlation of fruit weight, fruit length, fruit diameter, fruit volume, specific gravity, fresh pulp weight, dry pulp weight, stone weight and pulp: stone ratio was observed with all leaf nutrients viz. N, P, K, S, CA, Mg, Zn, Fe, cu and Mn at Samba.

The relationship between total soluble solids and leaf nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, zinc, iron, copper and manganese were found to be highly significant**.**

A positive and highly significant correlation was found between titratable acidity and leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese whereas, non significant relationship of titratable acidity was recorded with leaf potassium . TSS: acidity showed positive but non- significant relationship with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese. However TSS: acidity showed negative and non significant correlation with leaf S.

A positive and highly significant correlation of ascorbic acid was found with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese. Highly significant and positive correlation of total sugar was observed with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese, however total sugars was found to be non- significant with leaf Cu.

Reducing sugars was found to be positive and highly significant relationship with nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese. A positive and significant relationship of non- reducing sugar was found with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese. Non reducing sugar exhibited non significant relationship with leaf copper at Akhnoor.

The correlation of total soluble solids, titratable acidity, TSS: acidity, ascorbic acid, total sugars, reducing sugar and non-reducing sugar with leaf nitrogen, phosphorus, sulphur, calcium, magnesium, zinc, iron, copper and manganese showed non- significant relationship at Samba.

6.7 DRIS norms

6.7.1

In all, 45 nutrient expressions producing highest variance ratios were selected as DRIS norms viz., N/P, N×K, N/S, Ca/N, N×Mg, Zn/N, N/Fe, Cu/N, N/Mn, P×K, P/S, Ca/P, Mg/P, Zn/P, P/Fe, Cu/P, P×Mn, K/S, Ca/K, K× Mg, Zn/K, K/Fe, Cu/K, K× Mn, Ca/S, Mg/S, Zn/S, Fe/S, Cu/S, Mn/S, Ca/Mg, Ca/Zn, Ca/Fe, Ca/Cu, Ca/Mn, Zn/Mg, Mg/Fe, Cu/Mg, Mg/Mn, Zn/Fe, Cu/Zn, Zn/Mn, Cu/Fe, Mn/Fe, Cu/Mn with corresponding mean values of 11.074, 0.005,10.248, 1.045, 1.559, 0.001, 86.679, 0.001, 142.609, 0.006, 0.930, 11.553, 3.783, 0.012, 7.898, 0.010, 0.003, 1.626, 6.736, 0.253, 0.007, 13.784, 0.006, 0.005, 10.691, 3.457, 0.011, 0.119, 0.009, 0.072, 3.125, 955.608, 90.283, 1133.510, 148.785, 0.003, 48.726, 0.095, 0.849, 0.157, 0.080, 0.613, 0.132, respectively.

6.7.2

DRIS diagnostic approach and sufficiency range approach (Shear and Faust, 1980) were used to work out DRIS order of nutrient requirements, orchards having positive and negative indices and nutrient deficiencies and excesses.

6.7.2.1 Nitrogen

DRIS diagnostic approach diagnosed foliar N as the major relative deficient nutrient in 10 per cent orchards, whereas sufficiency range approach identified 16 per cent orchards as deficient in foliar N.

6.7.2.2 Phosphorus

DRIS approach identified foliar P as the major relative deficient nutrient in 18 per cent orchards whereas 2 per cent orchards identified in sufficiency range approach.

6.7.2.3 Potassium

Leaf K was identified as major relative deficient nutrient in 8 per cent orchards and sufficiency range approach identified none of the orchards as deficient or excess.

6.7.2.4 Sulphur

DRIS approach diagnosed foliar S as the major relative deficient nutrient in 30 per cent orchards whereas sufficiency range approach identified 18 per cent of the orchards as deficient.

6.7.2.5 Calcium

Diagnosis of leaf Ca status by DRIS approach identified 18 per cent having Ca as the major relative excess nutrient whereas sufficiency range approach identified 12 per cent of orchards as deficient.

6.7.2.6 Magnesium

Foliar Mg diagnosed as the major relative deficient nutrient in 2 per cent orchards. On the other hand sufficiency range approach identified none of the orchard as deficient or excess.

6.7.2.7 Zinc

DRIS diagnostic approach identified foliar Zn as the major relative excess nutrient in 6 per cent orchards. However sufficiency range approach identified 8 per cent orchard as deficient.

6.7.2.8 Iron

DRIS diagnostic approach revealed Fe as the major relative deficient nutrient 12 per cent orchards. However sufficiency range approach could diagnose 20 per cent orchards as deficient in leaf Fe.

6.7.2.9 Copper

Leaf copper was identified as major relative excess in 40 per cent orchards. Sufficiency range approach identified 12 per cent of orchard as deficient in leaf Cu.

6.7.2.10 Manganese

DRIS approach diagnosed foliar Mn as the major relative excess nutrient in 4 per cent orchards. Sufficiency range approach identified 14 per cent orchards as deficient for leaf Mn.

6.7.3

The DRIS approach diagnosed S as the major relative deficiency in 30 per cent orchards followed by P in 18 per cent, Ca in 14 per cent, Fe 12 per cent ,N 10 per cent, K in 8 per cent, Mg, Zn and Cu in 2 per cent and Mn in 0. On the other hand sufficiency range approach observed Fe as the major relative deficiency in 20 per cent orchards followed by S in 18 per cent, N in 16 per cent, and Mn in 14 per cent, and Zn in 18 per cent and P in 2 per cent orchards.

6.7.4

Nutrient imbalance indices and fruit yield ranged from 19.95 to 344.8 and 30.5 to 84.69 kg/tree, respectively in different mango orchards in Jammu region.

6.7.5

Leaf nutrient standards for mango were derived based on five leaf nutrient guides or ranges using mean and standard deviation (SD) as deficient, low, optimum, high and excess for each nutrient. Based on these leaf nutrient standards, the optimum ranges for N, P, K, S, Ca, Mg, Zn, Fe, Cu, Mn, for mango cv. Dashehari were 1.95 to 2.29 %, 0.15 to 0.23 %, 0.25 to 0.43 %, 0.16 to 0.26 %, 2.05 to 2.37 %, 0.53 to 0.93 %, 19.60 to 27.04 ppm, 194.65 to 303.37 ppm, 16.78 to 22.48 ppm and 122.43 to 178.53 ppm respectively.

Conclusion

From the present study, it can be concluded that the mango orchards of Samba and Akhnoor regions showed variation in nutrient elements in soil and leaf and in yield. The DRIS method expressed the results of plant nutritional diagnosis through DRIS indices, Nutritional Imbalances Index and Order of requirement of leaf nutrients of mango orchards of Jammu region. These indices are expressed by positive or negative values, which give an indication that the referred nutrient is in excess or deficiency. Thus, DRIS approach gives a measure of the concept of nutrient balance in the plant system by calculating nutrient imbalance index in relation to fruit yield. The DRIS method expresses results of plant nutritional diagnosis through indices, which represent the effect of each nutrient in the nutritional balance of the plant. Therefore, while interpreting leaf and soil nutritional status of the orchard, DRIS diagnostic approach along with sufficiency range diagnostic approach should be used as a guide for fertilizer application of mango trees for better fruit production.

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OGPA	: 7.14/10.00

CERTIFICATE-IV

Certified that all necessary corrections as suggested by external examiner and the advisory committee have been duly incorporated in the thesis entitled **"Standardization of Diagnosis and Recommendation Integrated System of mango (*Mangifera indica* L.) cv. Dashehari under Jammu Sub tropics"** submitted by **Mrs Jyoti Devi,** Registration No**. J-15-D-249-A.**

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