DIAGNOSTIC NORMS FOR NUTRITIONAL REQUIREMENT OF NAGPUR MANDARIN USING DRIS APPROACH

THESIS

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **"DIAGNOSTIC NORMS FOR NUTRITIONAL REQUIREMENT OF NAGPUR MANDARIN USING DRIS APPROACH"** or part there of has not been submitted for any other University for award of any diploma or degree. The data of this experimental work has not been derived from any thesis/publication of any University or Scientific Organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

Place: Akola

Dated: 13-01-2003

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C E R T I F I C A T E

This is to certify that the thesis entitled **"DIAGNOSTIC NORMS FOR NUTRITIONAL REQUIREMENT OF NAGPUR MANDARIN USING DRIS APPROACH"** submitted in partial fulfilment of the requirements for the degree of "Doctor of Philosophy" in Agriculture (Agricultural Chemistry and Soil Science) of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, is a record of bonafide research work carried out by **Mr. Dnyaneshwar Shriram Kankal** under my guidance and supervision. The subject of the thesis has been approved by the student's advisory committee.

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(D.S. Kankal)

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LIST OF ABBREVIATIONS USED

Abbreviations	Full form or meaning
%	Per cent
<	Less than
>	Greater than
Ca	Calcium
$CaCO_3$ or CC	Calcium carbonate
cm	Centimeter
cmol (p^+) kg^{-1}	Centimole positive charge per kilogram of soil
Cu	Copper
CV	Coefficient of variation
DRIS	Diagnosis and recommendation integrated system
dSm^{-1}	Deci siemons per meter
DTPA	Diethylene triamine penta acetic acid
e.g.	For example
EC	Electrical conductivity
ESP	Exchangeable sodium percentage
et al.	*et alia* (and others)
f	Function of
Fe	Iron or ferrous
Fig.	Figure
ha	Hectare
i.e.	*Id est* (that is)
K or K_2O	Potassium
kg/ha or $kgha^{-1}$	Kilogram per hectare
MAT	Mean air temperature
Mg	Magnesium
Mn	Manganese
N	Nitrogen
°C	Degree centigrade
OC	Organic carbon
P or P_2O_5	Phosphorus

INTRODUCTION

Pages 1 - 5

CHAPTER I

INTRODUCTION

Soils are the natural bodies in which plants grow. They provide the starting point for successful agriculture. People are dependent on soils, and conversely good soils are dependence on people and the use they make of land. Most great civilizations have dependence on good soils. Good soils help to build flourishing civilizations, in contrast, soil destruction or mismanagement is a contributing factor in their downfall. Thus, soil is a finite resource and has been meeting the basic requirements of human and animal population in the form of food, fodder, fuel and fibre. The demand of this finite soil resource is increasing exponentially due to the increasing population at the rate of 2.1 per cent in India. Experts predict that the population is doubling in many developing areas where two thirds of the world's population now lives. This population growth is leading to unfavorable man to land ratio. In our country, the per capita cultivable land holding has been declined from 0.5 ha in 1951-52 to 0.14 ha in 2000 A.D. The food production increased from 52 m tons and in 1950's to almost 200 m tons in 2000's. But this increase has been largely as a result of expansion in cultivated area and high inputs. The significant growth of agriculture has been at a cost of decline in soil quality and risk of soil degradation (Abrol and Sehgal , 1992).

The conservation and improvement of soils is one of the keys to meeting the challenge of feeding an increasing population. Soil and crop management systems must be developed and adapted to increase food production and simultaneously prevent soil deterioration.

Citrus have a prominent place among popular and extensively grown tropical and sub-tropical fruits. In India, citrus fruits rank third in area and production after banana and mango with an estimated production of 3699 thousand metric tons and an area of 442.9 thousand ha (Ghosh, 1999). The important commercial citrus fruits in India are the mandarin orange (*Citrus reticulata* Blanco) followed by sweet orange (*C. sinensis* Osbeck) and acid lime (*C. aurantifolia* Swingle). Among these citrus fruits, mandarin orange constitutes about 41 per cent, sweet orange 23 per cent and lime and lemons (*C. linion*) about 23 per cent of the total citrus produced. (Ghosh, 1999). Maharashtra state stands first followed by Andhra Pradesh and Punjab in area (75115 thousand ha) and second in production (418.6 thousand tones) next to Andhra Pradesh (842.5 thousand tons) (Singh, 1999).

Of the four regions of Maharahstra, Vidarbha grows mandarin in more than 97 per cent mandarin area of state is expected to produce 600000 tones. Districtwise distribution of area is as, Amravati - 68,300 ha, Nagpur - 33,794 ha, Wardha-12,890 ha, Yavatmal-14,759 ha and Akola (including Washim)-10,958ha.

While other districts *viz.* Buldhana, Bhandara and Chandrapur have very limited area (5000 ha) under orchards. This indicates that there is a scope for mandarin growing in the Western Vidarbha through expansion of area as well as through increased productivity. Citrus fruits are available throughout the year. They are not only delicious and refreshing to eat, but also provide vitamins, minerals and many other essential substances which are required for human health. They are especially important for growing children and are important natural source of vitamin-C.

Citrus plants require judicious supply of plant nutrients for proper growth and yield of high quality fruits. . Improper and inadequate nutrition is one of the major causes of citrus decline in India. Citrus trees are quite sensitive to excess of salts and are injured if total salt concentration in soil exceeds 1000 ppm (Rajput and Sri HariBabu, 1995). Calcium carbonate ($CaCO_3$) is important contributing factor for decreased availability of iron and zinc in soils. Zinc deficiency is widely seen in citrus (Bojappa and Bhargava, 1993).

Determination of the nutritional need is an important problem of the fruit growers. Often the fruit orchards are fertilized by the growers on the basis of recommendation by the horticulturist, speculation, salesmanship, and experience of a successful grower or emotion. However to ensure high economic productivity and to sustain the available soil nutrient status at a desirable level, correct doses of manures ånd fertilizers must be applied using reliable diagnostic tools. Considerations of economy, energy and environment make it imperative that fertilizers should be used efficiently. This can be obtained best by the use of one or more of the diagnostic methods in consideration with a background of research results.

The best diagnostic tool is one that recommends nutrient application only when a direct economic response is probable. Diagnostic tools are designed to avoid nutrient shortage or excess and used properly, so that no decrease in fruit production or quality should occur. Among several diagnostic methods, leaf analysis seems to be the most efficient in arriving need based manuring schedule for application of nutrients particularly to long duration crops (Bhargawa and Chadha, 1988). Since leaf is the principal site of plant metabolism, changes in nutrient supply are reflected in the composition of leaf. These changes are more pronounced at certain stages of development and are related to the performance of the crop.

Diagnosis is the art of investigating or analyzing the causes or nature of a condition, situation or problem. Therefore, in attempting to make diagnosis of factors limiting crop performance, it should be recognized that the yield and quality of a particular crop are governed by numerous factors having direct or indirect influence on crop growth. In any event, these factors often interact with one another. Under normal field condition, some of these factors are uncontrollable, for example, light and temperature and one has to accept whatever a given season brings. However, they should be used to calibrate the environment at a given site in terms of sustainable average yield. Over other factors such as soil moisture and cultivar, man has a considerable degree of control. For example, he can introduce irrigation where rainfall is insufficient or he can fertilize infertile soils or breed new more adapted varieties. However, there are elements of these factors that are not readily controllable, for example, excessive rainfall or poor physical soil conditions. Under certain conditions, these can become the most limiting factors to crop production. Nevertheless, it is essential to record as many parameters characterizing these factors as are capable of expression when establishing norms and making diagnosis. Man has a controllable degree of control over management practices which should be recorded in the same way as the uncontrollable and partially controllable factors.

All the above factors can or do have a direct or indirect effect on plant metabolism and all these influences must be studied and calibrated to obtain an understanding of how plant composition varies under different field conditions and what the relationship is between plant composition and crop yield and quality.

The Diagnosis and Recommendation Integrated System (DRIS) proposed by Beaufils (1971) offers a means of handling the collection, storage and calibration of data and the diagnosis and recommendations required if one recognizes that all these factors should be taken into account. The DRIS approach is a general experimental philosophy, which is capable of handling large amounts of data and studying and calibrating the interrelationships between all the above factors. This system is a form of plant, soil and environmental calibration, which takes into account as many factors affecting crop yield and quality as are capable of quantitative or qualitative expression. It should be borne in mind that the DRIS as well as all other diagnostic systems can only attempt to improve the chances of obtaining a higher yield and better crop quality at a given site because the possibility of one of the uncontrollable factors becoming the overall limiting factors in a given season is always very real.

On deriving DRIS norms it is possible to make a diagnosis of the condition of a particular crop thereby isolating these factors, which are likely to be limiting growth and production, in order of limiting importance. Plant indices considered on their own do not give an automatic indication of the nature and amount of a particular element which must be added to the soil, as indeed plant response is a function of soil properties and soil response to treatments. Finally optimizing of these factors creates conditions, which are likely to increase the chances of obtaining higher yields and quality of the particular crop. The DRIS proved satisfactory in fertilizer recommendations to the fruit crops like grape (Bhargava and Raghupathi 1993 & 1996) and pomegranate (Raghupathi and Bhargava, 1998).

Considering the importance of plant nutrition in determining the quality and production of citrus fruits and lack of information regarding the optimum range of nutrients in soil and plant particularly for maintaining the yield potential of quality fruits of Nagpur Mandarin orange in Western Vidarbha region, the present investigation is proposed. The investigation will generate the information to develop soil and plant nutrient diagnostic norms for Nagpur Mandarin orange using Diagnosis and Recommendation Integrated System (DRIS).

The proposed investigation was undertaken with following objectives:

i. To study the soil nutrient status of selected Nagpur Mandarin Orchards.

ii. To study the leaf nutrients status of selected Nagpur Mandarin Orchards.

iii. To evaluate and classify the Nagpur Mandarin Orchards on the basis of soil and leaf analysis.

iv. To develop the leaf nutrients norms for Nagpur Mandarin using DRIS.

v. To develop the soil fertility norms for Nagpur Mandarin using DRIS.

It is hoped that leaf and soil fertility norms attempted using DRIS for evaluation of nutrients status in relation to yield and to rationalize quantity of manures and fertilizers to be applied will be proved to be most useful for getting optimum yield economically as well as socially acceptable in the proposed area.

REVIEW OF LITERATURE

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Chapter II

REVIEW OF LITERATURE

Citrus is one of the important fruit crop commonly grown in Vidarbha with good drainage under an assured irrigation facilities of well water. It can be grown satisfactorily on a wide range of soil provided with the proper cultural practices. In Western Vidarbha region particularly in Amravati, Akola and Washim districts Nagpur Mandarin is most popular. There has been continuous increase in this area Nagpur mandarin orchards after fifties mostly due to spread of an electricity which served the source of power for lifting water from wells and transport facilities for marketing of fruits that gave more margin of profit as compared to other cash crops like cotton (Dixit, 1955). The implementation of Employment Guarantee Scheme (Rozgar Hami Yojana) for fruit crops in the state by the Government of Maharashtra is also one of the important reasons of increase in the area under this fruit crop. Today, Maharashtra enjoys topmost position in area in India, maximum acerage in Vidarbha.

Citrus plants require judicious supply of plant nutrients for proper growth and yield of high quality fruits. As it is the perennial crop, is quite different from seasonal crops in its nutritional requirement. Under normal field condition, a number of soil factors like pH, EC, organic matter, free $CaCO_3$ contents, nutrient status etc, can or do have a direct or indirect effect on crop yield and quality. If more than one nutrient is diagnosed, as being deficient is not possible to establish which is most limiting in terms of yield by traditional method like critical or sufficiency level approach. Therefore in the present investigation, DRIS approach, which derive such norms which make it possible to diagnose the condition of a particular crop thereby isolating those factors which are likely to be limiting growth and yield has been employed very first time for Nagpur mandarin in Vidarbha region.

Although considerable research has been devoted to developing soil tests, they are primarily designed to predict the possible occurrence of a deficiency. The soil tests have limited usefulness, particularly for citrus, in diagnostic situation. One should not underestimate the value of soil test when leaf analysis result is being interpreted. The two techniques when used together can effectively evaluate the soil plant nutrient environment by confirming the need for a particular nutrient and by specifying a corrective treatment (Munshi *et al.*, 1978).

However, no attempts have been made so far, to study the soils of these areas along with leaf analysis using DRIS approach for citrus crop.

The existing literature in respect of soil fertility status, leaf nutritional status and development of DRIS norms for growing citrus has been reviewed and presented briefly under the following heads.

2.1 Soil characteristics of citrus orchards

2.2 Soil fertility status of citrus orchards

2.2.1 Macronutrient

2.2.2 Micronutrient

2.3 Leaf nutritional status of citrus trees

2.3.1 Leaf macronutrients

2.3.2 Leaf micronutrients

2.4 Development of Diagnostic Norms using DRIS

2.1 Soil characteristics of citrus orchards

The important soil characteristics besides the available nutrients limiting the growth of citrus fruit trees are pH, EC, $CaCO_3$ and organic matter. These are briefly reviewed here.

Hass (1940) studied the soils requirements of different citrus species and claimed that citrus grows better in acidic soil than that of alkaline one. However, he advised to apply sufficient liming material to prevent the pH value falling below 5.5.

He also advised that the soil pH value of every citrus orchard should be determined once a year.

Richards (1954) reported that the cation exchange capacity (CEC) is a measure of soil activity to retain and supply plant nutrients. An exchange complex dominated by calcium is desirable and this is due to the case when the pH value is greater than 5.5.

Dhawan *et al.* (1957) observed that the safe limit of pH in citrus soil is 7.0 to 8.5. While Kanwar and Randhawa (1960) observed that the citrus cultivation was successful at the soil pH less than 8.5.

Hayes (1957) noted that the presence of lime in moderate amount is good for citrus cultivation as it is thought that this helps to the success of orchards.

Martin *et al.* (1959) reported that the trifoliate orange seedlings did not appear to be sensitive to excess $CaCO_3$. Two per cent lime added to the soil did not reduce growth. Whereas Kanwar and Randhawa (1960) reported high content of $CaCO_3$ in citrus soils of Punjab, which is believed to be an important contributing factor for deficiencies of Zn, Fe and Mn. They further reported that electrical conductivity (EC) of the 1:2 soil : water suspension should not be more than 0.5 mm hos / cm or dS m^{-1}. Otherwise the growth and production of citrus would be adversely affected and lead to chlorosis due to deficiency of zinc.

Bould (1963) conducted the experiment in California and found that pH value between 5.5 to 6.0 is considered to be optimum for citrus cultivation. Values lower than 5.5 tend to increase leaching of lime and magnesium and higher values are likely to reduce the availability of trace elements.

Dhingra and Kanwar(1963) studied various soil conditions such as soil reaction (pH), EC, $CaCO_3$ and organic matter affecting chlorosis of citrus. They observed the pH was slightly alkaline in both healthy and chlorotic cases and was almost similar. There was no salt concentration problem. The $CaCO_3$ content of the soils bearing chlorotic plants was about 2.0 per cent as compared to 0.5 per cent healthy soils.

Dudal and Bramo (1965) reported that dark clay soils of tropical and subtropical region have neutral to alkaline reaction due to their formation over basaltic (calcium rich) parent material and high or moderately alkaline earth contents.

Dhingra *et al.* (1965) studies the citrus belt of Punjab and showed that loamy soils with pH 8.1 to 8.5 and EC of 0.4 mmhos / cm or dsm^{-1} supported healthy orchards.

Kanwar *et al.* (1965) suggested that the pH of the soil should not be more than 8.5 and EC should be less than 0.5 mm hos/cm or dSm^{-1} for successful growth of citrus. However a detailed survey of the citrus soils of Bhatinda district has shown that citrus continued to make normal growth when the soil pH was as high as 8.8 (Singh, 1966).

A soil survey of the proposed citrus belt in Ferozpur, Bhatinda and Hissar districts (Dhingra *et al.* 1965, Kanwar *et al.*, 1965, Sehgal *et al.*, 1965) revealed that a high proportion of $CaCO_3$ and presence of lime concreations layer might be a hazard for successful cultivation of citrus in these districts.

Randhawa *et al.* (1966) suggested that citrus thrives well in soils which are very deep, loose, well aerated and devoid of any impregnated layers due to CaCO3 concretions or clay. The presence of these pans affected both the permeability and aeration of such soil.

Sehgal *et al.* (1965) reported that the high EC (more than 0.5 dSm^{-1}) at 25 °C is unsafe for the successful growth of citrus due to the toxic effect of accumulated ions in the plant tissues.

Singh and Lal (1968) reported that cation exchange capacity of soil depends upon the amount of nature of the clay and organic matter content. They further summarised that there is a significant correlation between organic carbon and CEC of soils.

Nijjar and Singh (1971) conducted experiment on the mineral status of healthy and declined sweet orange orchards located in Amritsar districts of Punjab. They observed that organic matter of the declined orchards was lowest. They further observed that EC and pH were higher in the declined orchards as compared with those of the healthy ones.

Anderson (1972) conducted a trial with young valencia oranges on rough lemon rootstock on newly cleared lakeland fine sand soil, amendments were applied annually so as to give soil pH levels of 4.0, 5.0, 6.0 or 7.0 together with calcium additions of 0-400 lb/acre/year in all combinations. With the first crop, differential treatment effects on tree size were marked, the largest trees occurring on high pH soils with high Ca addition. Yields were closely related to tree size. Data are also tabulated on the effects of the various treatments on internal quality of fruits.

The comparative studies were made of soil conditions in young orange orchards with patches of poor growth, and in adjacent areas with normal growth. Soil conditions in the affected areas were characterized by higher total soluble salt content (Milad *et al.*,1975).

According to Lande *et al.* (1977), total organic and water soluble sulphur showed positive correlation with organic carbon and pH of soil. However no significant correlation have been observed with $CaCO_3$ and different forms of sulphur.

Bhutani *et al.* (1978) planted sweet oranges Cv. Blood red in the soil pits (1 x 1 x 1 m) to which lime stone had been added and mixed so as to give 10, 20 or 30 per cent $CaCO_3$ by weight. Four and five years later leaf samples of sweet orange were analysed for the effects on nutrient element. They observed that leaf contents of nutrient elements were slightly affected but leaf Ca content of sweet oranges was slightly increased whereas leaf Mn contents and leaf Fe contents were reduced.

Malewar *et al.* (1978-a) studied healthy and declined citrus orchards of Marathwada region and revealed that organic carbon in healthy and medium orchards was more (0.88 to 1.56 per cent) as compared to declined orchards (0.70 to 0.76 per cent). Even though the orchard soils had pH and EC in narrow range of 7.4 to 7.8 and 0.174 to 0.418 mm hos per cm, respectively the values of pH and EC were higher in declined orchards than in healthy orchards.

They further showed that low zinc contents below normal level of five healthy leaf samples might have been associated with low status of available zinc and highly calcareous nature of soils.

While studying some Citrus growing tract of Marathwada in another case Malewar *et al.* (1978 b) observed that organic carbon was associated with availability of copper and clay or $CaCO_3$ with availability of manganese, while pH showed negative relationship with their availability.

Mann *et al.* (1978) suggested that citrus trees continue to make apparently normal growth when the pH is as high as 9.0, whereas EC was in the safe limits (less than 0.50 mmhos / cm) except orchards in Bhatinda district. They further reported that higher amount of free calcium carbonate in horizon upto 180 cm depth of soil will render the soil unfit for citrus cultivation. The poor growth of citrus was attributed to excessive free lime in 30 to 150 cm depth, which renders many nutrients such as Zn, Fe and Mn less available to plants. Similar results were demonstrated by Harding and Chapman (1950), Randhawa *et al.* (1961), Bhella (1966), Chadha (1966) and Singh (1966).

Mann *et al.* (1978) also observed that presence of lime concretions or hard pans more than critical limit 20 per cent affect both the permeability and aeration of the soil with the result the renewal of oxygen and displacement of carbon dioxide is adversely affected which attributed as the major cause of citrus decline.

Patil (1979) reviewed that although there exists large variations among citrus species and varieties, they all are rated as salinity sensitive. Lemons are more sensitive to salinity than orange and grape fruit.

Shawky *et al.* (1980) investigated the effect of pH on the growth and mineral content of some citrus root stock seedling and found that growth of citrus seedlings was best at pH 6 and it reduced on an average of 9.8%, 25.4% and 40.1 % at pH 5, 7 and 8, respectively.

Harmful effects of excessive accumulation of $CaCO_3$ on citrus have been reported by Nilangekar and Patil (1981). They reported that excessive accumulation of one or the other form of $CaCO_3$ in the layer of 0 to 80 cm depth might leave adversely affected the citrus trees. They concluded that it is difficult for orchard crops to penetrate their roots through clay and calcium pan, particularly at the lower horizons. Aeration and infiltration are also hampered thereby resulting into the chlorotic conditions of citrus. Similar results were observed by Agarwala and Mohrotra (1963).

Nilangekar and Patil (1981) reported that the organic carbon was medium in the profile of normal orchards while in the profile of chlorotic gardens it was rather low.

Six soil profiles from important citrus growing areas famous for quality citrus in Chamoli district of U.P. hills were studies in detail for their morphological and physico-chemical characteristics by Singh and Kunwar (1981). They found that these soils due to their good depth with good texture (sandy to clay loam), structure and adequate in organic carbon (0.70 to 2.36%) with suitable pH range (5.8 to 6.9) in surface horizons provide favorable physical conditions for the cultivation of citrus in the area except at Pipalkoti.

Kotur *et al.* (1982) reported that though non-cultivation and soil mulch decreased the pH, organic carbon and exchangeable cation exchange shading promoted these properties in Coorg mandarin cultivation.

Nilangekar and Patil (1982) studied soil profiles upto depth of 1.5 m at two locations in Aurangabad district of healthy and chlorotic citrus orchards. They observed that the all soils throughout profile depth were slightly alkaline in nature. The pH of the third layer of the profile (60-110 cm) of chlorotic trees was rather high. Profile samples of chlorotic site retained high amount of soluble salts, which seems to be undesirable for successful citrus cultivation. They also observed that high EC contributed to the citrus decline at Aurangabad soils affecting the availability of the plant nutrients to the plant on black soils.

Nilangekar and Patil (1982) further noted the total $CaCO_3$ content, which was substentially high (more than 11.28%) in the profiles upto the depth of 110 cm, supporting chlorotic trees. They observed that organic carbon content in the normal profiles was substantially higher than in the one having chlorotic plants and more particularly in the upper layer.

Singh and Kunwar (1982) conducted studies in eight orchards of sweet range selected at different locations in Chamoli district of U.P. hills and observed that the pH of some sweet orange orchards soil was 6.7 to 6.8 and organic carbon was 0.69 to 1.81 per cent in different soil depth.

Stevenson (1982) reported that organic matter has indirect effect on nutrient availability. Organic matter acts as a major factor regulating the availability of organic forms of N, P and S in soil.

Singh (1982) observed that all the soils of sweet orange orchards were alkaline in reaction (pH 8.1-9.9).

Chakravarty and Barua (1983) found that clay contribute significantly towards increasing the acidity of soils where pH decreased down the profile while organic matter has significant contribution with pH in the soils where surface pH is lower and has a tendency to increase downwords.

Kalbande *et al.* (1983) investigated four major orange growing soils (Musarkhapa, Karla, Panjra and Linga series) in Nagpur district to assess their suitability for cultivation of orange. They revealed that Panjra soils showed healthy and superior in growth than Linga soils where the pH of surface soils of Panjra series is comparatively more than pH of Linga soils and EC showed no more difference.

Singh and Tripathi (1983) studied twenty citrus orchards of Agra region and observed that organic carbon was highest in the surface layer while in case of $CaCO_3$ it was so in 120–130 cm depth while organic carbon had positive correlation with available Mn, pH and $CaCO_3$.

Chauhan *et al.* (1984) surveyed 13 citrus orchards of western Haryana and observed that most of the soils of orchards were found to be low in organic carbon (0.17 to 0.53%), EC ranged from 0.06 to 0.38 mmhos /cm which was in safe limit, pH was alkaline (8.20 to 8.70) which was found to be associated with general health and yield of orchards while $CaCO_3$ was observed in desired range (0.61 to 5.12 %).

Kaushal *et al.* (1986) reported that the soil rises with depth due to corresponding increase in $CaCO_3$ and to some extent salt content in some lower layers.

Otha *et al.* (1986) observed that fine organic particles and water-soluble organic matter might be retained in soil sample by the sieving effects and adsorption respectively. From their experiments on soluble organic matter penetration into the soil columns by water showed that distribution of organic matter translocated into columns decreased with depth and C/N ratio of the organic matter which penetrated down to the lower parts of columns were lower than those in the upper sectors. The similar observations were noted by Gite (1990).

Ko and Kim (1987) analysed the soil samples from 200 Satsuma orchards and the average values for the soils were found to be pH 5.7 and organic matter 8.86 per cent.

Some of the physiochemical properties of citrus growing soils of Dhaulakuan in Sirmour district of Himachal Pradesh were studied by Raina (1988). The soils were medium to high in organic carbon (average 0.37 %) and nearly neutral in soil reaction (average pH 6.6). A slight increase in pH was observed with increasing depth and was negatively and significantly correlated with available K. All soil profiles exhibited a decrease in organic carbon with increasing depth. A significant positive correlation between organic carbon and available K was observed.

Positive relation was found between soil organic carbon and yield of Kinnow orchards in Ferozpur district in Punjab, but the organic carbon of soil showed a negative correlation with fruit weight, both in healthy and declining plants (Dhillon and Dhatt, 1988).

Giri (1990) observed that the soil pH increases with depth and may be influenced by presence of $CaCO_3$ content, and most of the nutrients are available in pH range of 6.5 to 7.5.

Khanna and Kumar (1990) studied the effect of sodium chloride, sodium sulphate and a mixutre of these two salts at three different levels of salinity, that is EC-3, 6 and 9 mmhos/cm on Nagpur mandarin budded on Jambheri rootstock. They reported that shoot growth and leaf number per shoot was reduced after 90 days of treatment in NaCl treated plants whereas Na_2 SO_4 treated plants did not show significant change. After 60 days of treatment, the reduction in leaf area was significantly in NaCl and mixed salts whereas Na_2 SO_4 treated plants showed no significant change.

Kharche (1990) observed slight variation in EC with increasing depth at the surface horizons due to leaching of salts from surface to down below through percolating water followed by evapotranspiration resulting in the salt accumulation at the surface horizon.

Sharma and Mahajan (1990) started that the pH and organic carbon content of soils in mandarin orchards in Himachal Pradesh was slightly neutral to alkaline and low to medium, respectively.

Kharkar *et al.* (1991) observed that Nagpur mandarin orchards in Vidarbha region contain low soil organic carbon (0.16 to 0.36 %) excepting few soils. The pH of upper layer (0-30 cm) had lower values (7.8 – 8.2) as compared to lower layer excepting very few samples (pH 8.8 to 8.7). The reverse trend of the pH was exhibited by EC, which was within permissible limit (0.10 to 0.53 mmhos / cm in surface layer). The calcium carbonate was higher (15%) in surface soil layer. They further reported that the presence of excessive $CaCO_3$ reduces the availability of P and micronutrients.

Walia and Chamuah (1991) reported that soils of citrus growing belts of North Cachar hills was acidic with low base saturation and classified under Ultisols and Alfisols, while organic carbon also favours the spread of citrus cultivation.

Electrical conductivity of low yielding areas of citrus orchards in semiarid climate of northwestern Mexico was higher (3.8 dSm^{-1}) than of high yielding areas (Nunez and Valdez, 1993).

Citrus trees thrive well in the soil having pH 5.5 to 6.5. In alkaline soils the availability of micronutrients is reduced to such an extent that deficiency symptoms will occur sooner or later. High organic matter in the soil minimize the adverse effect of $CaCO_3$ in citrus (Rajput and Sri Hari Babu, 1995).

According to Patil and Malewar (1998), available Zn, Fe, Mn and Cu had negative correlation with pH, EC and $CaCO_3$ content, while positive correlation with organic carbon content in soils of mandarin orange orchards in Amravati district of West Vidarbha. They observed moderately alkaline pH of soils EC, (dSm^{-1}) 4.45 i.e. saline in nature, $CaCO_3$ varied from 43.8 to 162.5 g kg^{-1} indicating the calcareous nature of soils while organic carbon ranged from 4.30 to 11.90 g kg^{-1} in these soils.

Dey and Singha (1998) studied healthy and decline citrus orchards of hill region of Assam and revealed that citrus soils were acidic (pH 4.4-6.0), the EC was low (0.030-0.406 dSm^{-1}) and had high organic matter content to a depth of 45 cm (1.52 to 6.0%).

Patiram *et al.* (2000) studied micronutrient status of mandarin orchards of Sikkim and found that soil pH had the negative correlation with available Fe Mn and positive with Zn and Cu. They further observed that the micronutrient concentration of leaf was significantly and negatively related to soil organic carbon. Soil pH of mandarin orchards varied from 5.0 to 6.9, which remained almost constant at all depths of soil, while organic carbon 6.4 to 30.9 g kg^{-1}, which decreased with increasing soil depth.

2.2 Soil fertility status of citrus orchards

2.2.1 Macronutrients

Martin *et al.* (1959) studied the influence of exchangeable cations (Na and K) on growth of trifoliate orange seedlings in clay loam and sandy loam soils. They observed that increasing Na and/or K decreased growth of trifoliate orange seedlings. Growth reduction was much more severe in the clay loam soil. Similar effect of Na and K was also observed by Jones *et al.* (1957).

Dhingra and Kanwar (1963) found that total N and P_2O_5 status of both healthy and chlorotic citrus orchards were low while total K_2O content was high under unhealthy condition.

Randhawa *et al.* (1966) reviewed that citrus soils of Punjab are medium to low in available nitrogen and phosphorus excepting some soils, which are in the deficient range, while most of these soils are low to medium in available potassium.

Sweet orange orchards in Amritsar district were surveyed by Nijjar and Singh (1971) for mineral nutrition status. They observed that available N was more in the soils supporting the healthy orange trees as compared with that of declined one. Unlike N, the exchangeable P and K were higher in the declined orchards than those of the healthy ones with one exception.

Comparative studie. were made of the soil conditions in young orange orchards with patches of poor growth, and in adjacent areas with normal growth. Soil conditions in affected areas were characterized by higher per centage of soluble and exchangeable Na and lower per centage of soluble Ca and Mg. (Milad *et al.* 1975).

According to Chapman (1975),a normal soil would have an exchangeable Ca content of 60 to 85 per cent of the total exchange capacity and such soils are neutral in reaction

Pinto and Leal (1976) studied the nutritional status of some orange orchards in the Vales Altos of Carabobo, Venezuela and observed that all orange orchard soils are well drained and very acid, with low Ca and P contents as medium to high K contents.

Malewar *et al.* (1978-b) observed that available phosphorus of citrus orchards of Marathwada region soils was in the range of 0.0024 to 0.070 per cent. However, relatively high content of available phosphorus in medium and healthy orchards may be attributed to the intermittent application of organic manure, which further builds up high level of phosphorus.

Nilangekar and Patil (1981) reported that the available nitrogen was low throughout the soil profiles of chlorotic citrus gardens. Poor supply of nitrogen may be one of the reasons of chlorosis in citrus. Such results are also reported by Dikshit (1963). Available phosphorus content was of higher order in the profile of normal gardens. They further observed that exchangeable Ca and Mg values were of higher order in the profiles of chlorotic gardens. The profile of chlorotic gardens also had decreasing Ca content with increasing depth.

Six soil profiles from important citrus growing areas famous for quality citrus in Chamoli district of U.P. hills were studied in detail for their morphological and physicochemical characteristics (Singh and Kunwar, 1981). The data reflect that all the surface soils were medium in available nitrogen except for Joshimath soils where it was under low category, which may attributed to slow rate of mineralization due to lower temperature at high altitude. The status of available P and K in surface horizons falls under medium to high category except for Pipalkoti soils.

Kotur *et al.* (1982) evaluated some long-term cultural practices in relation to chemical properties in Coorg mandarin cultivation. They reported that exchangeable Ca and Mg was highest in shading treatment than all other treatments while in respect of exchangeable potassium content shading showed a higher content than the rest of the treatments with no significant effect.

Nilangekar and Patil (1982) while studying the soil factors as related to the citrus decline observed that exchangeable Ca and Mg contents were somewhat low in chlorotic profile than in the normal one, while exchangeable K and Na were high in chlorotic profile than in the normal one. Available nutrients particularly N and P were more in the profile supporting normal citrus plants.

Soils in general of citrus growing belts of Assam were found to be high in available K, high to medium in organic carbon and medium to low in available P. The influence of profile depth on the fertility status can be judged from the observation that the lower horizons were mostly medium in available K and low in organic carbon and available P. (Chakravarty and Barua, 1983).

Data revealed that the declining condition of mandarin orchards was associated with low available N, K and Ca status and medium to high available P and significantly higher exchangeable Mg status of the citrus growing soils (Awasthi *et al.*, 1984).

Chauhan *et al.* (1984) reported that soils of citrus orchards of Haryana low in available phosphorus (12-25 kg / ha) and medium to high in available potassium (206 to 1190 kg / ha). They state that the low level of phosphorus seems to be due to the fact that farmers were applying very less quantity of this nutrient.

Exchangeable K, Ca and Na levels of 1.37, 6.73, 2.26 and 0.2 meq. respectively were observed in soil samples from Satsuma Orchards. All mineral levels were slightly higher in the northern area of Cheju country. Higher yielding orchards were generally high in soil mineral content but low in P (Ko, *et al.* . 1987)

Raina (1988) observed that surface citrus growing soils of Dhanlakuan in Himachal Pradesh were low in available N, medium to high in available P and medium in available K content. The depth wise distribution of available P varied from 13.4 80.5 kg / ha with a mean of 39.2 kg / ha, while of available K varied from 89.6 to 278.5 kg / ha with an average of 184.7 kg/ha. Thus, the entire profile soil samples were high in P status and medium to high in K status

Fawzi *et al.* (1989) studied the citrus orchards in Egypt and found that citrus growing alluvial soils were very rich in K and that sandy and calcareous soils were low in K. Annual application of K combined with balanced application of other nutrients increased fruit yield. It was concluded that orchards on poor sandy and calcareous soils, and also those on Nite-alluvial soils are in need of annual-K fertilizer application, and that the reliability of exchangeable soil K as an index of availability under Egypitical conditions was doubtful.

While studying nutritional status and productivity of Kinnow orchards in Ferozepur district in Punjab Dhillon and Dhatt (1988) observed P and K levels having significantly higher correlation with yield whereas a negative significant correlation was found between soil P and fruit weight of healthy citrus trees. Potassium content of soil showed a negative relation with fruit weight, both in healthy and declining trees.

Diware and Kolte (1990) analised the factors responsible for decline of citrus in Vidarbha region and observed that trees receiving less than 0.5 kg N showed maximum tree decline (28.31%), while tree decline in the range of 0.5 to 1 kg N was decreased to 18.10 per cent and was the least (3.06 %) with the N level above one kg.

Sharma and Mahajan (1990) studied the nutrient status of 17 citrus orchards to represent general tree conditions of Himachal Pradesh. Soil analysis up to 120 cm soil depth revealed that orchards were low in available N, low to medium in available P and K and optimum in Ca and Mg. Except Ca and Mg, all the nutrients were higher in surface than sub-surface soils. It may be due to higher organic carbon content and addition of fertilizers on surface layers.

The 4-year survey was carried out in 60 orchards in 11 municipalities distributed among the 3 main citrus producing areas of Bahiu state, by Coehlo and Matos (1991). They reported that Ca and K levels were low in 65 and 40 per cent of the orchards, respectively. Unsatisfactory P and Zn level were also found in 35 per cent of the orchards.

Kharkar *et al.* (1991) undertook the survey of Nagpur mandarin orchards of Vidarbha region with a view to know the nutritional status of the orchard soils and led to the conclusion that available phosphorus was low to optimum (13.44 to 72.68 kg/ha) in majority samples while available K_2O content was in a moderately high to excessive range (268.8 to 851.1 kg/ ha) at upper layer.

Lim *et al.* (1993) studied the problems of decline in neck oranges at Amphur Chana and analyzed the soil samples. The soil was found to be deficient in Nitrogen and Phosphorus. In greenhouse trials using maize, the optimum concentrations of these elements were 120 and 150 kg/ha, respectively. These rates were subsequently tested with mandarins in the field.

The main nutritional problems encountered by citrus production in Taiwan are high soil N contents and low soil K contents (Chang *et al.*, 1994)

Dey and Singha (1998) revealed that citrus soils were deficient in available P_2O_5 (1-16 kg/ha) while available N and K_2O were medium to high in the surface layer (220-568 and 246-820 kg/ha, respectively) and low to high in the subsurface (112-517 and 122 – 651 kg /ha, respectively). The content of Mg tended to be higher in the subsurface than surface layer in Karbi Anglong. In respect of all major nutrients (N, P, K, Ca and Mg) citrus orchards from Cachar hills were richer than that of Karbi Anglong.

They further reported that in Karbi Anglong, the declining citrus orchards had higher soil contents of available N, P, Ca, and Mg but, lower in respect of available K than that of healthy orchards.

Saini *et al.* (1999) conducted the study at two locations i.e. Hoshiarpur and Abohar in Punjab to correlate the nutritional status of orchard soil and Kinnow leaves with fruit drop. They found that the soil (0-15 cm) of the orchard at both locations during the period of maximum fruit drop (May and September) was low in nitrogen and medium in phosphorus and potassium. Govind and Prasad (1982) reported the similar trend of nitrogen and suggested that the application of nitrogen decreased fruit drop in sweet lime.

Exchangeable Ca and Mg of Mandarin orchards soils of Sikkim was found in the range of 3.82 to 22.93 cmol (p^+) kg^{-1} which was decreased with increasing soil depth. (Patiram *et al.*, 2000).

2.2.2 Micronutrients

Smith and Specht (1953) studied heavy metal nutrition in relation to iron chlorosis of citrus seedlings who found that heavy metals like Cu, Zn and Mn interfered with iron metabolism in such a way as to induce iron chlorosis.

Chapman (1960) reported that Zn less than 1.0 ppm in the soil having pH above 7.0 was inadequate for citrus.

Dhingra and Kanwar (1963) revealed that the exchangeable Cu, Zn and Fe status of chlorotic citrus growing soils was lower than that of healthy soils, whereas the exchangeable Mn content was slightly higher in soils bearing chlorotic citrus plants than healthy plants.

The nutritional balance between different micronutrients might have been disturbed by this fairly high content of available Mn in unhealthy soils as, was also observed by Reuther and Smith (1953).

Dhingra *et al.* (1965) reported that the high amount of exchangeable Mn might have caused an antagonistic effect on the availability of other micronutrients like Cu, Zn, Fe and the deficiency of Fe might be due to the calcareous nature of the orchard soils of Punjab.

The available as well as total Zn was found to be higher in the first 30 cm and gradually decreases with depth as the plants take up Zn from subsoil and translocate to the leaves. When these leaves fall and decay, Zn is released from the plant tissues and fixed in the surface soil (Nair *et al.* 1968).

Jadhav *et al.* (1978) studied seventeen soil samples from four profiles from citrus growing tract of Marathwada. They revealed that the total zinc and iron content varied from 84 to 124 ppm and 5.28 to 7.20 per cent, respectively. Available (DTPA extractable) zinc and iron ranged from 0.18 to 2.82 ppm and 9.0 to 19.8 ppm, respectively. In general, total and available zinc decreased with depth, however, in few profiles it increased suddenly in the fourth horizon. Total and available iron did not indicate any definite pattern of distribution. No soil parameter was associated with the availability of zinc and iron.

Deficiencies of micronutrients cannot be detected from their total contents, as the amounts involved are too small. The micronutrients such as Fe, Mn, Cu and Zn become less available in alkaline conditions. Oranges grown on calcareous black cotton soils sometimes show deficiencies of Mn, Fe, and Zn (Anonymous 1952 and Singh 1953). Soil tests measure one or more forms of the nutrient elements present and help to separate out deficient areas from non-deficient ones giving some information about their extent and their likely response to their applications (Tisdale *et al.*, 1985).

Malewar *et al.* (1978–a) reported that in the citrus orchard soils contents of total zinc, iron manganese and copper were independent of decline and healthy condition of orchards. The orchard soils contained 0.72 to 1.40 ppm and 15.0 to 23.0 ppm available zinc and manganese, respectively. However available zinc and manganese content were invariably higher in healthy orchards as compared to the declined one except that of declined Jalna orchard. Available iron and copper were present in the range of 9.4 to 20.6 ppm and 2.40 to 8.84 ppm, respectively. They further depicted that availability of iron and copper mostly depends on their total reserves.

In another study Malewar *et al.* (1978-b) observed that total manganese and copper content of citrus growing soils varied from 1042 to 1814 and 84 to 176 ppm, respectively. Available Mn and Cu ranged from 32 to 88 ppm and 1.84 to 4.56 ppm, respectively. Total/available Mn showed no consistant trend, while, total/available Cu decreased with depth.

According to Nilangekar and Patil (1982), there was no appreciable difference in Fe and Zn contents of various soil profiles from citrus orchards with healthy and chlorotic trees at two locations in Aurangabad district.

Badhe *et al.* (1983) observed medium high range of Zn, Fe and Mn and sufficient quantity of Cu in the citrus orchard soils of Nagpur district.

Singh and Tripathi (1983) reported that the available iron in citrus growing soils of Agra region ranged between 1.68 and 25.20 ppm (average 5.96 ppm), which was lowest in surface soils and highest at 90-120 and 120 – 180 cm depths. In case of available Mn in the profile, highest concentration was in the surface layer and decreased with depth, the average was 20.4 ppm which could be rated as adequate in almost all the soils. The available Cu in the soils (0.5 to 2.4 ppm) seemed to be sufficient and was found to be decreased with depth. The concentration of available Zn showed a progressive decline with depth and was considered sufficient in average available Zn (2.04 ppm).

Chauhan *et al.* (1984) observed that 69 per cent of total citrus orchards surveyed were deficient in zinc content (0.28 to 1.12 ppm), while iron content varied from 3.92 to 12.52 ppm, which was in desired range in all the orchards except few orchards of Mirpur and Tejakhera.

Awasthi *et al.* (1984) observed that available Zn, Cu and Mn were found to be significantly higher in healthy than the declining orchard soils of Nurpur area in Himachal Pradesh, while there were no significant differences between available Fe of the healthy and declining orchard soils. However, Mn and Fe strongly interact to the extent of their proportional presence and more supply of one may induce the deficiency of other by oxidation.

Raina (1988) revealed that available micronutrients (Cu, Zn, Fe and Mn) contents decreased progressively with increasing depth and reported a positive significant correlation of available Cu, Zn Fe, and Mn with clay and organic content in acidic soils of Dhaulakuan in Himachal Pradesh. Available Mn and Zn were deficient, while the Cu and Fe were in sufficient amount in these soils.

The interrelations and antagonisms of the elements influence their role in plant metabolism. Such antagonistic effects between manganese and iron, calcium and copper and also between calcium and boron are amongst many. Manganese toxicity is associated with calcium deficiency and *vice versa*. A close antagonism between calcium and boron is well known (Biswas and Mukherjee, 1987). This antagonism of Ca and boron for citrus is also reported by Nijjar (1990).

Koo (1988) reported that the specific effects of omitting Mn, Cu, B and Fe on tree growth fruit production, and fruit quality was observed in a long-term experiment with pineapple orange trees in Florida. Reduction in tree growth was observed from omission of Mn, Zn, Cu and B from a standard fertilizer programme, but not from the omission of Fe. A decline in fruit production was found only in trees that had not received Mn fertilization. The omission of the micronutrients had little effect on external fruit quality.

Sharma and Mahajan (1990) found that the surface layers of Indora-Nurpur soils of mandarin orchards in Himachal Pradesh contain more amounts of available micronutrients (Zn, Mn, Fe and Cu) than subsurface soils. It was thought to be due to continuous decay and fall of mandarin leaves maintain higher concentration of nutrients in surface layers. The orchards were found to be low to high in available Zn, optimum in Mn and high in Cu and Fe.

According to Rajput and Sri Haribabu (1995), availability of Zn in the soils is affected by Fe, Ca and P etc. and soil pH more than 6.0. Deficiency of iron is most common in calcareous soils where the availability of iron is reduced by calcium carbonate while excess of nitrogen induces copper deficiency which is commonly known as 'Die-back', 'ammoniation', 'red-rust' and 'exanthema'. Manganese exercises an influence on iron transport and its utilization within the plant, of which deficiency is found in almost all citrus growing areas.

Ouyang (1993-a) studied micronutrient content in major citrus soils of southern China including seven great soil groups in eight provinces and an autonomous region of southern China. Citrus orchard soils derived from sandstone, sandy shale quaternary red clay, alluvial deposit, granite gneiss and neritic deposits were deficient in available Mo and B and low in Zn. Those developed on purple sandy shale, limestone and slope deposits were deficient in available Zn, B and Mo. Costal solonchak was fairly abundant in B, but was low in available Fe, Zn and Mo.

Diwakar and Singh (1995) studied the micronutrients in soils, clays and concretions in vertisols of Bihar and observed that DTPA-Zn, Fe, Cu and Mn show decreasing trend with depth within the pedons. The variation of these elements is mainly attributed to pH and organic matter.

Patil and Malewar (1998) studied micronutrient status of export oriented mandarin orchards in Amravati area of Maha rashtra. They observed that among the micronutrients, DTPA-Zn in orchards soils varied from 1.05 to 4.80 mg kg^{-1} showing *marginality to sufficiency in available zinc. The soils were adequate in Fe content* with three exceptions. The iron availability started to decline due to formation of iron carbonate in presence of high lime in these orchards. There was adequacy of available Mn (3.10 to 13.20 mg kg^{-1}) and Cu (0.75 to 1.85 mg kg^{-1}) to meet the requirement of mandarin.

Saini *et al.* (1999) conducted the study at two locations i.e. Hoshiarpur and Abhar in Punjab to correlate the nutritional status of mandarin orchards soils and Kinnow leaves with fruit drop. They revealed that the soil ($0^{-1}5$ cm) of the orchard at both locations during the period of maximum fruit drop was low in zinc and high in copper, iron and manganese.

Micronutrient cation status of 32 Mandarin orchards of Sikkim was studied in soils of 0-20, 20-40 and 40-60 cm depths by Patiram *et al.* (2000). They observed that the orchard soils were sufficient in available Zn, Cu, Mn, and Fe. The total micronutrient concentration was high in 20-40 cm depth excepting Fe and highly correlated to each other and clay content. Available micronutrient cation content decreased with increasing soil depths, and did not correlate to their concentration in mandarin leaf. It indicated that the availability of micronutrients was well controlled by their total concentration in soils.

Yadav *et al.* (1995) conducted the project on micronutrient deficiencies in Nagpur mandarin and their management in different soil types of Nagpur district and observed that the DTPA extractable Zn, Mn, Fe and Cu in surface soil layers ranged from 0.31 to 3.14 ppm, 12.9 to 39.45 ppm, 5.71 to 15.41 ppm and 1.73 to 8.2 ppm respectively. It seems that Zn was deficient in majority of soils, Cu was in optimum range in all the orchards and the critical contents of Mn and Fe vary widely from crop to crop hence no generalization can be made.

2.3 Leaf nutritional status of citrus trees

2.3.1 Leaf macronutrients

Martin *et al.* (1959) studied nutrition of trifoliate orange and reported that, in the leaves remaining on plants at harvest, about 3 per cent K and 0.03 per cent Na were associated with plants which had shown leaf injury. With excess K irregular necrotic spots developed at the leaf margins and within the leaves.

Embleton *et al.* (1963) investigated the effects of sampling leaves of various ages and locations on orange trees. Compared to the standard sample (5-month-old-basal leaves from nonfruiting spring cycle growth) older leaves or leaves from fruiting terminals contained lower concentrations of N, P and K and higher Ca and Mg concentrations. Nitrogen, Ca and Mg concentrations were lower in young basal leaves than in the young terminal leaves, both from non-fruiting twigs.

In studies on orange low K content in the tree was shown to be partially responsible for rind splitting which causes premature fruit drop. Fruit drop over a 6 week period varied from 1090 fruits / tree on K deficient trees to 158 fruits / tree, where K level was adequately maintained. Leaf K ranged from 0.45 to 1.35 per cent. The number of split fruit fall sharply where K was above 1.25 per cent. (Koo, 1963).

Randhawa *et al.* (1967) studied the role of soil and plant composition in diagnosis of citrus decline in Punjab and reported that the N in the leaves of healthy trees was higher than that in the leaves of declining trees.

Ortuna *et al.* (1968) observed the change in major elements during the active growth and development of lemon leaves and reported that the leaf nitrogen under normal conditions increased evenly upto 200 days and thereafter, it remains constant.

While studying the mineral composition of orange leaves of certain varieties Gonzaler and Guardisla (1969) have observed that the phosphorus content of the citrus leaves decreased with increasing age of the leaves.

Citrus leaf samples were taken in January in three successive years from a terraced orchard divided into areas receiving low, moderate and high amounts of sunlight. There was evidence in the first year that sunlight favoured the uptake of N, P and K but not of Ca. The higher the terrace, the greater were the foliar K levels. These were negatively correlated with Mg (Braga, 1970).

Nijjar and Singh (1971) reported that leaf N was higher in the healthy citrus orchards as compared with the declined ones in Amritsar district of Punjab Medium and declined orchards were in low to deficient leaf N. The foliar P and K in the healthy and declined orchards showed no definite trend, however, P was higher than the optimum range in five out of eight citrus orchards and the foliar K was in excess in all the orchards.

Bar-Okiva (1973) observed that the nitrogen content of citrus leaves decreased with increasing age of the leaves. He also observed nitrate content in the leaves as a sensitive indicator for the fertilization.

Working with mandarin grown on sandy clay soil, Milella and Deidda (1976) observed that leaf nitrogen was affected by nitrogen application but it was not affected by irrigation. High nitrogen and irrigation intervals decreased in the foliar P, K and Ca.

A 7-year-old orchard of Washington Navel orange on sour orange at Miranda and a 6-year-old orchard of Valencia orange on sour orange at Bejuma were studied by Pinto and Leal (1976). Leaf analysis showed deficiencies of Ca, P and N. In the second orchard, lime application at two t/ha lead to enhanced nutrient absorption by the trees. However, application of 0.5 kg Mg sulphate/ tree did not lead to enhanced Mg absorption as shown by leaf analysis.

Mann *et al.* (1979) reported that the total N content in the leaves of healthy sweet-orange trees was significantly higher (average 2.21%) than the leaves of declining trees (average 1.89%). Apparently P is not the cause of decline, although about 50 per cent of the orchards fall under low to deficient range because of P deficiency in the Punjab orchards soils. Healthy trees had less P than declining trees in most cases, with a mean value of 0.11 per cent in both the cases. The K content in the leaves of healthy trees was 1.49 per cent (average), while in the declining trees the value was 1.78 per cent.

Ca (3.22 to 3.70 %)was present in the optimum concentration in the leaves of healthy trees, but the amount was significantly lower in declining trees and was attributable to the antagonistic effects of the excess of K. Though there was no definite trend, the healthy trees had slightly more Mg and were low to optimum in both healthy and declining trees (0.28 and 0.26,respectively).

Twelve mandarin and mandarin like cultivars were studied for nutritional status in mature leaves of non-fruiting terminals at the beginning and the end of each growing season. In all the cultivars nutrients tended to accumulate in autumn rather than spring. There was significant difference in the leaf N, P, K, Ca, Cu and N levels between cultivars. These differences could be related to vigour. (Casu and Agabbio, 1981)

Ahlawat *et al.* (1982) observed that the leaf nitrogen content was more in healthy sweet orange trees as compared to declining one. Leaf Phosphorus and potassium contents of declining sweet orange trees were higher as compared to healthy ones. The nitrogen content in most of healthy orchards was found to be in satisfactory range. Phosphorus levels was normal in eight orchards out of ten and rest of the orchards were in deficient range, while potassium content of the leaves was in satisfactory range.

Eight orchards of sweet orange selected at different locations in Chamoli district of U.P. hills of 10-12 years age with uniform size and vigor were studied for the mineral composition of sweet orange leaves from different flushes. Singh and Kunwar (1982), in this investigation reported that there were non-significant differences between the leaves of different flushes for N, K and Mg contents. P content was however, significantly higher in spring flush whereas Ca in autumn flush leaves. They suggested that nutrient status in citrus should be determined by sampling analyzing the spring flush leaves.

Singh (1982) reported that the leaf analysis of leaf samples of sweet orange indicated a deficiency of nitrogen in the orchard studied, which varied from 1.85 to 3.00 per cent with a mean value of 2.44 per cent. Nitrogen content in leaves had significant and negative correlation with P and Fe. The phosphorus status of leaf at all the locations was adequate (0.17 to 0.30%) for the growth of plants.

Gururani and Singh (1983) analysed leaf samples from three growth flushes of Kinnow mandarin namely spring (February- March), summer (June- July) and autumn (October- November). In spring flush calcium was in highest amounts nitrogen and sulphur in moderate amounts, whereas phosphorus and potassium in the lowest amount. In summer flush, the content of phosphorus was moderate and the contents of nitrogen, sulphur, calcium and magnesium were the lowest. The autumn flush contained the highest contents of nitrogen, phosphorus, sulphur and magnesium, whereas potassium and calcium were intermediate. As most of the mineral nutrients were in their optimum range in spring flush, this flush was suggested as the standard for collection of leaf samples to diagnose the nutrient status of the plant.

Hernandez (1983)reported that healthy citrus (orange) trees had 2.1 to 2.6 per cent leaf N, while deficient trees had less than 2.0 per cent leaf N. Increasing the N supply did not markedly increase leaf N concentration. Mean P and K values in healthy trees were 0.11 and 1.02 per cent respectively, while critical values were about 0.091 and 0.70 per cent, respectively.

Yamdagni *et al.* (1983) observed that phosphorus and potassium content of kinnow leaves were higher in the declining trees (0.235 and 0.342 % respectively) as compared to healthy trees (0.183 and 0.302 % respectively) lesser amounts of calcium and magnesium in leaf samples were also observed in healthy trees. Nitrogen content was more (3.490)% in normal growing trees as compared to the declined trees (3.190 %).

Chauhan *et al.* (1984) surveyed 13 citrus orchards of western Haryana. The leaf nutrient status of the orchards revealed that the phosphorus and potash were in desired range of 0.075 to 0.120 per cent and 0.76 to 1.81 per cent, respectively whereas nitrogen was deficient (1.5 to 2.9 %) in most of the orchards. They concluded that the area is not deficient in phosphorus and potash, while nitrogen level was low and needed to be rectified by regular foliar and/ or soil application of fertilizers to get higher yield.

Awasthi *et al.*(1984) observed that mean leaf concentrations of nitrogen and calcium were significantly higher in healthy mandarin trees (1.86, and 5.67 % respectively) than the declining trees (1.63 and 5.13 % respectively). Most of these trees represent low range of nitrogen and optimum range of calcium. The mean P and Mg concentration of healthy and declining trees was not found to be significantly different from each other and represented optimum P and Mg status of the orchards. The leaf K status was significantly higher in the declining (0.58%) than the healthy (0.50%) trees, and represented low range.

Rana *et al.* (1984) selected sixty mandarin orchards randomly from six villages in Indora and Nurpur areas of Kangra district in Himachal Pradesh and analysed the leaf samples for different nutrients. They found that orchards were deficient in nitrogen. On the average 37% in Ca, 28% in N, 5% in Mg and one per cent in K were below optimum nutrient status. Sixty nine per cent orchards in K and 58 per cent in P were high in nutrient status. N content showed a highly significant negative relationship with P concentration.

Dhillon and Dhatt (1988) observed that the healthy kinnow trees from all the productive orchards in Ferozepur district of Punjab were always higher in their leaf N, P and K contents than the declined kinnow trees. Leaf N in the healthy trees ranged between 2.72 and 2.98 per cent, P between 0.12 and 0.16 per cent and K between 1.17 and 1.34 per cent.

The declined trees, on the other hand contained 1.90 to 2.13 per cent N; 0.09 to 0.13 per cent P and 0.90 to 1.02 per cent K. They further reported that the fruit yield was significantly higher in the healthy trees as compared with declined trees. Foliar N, P and K showed positive correlation with the yield in both healthy and declined trees.

Hernandez (1988) recommended that leaf N analysis should be used mainly for the control of N deficiency in citrus. In mandarin orange the leaf nitrogen level was found related to yield and maximum fruit production occurred when a leaf nitrogen level of 1.90 to 2.13 per cent was maintained in trees of 38 to 40 years in age (Mitra *et al.* 1988).

Sharma and Mahajan (1990) reported that concentration of leaf nitrogen was significantly higher in healthy trees than in the declining trees of mandarin orchards. Total amount of P, K, Ca and Mg in mandarin leaves were statically same in trees representing different health conditions. On the basis of leaf composition; 3, 8 and 9 orchards were found deficient in K, P and N,respectively.

Twelve elite acid lime orchards in Gujrat were studied for manurial practices and leaf nutritional status by Chundawat *et al.* (1991). They observed that the average leaf contents of N (2.52%), K (0.92), Ca (3.25%) and Mg (0.35%) fell within the recommended optimum ranges for citrus. The level of P in the leaves (1.48) was however in excess of the recommended range indicating overfeeding with P.

Kharkar *et al.* (1991) revealed that nitrogen content in Nagpur mandarin leaf was found generally low (1.56% av.) in about 59 per cent samples from healthy orchards and nine per cent samples from declining orchards (1.4% av). In about 45 per cent samples, phosphorus content was deficient to low (0.10 to 0.11%) in healthy orchards, while it was 84 per cent in declining orchards (0.04 to 0.8%). The potassium content was in optimum range. Most of the healthy and declined orchards were optimum in leaf Ca and Mg.

Citrus leaf analysis in Fujan country indicated that leaves of affected leaf yellowing trees contained low magnesium (0.22 to 0.31%). (Zhang *et al.*, 1991).

Chang *et al.* (1994) established leaf diagnosis criteria in Taiwan for fertilization recommendation for citrus orchards as – 3.0 to 3.2 per cent N for Ponkan (*Citrus tankan*), 2.9 to 3.1 per cent N for Liucheng and 2.2 to 2.5 per cent N for Pummelo CV Wentan.

Souza *et al.* (1997) reported that nitrogen and magnesium followed normal distribution, while phosphorus, potassium and calcium followed long normal distribution in leaves of orange trees. The highest coefficients of variation were for K and the lowest was for N.

Dey and Singha (1998) observed that both healthy and declined citrus orchards in hill region of Assam of Karbi Anglong were high in K, but low in both Ca and P in respect of foliar content. These orchards showed positive correlation of fruit yield with foliar K content. In North Cachar Hills, orchards were low in leaf Ca but commonly high in leaf K. Declining orchards of these hills were low in foliar P content; and low fruit yield in these orchards was associated with lower foliar Ca content and lower Ca: Mg ratio in leaf.

Seasonal changes in the nutritional status of citrus leaves in New-Zealand were studied by Sale (1998). He reported that Navel oranges, Seminol tangelos and satsumas showed similar seasonal patterns. Navel oranges had significantly higher leaf N and K concentrations than standard lemons. There were significant difference between the two season for all nutrients except N, Ca and Fe.

Varlakshmi and Bhargava (1998) studied plant nutrient status and leaf diagnostic norms for acid lime. The norms for optimum N ranged from 1.53 to 2.10 per cent, for P 0.10 to 0.95 per cent, for K 0.96 to 1.66 per cent, for Ca 3.05 to 3.43 per cent, for Mg 0.46 to 0.60 per cent and for 5.025 to 0.29 per cent. The mean concentration in the index leaf of N, P and K was 1.82, 0.12 and 1.31 per cent respectively. Calcium availability was adequate to excess in majority of the orchards (2.89 to 4.23%), which may be attributed to neutral to alkaline nature of soils and regular application of calcium ammonium nitrate fertilizer by growers of this area. Magnesium concentration in index leaf of acid lime was low which ranged from 0.22 per cent to 0.30 per cent with a mean value of 0.27 per cent.

The study was conducted at two locations i.e. Hoshiarpur and Abohar in Punjab to correlate the nutritional status of orchard soil and kinnow leaves with fruit drop (Saini *et al.*, 1999). The mean levels of the nutrients *viz.* N, P, K, Ca and S in leaves were found low in declining plants than in healthy plants during May and September. The average level of N in plant was optimum at Abohar, but deficient at Hoshiarpur in healthy and declining plants during mid May. The P level was optimum at both locations and in both types of plants. Similar trend was observed for plant K. Ca was low in healthy as well as declined plants at both locations during fruit drop.

2.3.2 Leaf micronutrients

Champman (1960) suggested that the optimum level of Mn, and Cu in orange leaves should be in range of 20.0 to 80.0 ppm and 6.0 to 16.0 ppm respectively. He also suggested the optimum level of Zn and Fe as 25.0 ppm and 60.0 ppm respectively in leaves of citrus tree.

Kanwar and Dhingra (1961) collected healthy and unhealthy citrus leaves from six different garden colonies in Punjab and revealed that zinc and manganese were significantly high in healthy plants. Chlorotic condition of citrus might be due to the deficiency of zinc and nutritional distribution of other trace elements due to presence of high amount of Mn in soils supporting unhealthy citrus.

The characteristic pattern of iron deficiency was more uniform and strikingly evident on *jamberi* leaves, where it occurred than on Santra leaves in which confusing variations were common. Of the citrus species budded on *jamberi*, the *Santra* was most susceptible to iron shortage followed by the sour lime (*C.amazantifolia*) and Musambi (*C. sinensis*) in that order (Singh 1953).

Nijjar and Singh (1971) reported that Zn was deficient in all the citrus orchards surveyed of Amritsar district as it ranged from 8.02 to 20.32 ppm. Iron and Mn were optimum only in three orchards. They further suggested that the low uptake of Zn might be due to the poor Zn status; high pH and the high P and K contents in the soil. Kanwar *et al.* (1963) also reported a deficiency of zinc in citrus orchards of Punjab. Zn deficiency was observed in range orchards of Venezuela by Pinto and Leal (1976).

Malewar *et al.* (1978-a) observed that zinc, manganese and copper content of leaves of unhealthy trees was significantly lower than that of healthy trees of citrus orchards of Marathwada region. They further revealed that differences in zinc content of healthy and unhealthy leaves were highly significant. Out of nine orchards samples of healthy trees, five orchards were optimum in content of Zn (25 ppm) where as four orchards contained zinc below the normal level. The concentration of iron in healthy and unhealthy leaves was quite high when compared with optimum level (60 ppm).

Mann *et al.* (1979) reported that in the declining citrus trees the Zn in the leaves decreased significantly from those of healthy citrus trees by 5.3 to 13.7 ppm (av. 8.4 ppm). They further reported that most of the citrus orchards contained the optimum range of Cu, Fe and Mn in the leaves in both healthy and declining trees. In the leaves of the both healthy and declining trees, Boron was optimum to excess and its amount was not related to the health of the trees.

Ahlawat *et al.* (1982) revealed that zinc content in healthy sweet orange trees was higher as compared to that in declining ones, though all the sample trees were in deficient range. Acute deficiency of zinc in these orchards was further evidenced by resetting of leaves and chlorosis. Similarly , Dixit *et al.* (1970) and Manchanda *et al.* (1971) also reported deficiency of zinc in citrus plants. Ahlawat *et al.* (1982) further reported that iron content in the leaves of healthy and declining trees did not indicate any trend. However, it was in satisfactory range in all the orchards.

Singh (1982) observed that all leaf samples were rated to have either very high or excess level of iron in the leaves of sweet orange trees, as they contained 200 ppm or more. Leaf Mn and Cu status of sweet orange trees were satisfactory or high as its content in leaves varied from 25 to 80 ppm and 6.0 to 24.0 ppm, respectively. The leaf zinc content varied from 9.0 to 31.5 ppm with a mean value of 17.8 ppm; while 50 per cent leaf samples belong to deficient category, 38 per cent showed low level of zinc and remaining 12 per cent samples contained satisfactory level of zinc.

Variation in mineral composition of leaves from different flushes of Kinnow Mandarin under Tarai conditions was studied by Gururani and Singh (1983). They observed that copper (16.40 ppm) and zinc (12.53 ppm) were the lowest in spring flush leaves when compared with the other flushes. Manganese content was almost constant (31.25 ppm) during June, July and August in spring flush, while boron and iron were the highest (134.58 ppm and 69.1 ppm, respectively) when compared with standard. In summer flush the leaf iron content was moderate; and the leaf content of Mn and B were the lowest. In the autumn flush there was highest contents of Cu, B and Zn whereas the Fe content was the lowest.

Yamdagni *et al.* (1983) reported that copper and zinc content of citrus leaves were found in deficient range in healthy as well as declining Kinnow trees. However, Zn and Mn were found to be higher (10.4 and 29.7 ppm respectively) in healthy conditions than that of in declined one (8.4 and 28.6) respectively), while Cu content in Kinnow leaves was more in declined health of trees.

It was observed that almost all the 13 citrus orchards of western Haryana were deficient in foliar zinc, which varied from 8 to 26 ppm; and leaf iron content of different orchards of the area ranged between 75 and 125 ppm, which was in satisfactory range (Chauhan *et al.*, 1984).

Awasthi *et al.* (1984) revealed that the leaf Zn and Cu concentrations were not significantly different between healthy and declining mandarin trees and most of the orchards indicated that the deficiency of Zn was identical in healthy and declining trees. However the Cu uptake by healthy and declining trees was within the optimum range. The leaf Mn concentration was significantly higher in declining than the healthy trees, whereas reverse was found for Fe.

Rana *et al.* (1984) observed that out of four micronutrients under study 75 per cent mandarin orchards in leaf Zn and three per cent orchards in leaf Mn were below optimum. Out of these 75 per cent mandarin orchards; 68 per cent orchards were low in Zn revealing a vide spread hidden hunger for Zn in these orchards and only seven per cent orchards were deficient in Zn. In contrast to this, 90 per cent orchard in Fe and seven per cent in Cu were above optimum in nutrient status, and only Fe in 33 per cent orchards was in excess. Micronutrients status of healthy and declining mandarin orchard showed that Cu and Fe content in mandarin leaves were statistically same in both healthy and declining condition of trees; whereas healthy trees showed significantly higher leaf concentrations of Zn and Mn than declining trees (Sharma and Mahajan, 1990).

Kharkar *et al.* (1991) reported that leaf zinc content was deficient (less than 18 ppm) in about 90 per cent samples irrespective of the samples from healthy or declined mandarin orchards. Manganese content was found in optimum range (20 to 50 ppm respectively). Copper content was found in an excessive range (more than 50 ppm and upto 138 ppm) in both healthy and declined mandarin orchards. About iron content in mandarin leaves, 99 per cent samples from healthy category were in an optimum to high (40 to 197 ppm) range.

Zhang *et al.* (1991) observed that the leaves of affected citrus trees contained much more boron (110-258 ppm) and Cu (26-41 ppm) than the recommended values for these nutrients while Mg was low (0.22 – 0.31 %).

Ouyang (1993-b) reported the significant positive correlation between available micronutrients such as Zn, Mo and Cu in the soil and those in the leaves of citrus tree. The ultramicroscopic characterized Zn deficiency in citrus leaves was also investigated.

Yadav *et al.* (1995) observed that the total Zn, Fe and Cu contents in 5-7 months old *mrig*_flush leaves varied from 8.40 to 27.70 ppm, 62.50 to 149.70 ppm and 4.50 to 18.15 ppm respectively. As per standards, all orchards except one were found to be deficient or low in Zn and optimum in Cu and Fe.

In next year study the same orchards of Nagpur district showed the same range of Zn, Cu and Mn with slight changes in values of leaf Zn, Cu and Mn contents, while the leaf Fe contents (67.9 to 143.1 ppm) were in optimum range as per the California standards (Yadav *et al.* 1996).

Singh *et al.* (1997) investigated the leaf nutrients status of fruiting and nonfruiting terminals, and observed that leaves of bearing twigs contained higher concentrations of Zn and Cu than those of nonbearing shoots, whereas there was not much difference between both the twigs for and Mn and Fe.

Souza *et al.* (1997) reported that zinc and copper were found to be normally distributed in all points where from citrus leaves were collected, while Mn and Fe followed long-normal distribution.

Patiram *et al.* (2000) observed that the concentrations of Zn, Cu, Mn and Fe of the non-bearing mandarin twigs leaf ranged from 19.5 to 50.0, 5.5 to 24.0 16.5 to 80.5 and 100 to 373 mg Kg^{-1}, respectively. On the basis of leaf analysis guide for nutrient status of orange trees, one-third orchards were found low in Zn and Mn, sufficient in Cu and in 80 per cent high in excess for Fe.

Patiram *et al.* (2000) further suggested that leaf analysis is the only useful tool for determining the current mandarin nutritional status for fertilizer application.

2.4 Development of diagnostic norms using DRIS

Use of Beaufil's Diagnosis and Recommendation Integrated System (DRIS) is quite a new approach on which little research has been initiated and therefore, a scanty literature is available to compare the findings of present investigation with DRIS.

The dynamic nature of leaf composition which is governed by a large number of inherent factors, environment and management makes foliar diagnosis a complex exercise. A process involving multiple steps has been worked out and is named as DRIS, which was developed by Beaufils (1971 and 1973) for improving maize production. He noted that in DRIS parameters, which have influence on yields, are important factors while others have little or no influence on yields. It was assumed that the important parameters are those in which the variance of the desirable population is significantly lower than that of an undesirable population. He has shown that the highest yields are obtained only when the values of important parameters approach their optima.

Sumner (1975) studied the preliminary diagnosis of the NPK requirements of sugarcane irrespective of plant age and season using DRIS and reported that DRIS was found to agree well with diagnosis by the sufficiency range or critical level approaches. Because DRIS is based on nutrient balance, it indicates not only the most limiting nutrient but also the order in which other nutrients are likely to limit yield.

Sumner and Beaufils (1975) reported that the greater accuracy of DRIS compared with the conventional approach may be due to its insensitivity to factors such as the age of the tissue, the position of leaf, and cultivar factors which can strongly affect nutrient concentrations of the tissue and diagnosis produced by the critical concentration approach.

Beaufils and Sumner (1976) developed DRIS norms for soil test P, K, Ca and Mg to be applied to sugarcane culture on South African Soils. As with foliar nutrient values, soil test levels of the various nutrients were retained and norms were generated by averaging values from those observations associated with high yields. Coefficients of variation were also generated from these data and DRIS indices were calculated in a manner identical to the described by plant tissue data.

Beaufils and Sumner (1977) investigated the effect of time of sampling on the diagnosis of the N, P, K, Ca and Mg requirements of sugarcane by the DRIS approach and observed that DRIS was less sensitive to sampling variables, and so could make accurate diagnosis using tissue of a time or age other than that normally recommended.

Sumner (1977-a) derived foliar diagnostic norms for NPK in wheat leaves using DRIS and reported that the preliminary norms appear to be applicable to wheat irrespective of variety and age at which the leaf sample was taken. These norms are able to correctly diagnose the requirements of the crop more than those based on the critical or sufficiency level approach.

Data for corn previously published in the literature were used to test the precision of the DRIS and critical value approaches by Sumner (1977-b). He showed that the DRIS approach is not only superior because it is capable of making valid diagnoses irrespective of crop age, but also able to rank nutrients in their limiting order on crop yield which emphasizes the importance of nutrient balance in plant nutrition.

Sumner (1977-c) used the DRIS indices to interpret previously published data on the variation in N, P, K Ca and Mg content in corn leaves. He observed that the DRIS approach is able to make consistent diagnoses of the order of requirement of above elements by the plant irrespective of position of the leaf on the plant and portion of the leaf sampled within certain limits. He also found that the diagnoses are completely consistent if any whole leaf from the middle of the plant is sampled. The similar results were observed by Sumner (1977-d), when he developed preliminary DRIS norms for soybean leaves from 1245 sets of data on N, P, K leaf composition and corresponding yields. He suggested that the advantage of the DRIS system in predicting nutrients imbalance even when the nutrients concentration in the plant is in or above the critical or sufficiency level range.

Sumner (1979) compared the classical critical value approach with the newer DRIS in evaluating diagnosis from the some sets of data. He observed that DRIS is superior to the critical value approach in that it is able to make valid diagnosis more frequently because variations due to tissue age were taken into account.

According to Jones (1981), though several workers have shown that DRIS often produces more accurate diagnoses of nutrients element deficiency than conventional approaches, the complexity of the DRIS methodology has discouraged its use. He offered three modifications of the DRIS methodology and claimed that these modifications can simplify its use and interpretation. These modifications later have been refused by Walworth and Sumner (1987) with some discussion.

Jones and Bowen (1981) suggested that both locally calibrated crop log and DRIS approaches give slightly more accurate diagnoses of nutrient deficiencies than the conventional crop log approach on the Hilo and Hambleur sugar companies of the Island of Hawaii.

Elwali and Gascho (1983) observed that application of nutrients during the grand growth period (July) as indicated by DRIS indices significantly increased both cane and sugar yields, of sugarcane on Florida Histosols (Medisaprists) over those obtained from plots which did not receive fertilizers in July. The DRIS indices for leaf nutrients during the grand growth period revealed that a shortage of P and excess of K had been applied at planting, a fact which would have gone undetected by conventional nutrients level monitoring. The increase in cane and sugar yields from the DRIS corrective treatment resulted primarily from better nutrient balance as revealed by DRIS indices for leaf nutrients late in the season.

Mayer (1981) also evaluated the DRIS based on leaf analysis for sugarcane in South Africa and observed that DRIS was reliable in diagnosing nutrients treatment despite ranges in the tissue sampled or the time of sampling.

Erickson *et al.* (1982) predicted alfalfa P, K and S needs through DRIS and observed that when in the base treatment the nutrient having lowest DRIS index considered the most lacking and added, it increased as did the yield, while the sum of indices declined. They conclude that the additional nutrient using DRIS index was the proper treatment and found it correct.

Though DRIS was often less sensitive to sampling variables, and so could make accurate diagnoses using tissue of a type or age other than that normally recommended in various crops, it was found sensitive to sampling variables i.e. type and age of the tissue sampled in citrus (Beverly *et al.* 1984). DRIS reflected changes in nutrients concentrations due to alternate bearing or crop load effects and agreed with sufficiency range method when concentration changes were sufficient to affect the latter method. Hunson (1981) also found that DRIS was sensitive to plant age for soybean plants nearing maturity.

Elwali and Gascho (1984) observed that fertilization to the DRIS significantly increased both cane and sugar yields compared with those obtained when fertilization was guided by foliar analysis using the Critical Nutrient Level (CNL) approach or soil testing in sugarcane. Differences were not significant between foliar analysis using CNL approach or soil testing. The high cane and sugar yields obtained by DRIS guided fertilization were distributed to the better nutrient balance as revealed by DRIS indices late in the season. Foliar analysis using the DRIS proved to be a better guide for fertilization of sugarcane than the soil testing method currently in use.

Letzsch and Sumner (1984) investigated the effect of population size and yield level in selection of DRIS with a data bank comprising over 8000 observations of yield and tissue composition assembled from a wide range of locations and conditions. They observed that the best banks were those, which were large, random and had a substantial number of high yield observations.

Elwali *et al.* (1985) conducted the study to determine the DRIS reference norms of 11 nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B). A database of approximately 10000 observations of leaf nutrient concentrations and yield of corn grown in several states and countries was used to establish the norms on corn leaves. They excepted that the DRIS norms should be useful in diagnosis of nutrient imbalance in order to make adjustments in the nutritional status of corn plants.

DRIS was applied for foliar diagnosis of soybean (*Glycine max*) using a data bank in excess of 3500 tissue samples, reference values for evaluating the status of soybean with respect to N, P, K, Ca, Mg, Mn, Fe, Cu, Zn, Mo, B and Al were derived (Beverly, 1986). He observed that DRIS diagnosis generally agreed with those obtained by the sufficiency range method. He also identified geographic differences in DRIS norms and suggests that regional derivation of diagnosis values may be necessary.

Walworth and Sumner (1987) suggested that, there is particularly a need of data representing plants at various stages of growth, and for evaluation of these data with respect to stability of various forms of nutrient expressions that will ultimately allow greater flexibility in tissue sampling a wider applicability of subsequent recommendations for widespread routine use of DRIS.

Bhargava and Chadha (1988) stated that the leaf nutrient guide approach utilized in interpreting the leaf analysis, has severe constraint on the period during which leaf samples can be taken. DRIS provide the facility of taking samples at any stage of growth.

The efficiency of predicting nutrient imbalances and deficiencies in coconut were tested using DRIS by Khan *et al.* (1988). They reported that based on the norms developed nutrients application can be suggested for a targeted production. They further suggested that there is ample scope for refinement of DRIS norms by sampling a larger population and utilizing it as an effective tool for fertilizer recommendation for coconut.

Ramchander and Shikhamany (1989) made an attempt to replace some of the empirical methods involved in the calculations of DRIS norms by mathematical and statistical basis. In the development of norms they brought out two modifications and nutrient indices were worked out by the modified approach using the bloom time petiole nutrients contents of Thompson Seedless grape. Yield was considered as power function of the ratios of nutrients contents instead of linear functions. Secondly, in the grouping of plants as low or high yielding, the population means ± standard deviation was used instead of arbitrary categorization. In addition, the discriminate function is employed to maximize the differences between the two groups.

Sharma (1991) applied the DRIS for developing N, P and K foliar diagnostic norms for potato, from 1536 sets of data on N, P and K composition and corresponding yields. He also suggested the usual thought that the diagnosis could be made for the deficiency of nutrients in the order of their requirements.

Bhargava and Raghupathi (1996) carried out a survey in the states of Maharashtra, Andhra Pradesh and Karnataka to study the present status of calcium in petioles of vineyards. The optimum range of calcium requirement in petioles of grapevines and soils was worked out using DRIS.

Hundal and Arora (1996) observed that DRIS norms are generally better than the diagnosis made by sufficiency range method, with the advantage that DRIS reflects nutrient balance, and identifies the order in which the nutrients are likely to become limiting. They further showed that DRIS norms can be used irrespective of variety and position of leaf sampled from the floral or non-floral panicles.

Raghupathi and Bhargava (1998) developed DRIS norms of leaf and soil nutrients for Pomegranate in Bijapur district of northern Karnataka and optimum range of nutrient in leaf and soil was recorded. They observed that the yield level of pomegranate ranging from 15.5 to 18.8 t ha^{-1} for the optimum ranges of nutrients. Similarly leaf nutrients diagnostic norms for acid lime from 50 orchards grown on Entisols and Alfisols in Cuddapah district of Andhra Pradesh were developed using DRIS by Varlakshmi and Bhargava (1998).

Raghupathi and Bhargava (1999) carried out a regional survey in 112 selected commercial orchards of pomegranate. The diagnostic norms developed using unvariable critical value approach (CVA), bivariate DRIS and multivariable compositional nutritional Diagnosis (CND) were compared. The differences in the norm values were noticed for N, Ca, Fe and Zn between CVA, DRIS and CND. They reported that the norm values and identification of yield limiting nutrients were close to each other with DRIS and CND while there was no consensus with CVA norms and diagnosis when several nutrients are limiting yield simultaneously, the diagnosis of mineral disorder by multivariate CND approach is required for higher diagnostic precision.

MATERIAL AND METHODS

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CHAPTER III

MATERIAL AND METHODS

The study area for present investigation consists of Akola, Amravati, Buldana, Washim and Yavatmal districts of Western Vidarbha in Maharashtra State. One hundred and fifty mandarin orchards, i.e. seventy-five each from *ambia* (spring) and *mrig* (summer) flushes each were selected in 52 different villages (Fig. 1). Care was taken that the age of mandarin orchards is in the productive age range of 10 to 13 years. Representative leaf and soil samples from each mandarin orchard were collected as recommended by Srivastava (1997). The set of these soil and leaf samples were analysed in the laboratory for nutrient status to provide diagnosis and nutrient management for subsequent crops.

This investigation is to generate the information to develop soil and plant nutrient diagnostic norms for Nagpur mandarin using Diagnosis and Recommendation Integrated System (DRIS) so as to arrive at the soil and plant characters or parameters that contribute to the growth and yield of mandarins in the area. The yields of two seasons (flushes) *viz*., *ambia* and *mrig* flushes from each orchard on different soils were recorded from farmers as number of fruits per plant.

The details of material and methods adopted during this investigation are presented under the following heads and subheads.

3.1 Material

- 3.1.1 Location
- 3.1.2 Climate

Figure 1; Map of study area

3.1 Material

3.1.1 Location

The area selected for the study covers a part of Akola, Amravati, Buldana, Washim and Yavatmal districts in Maharashtra State, where Nagpur mandarin is extensively cultivated. It extends from $19^\circ 26'$ to $21^\circ 46'$ N Latitudes and $75^\circ 57'$ to $79^\circ 98'$ E Longitudes. Within this area fifty-two villages were identified and list of cultivators along with information regarding the orchard is presented in Appendix I.

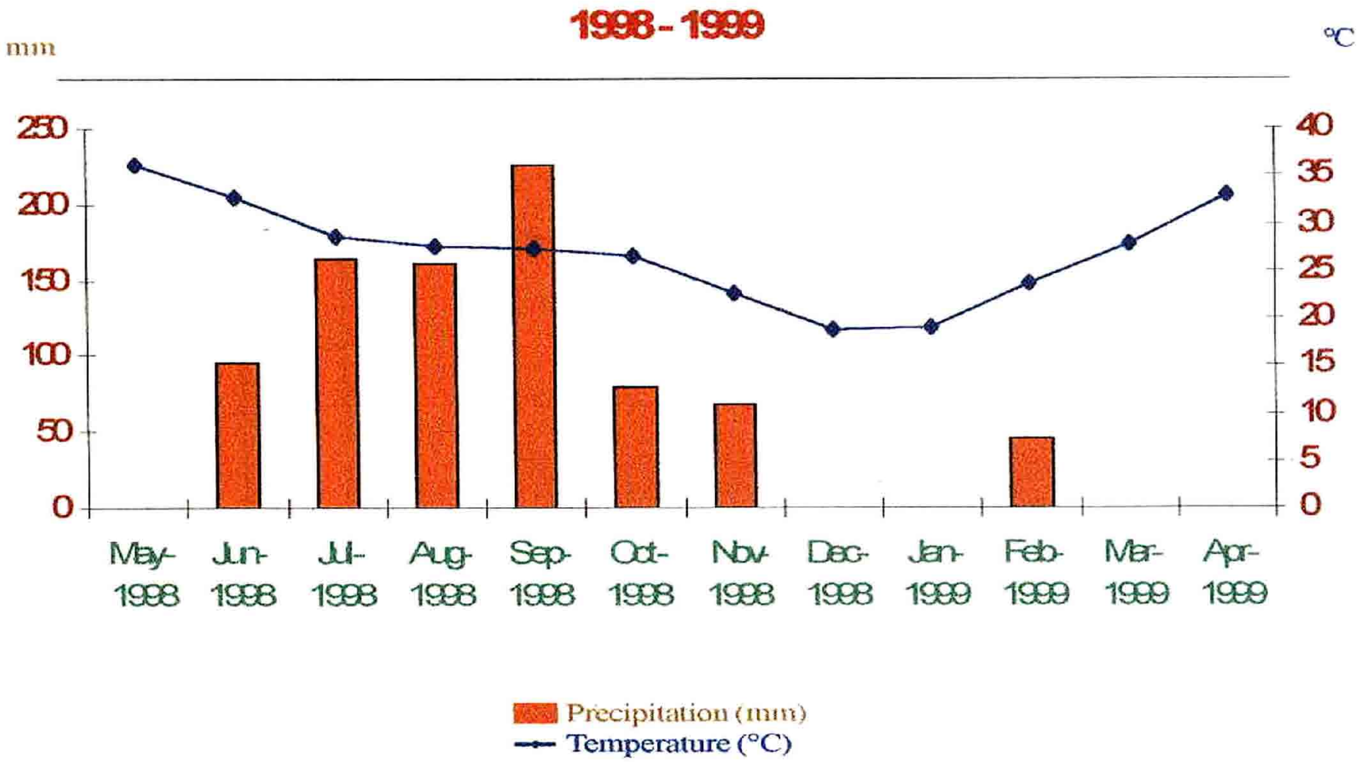
3.1.2 Climate

The climate of the study area is tropical monsoon type and characterized by three distinct seasons *viz.*, summer with hot and dry weather from March to May, rainy season-warm and rainy from June to September and winter-dry with mild cold from November to February. The annual rainfall varies from 750 to 950 mm distributed over 48 to 60 days. Based on the distribution of rainfall, the study area comes under the "assured rainfall zone" (Buldana, Washim, Akola and Amravati districts). The average annual temperature ranges from 26 to 40 °C. High temperature of 45 °C or more are observed during May, while temperatures of about 8 to 10 °C are recorded in the month of December and January (Thakre *et al.* , 2000).

Monthly weather data for the year 1998-99 and 1999-2000 collected from Akola , Amaravati, Buldana, Washim and Yavatmal and recorded at meteorological observatory of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is presented in Tables 1 and 2 and figures 2 to 6 .

3.1.2.1 Precipitation

Mandarin has two flowering seasons in a year. Flowering that occurs during February is called '*ambia* ' or spring flush and that during June- July is '*mrig*' or summer flush . The rainfall data (Table 1) show the average precipitation of five



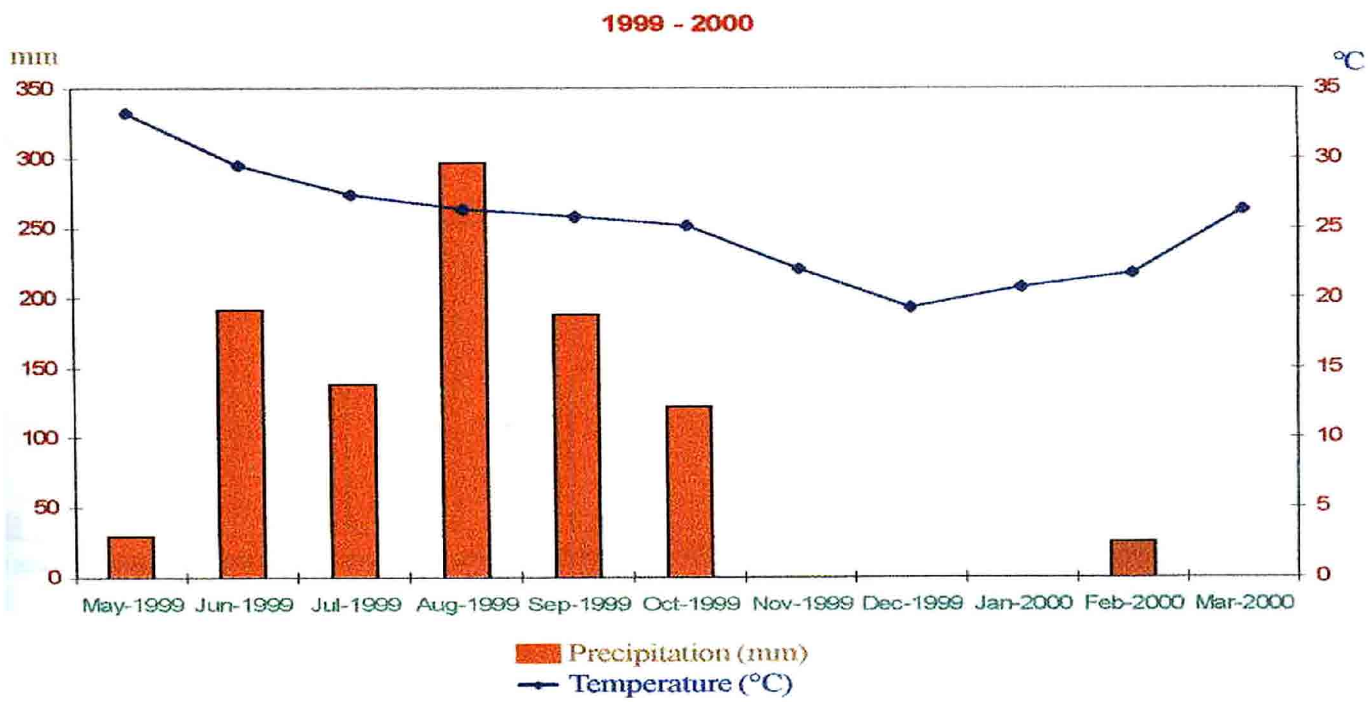
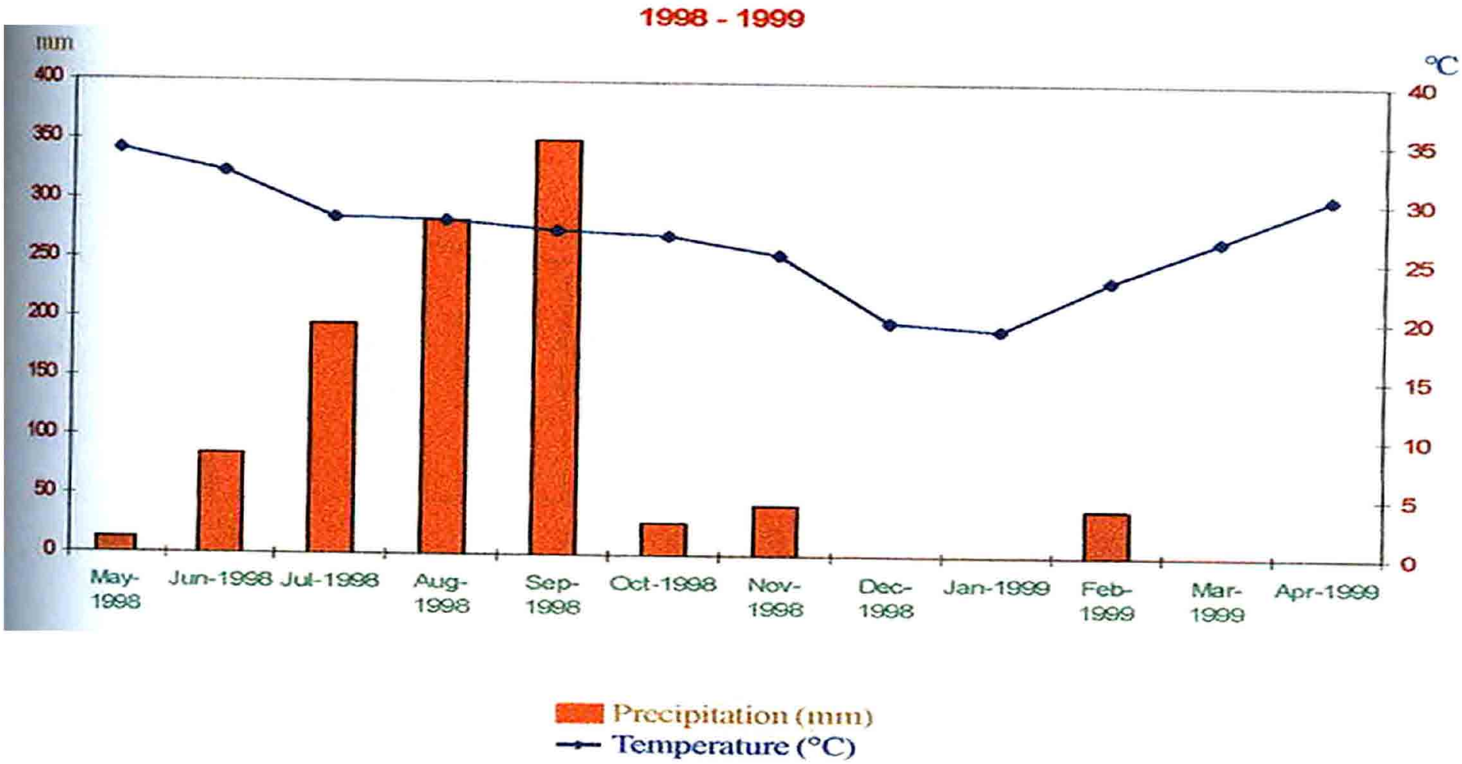


Figure 2 : Precipitation and temperature of Akola district



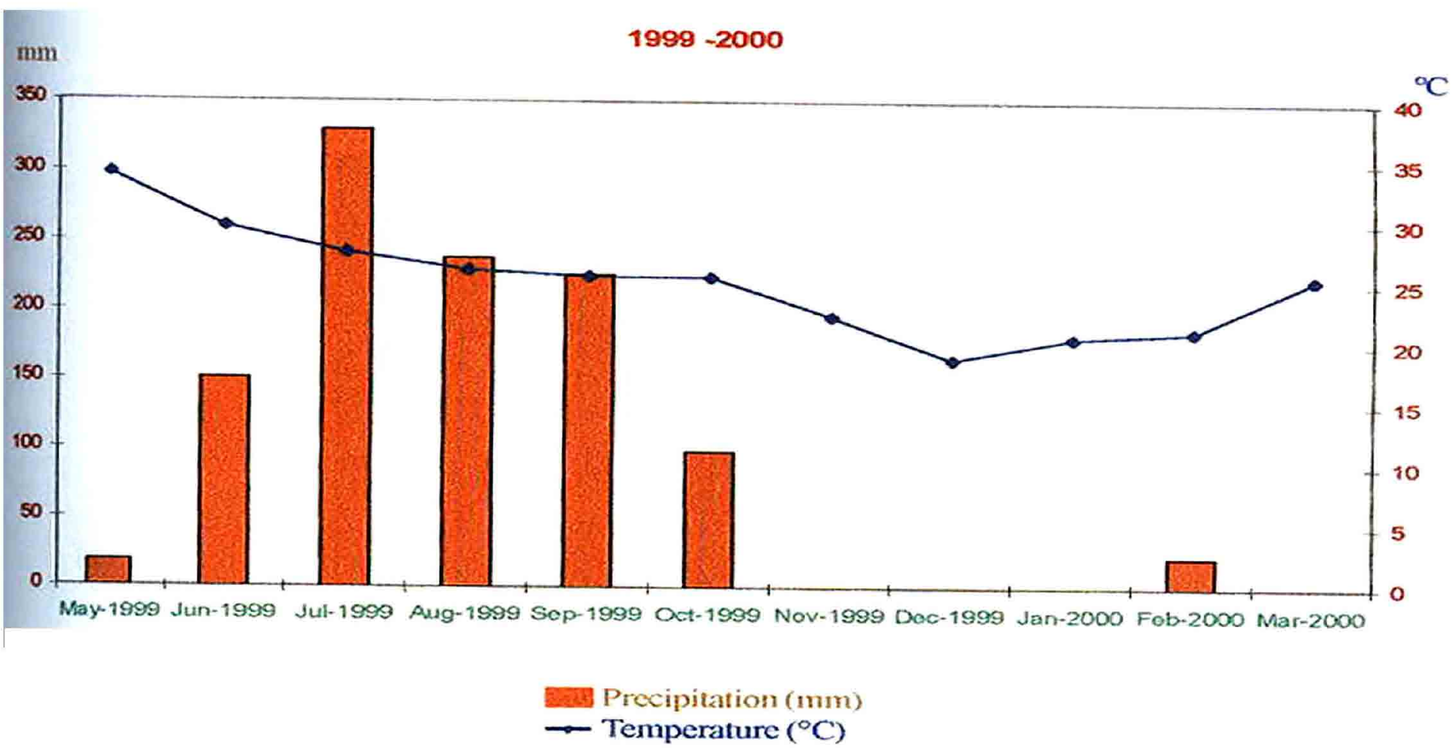
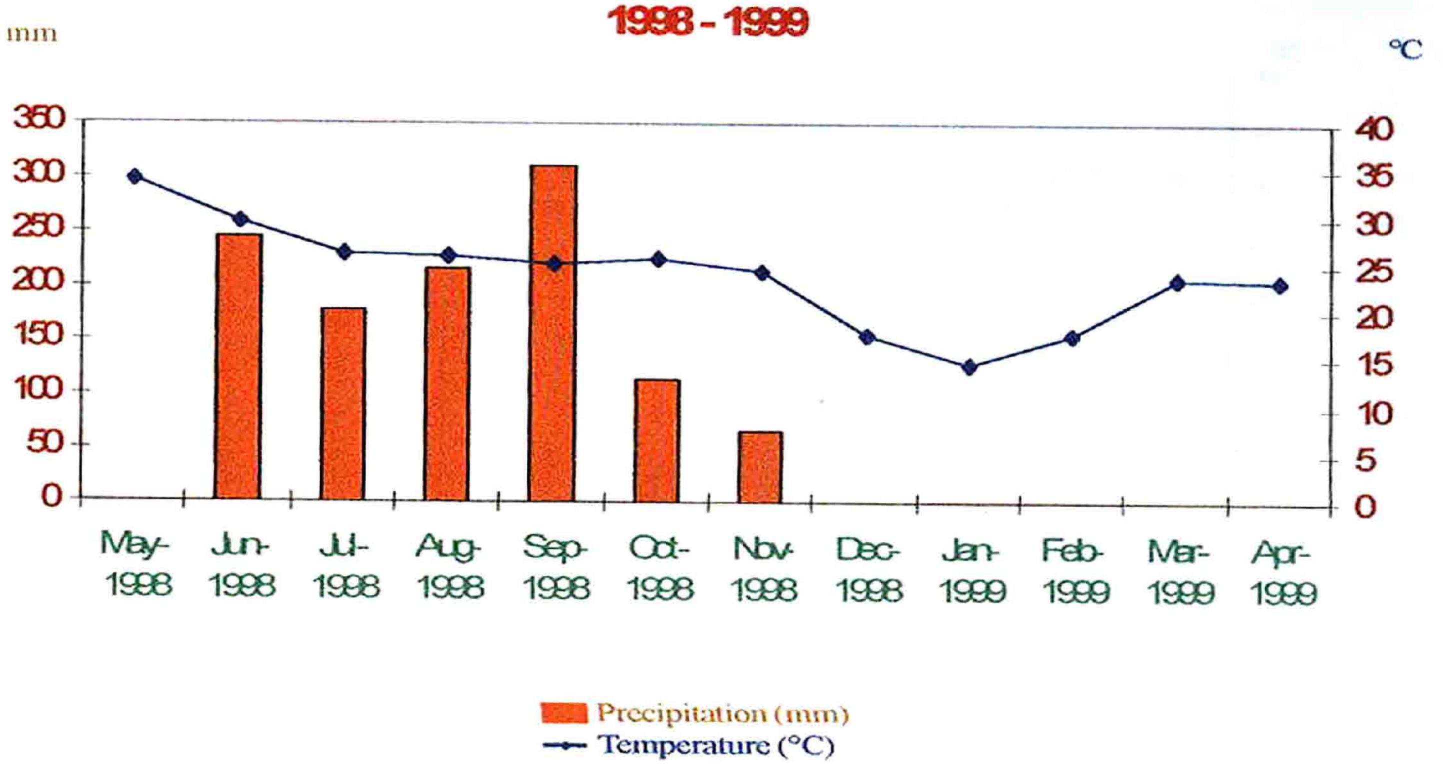


Figure 3 : Precipitation and temperature of Amravati district



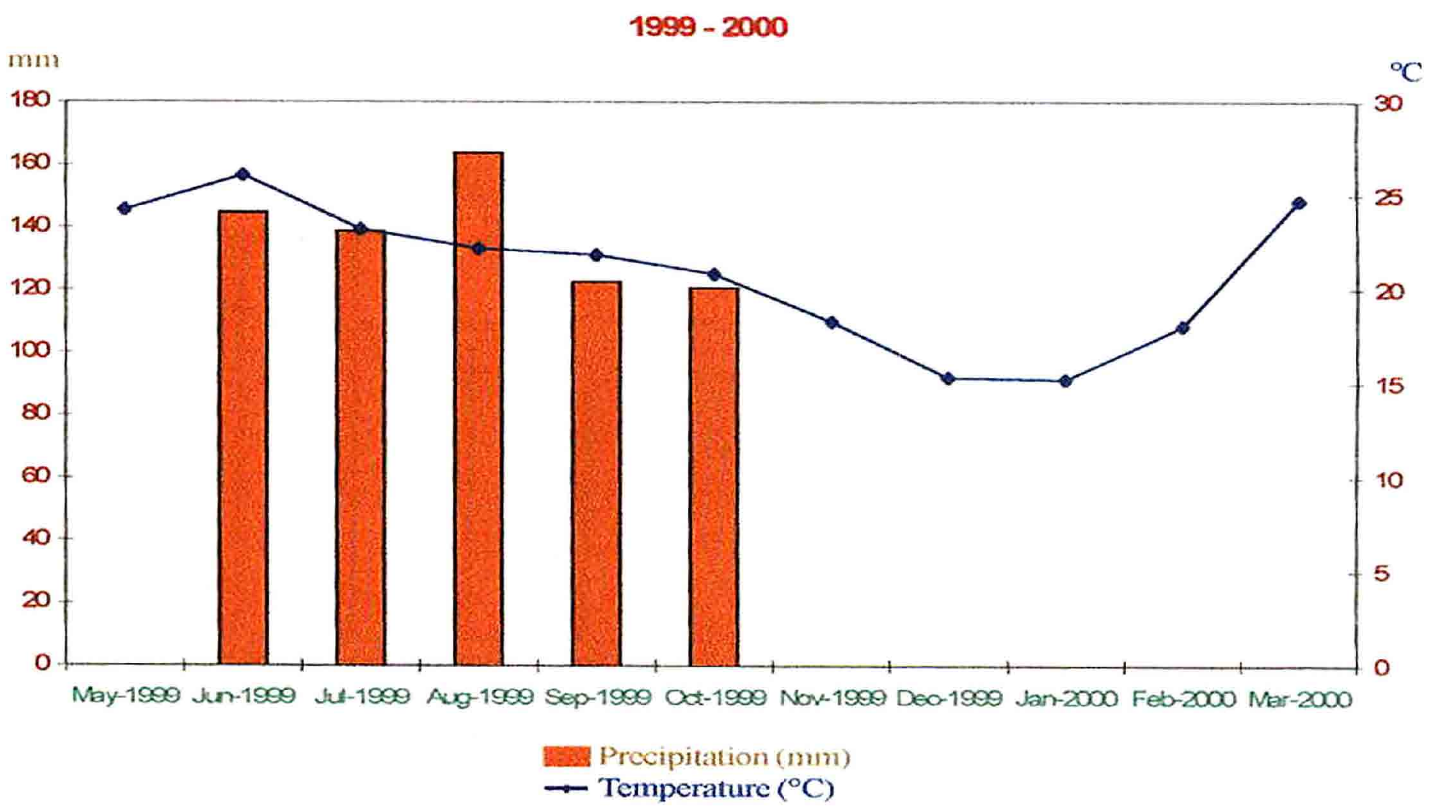


Figure 4 : Precipitation and temperature of Buldhana district

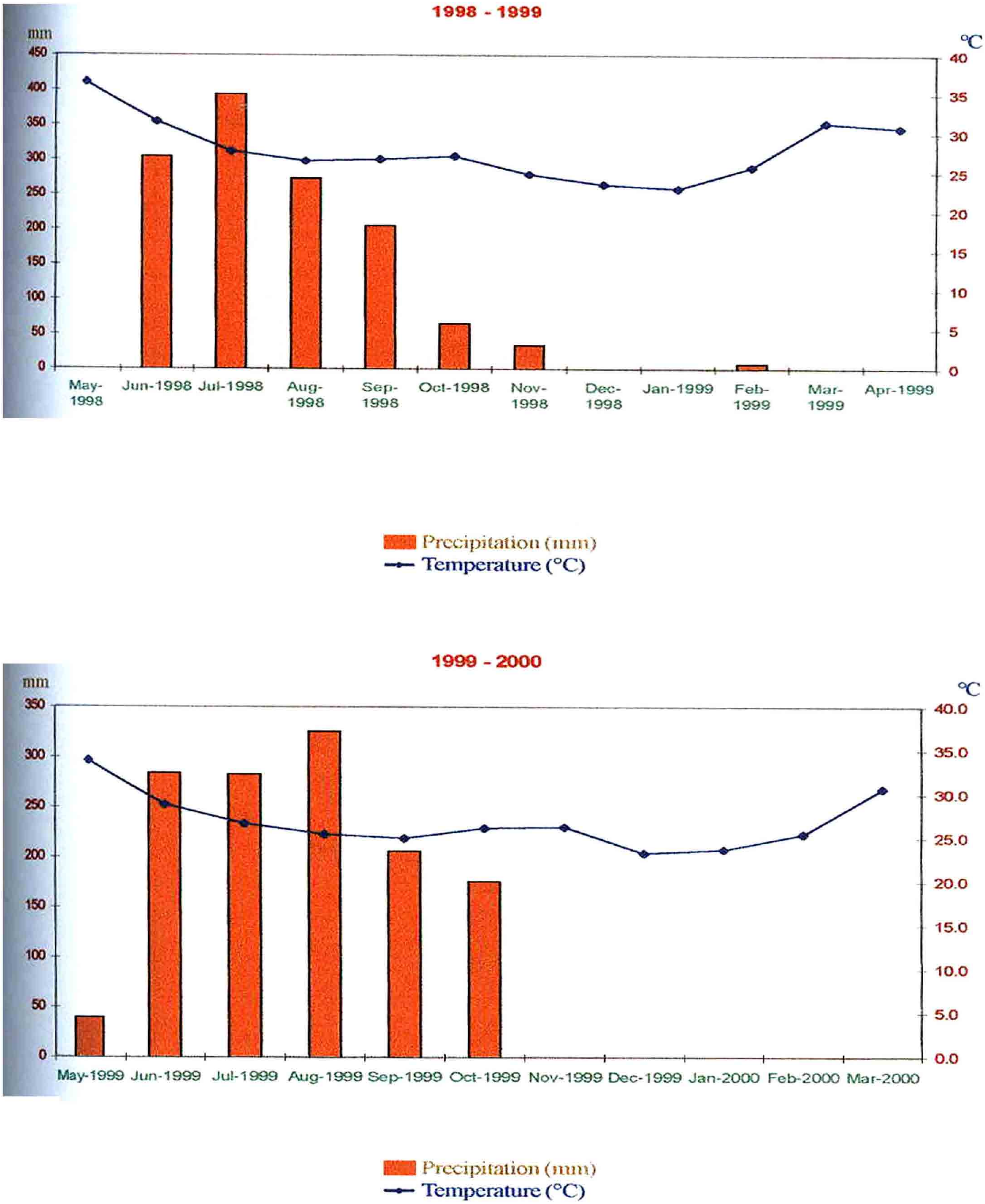
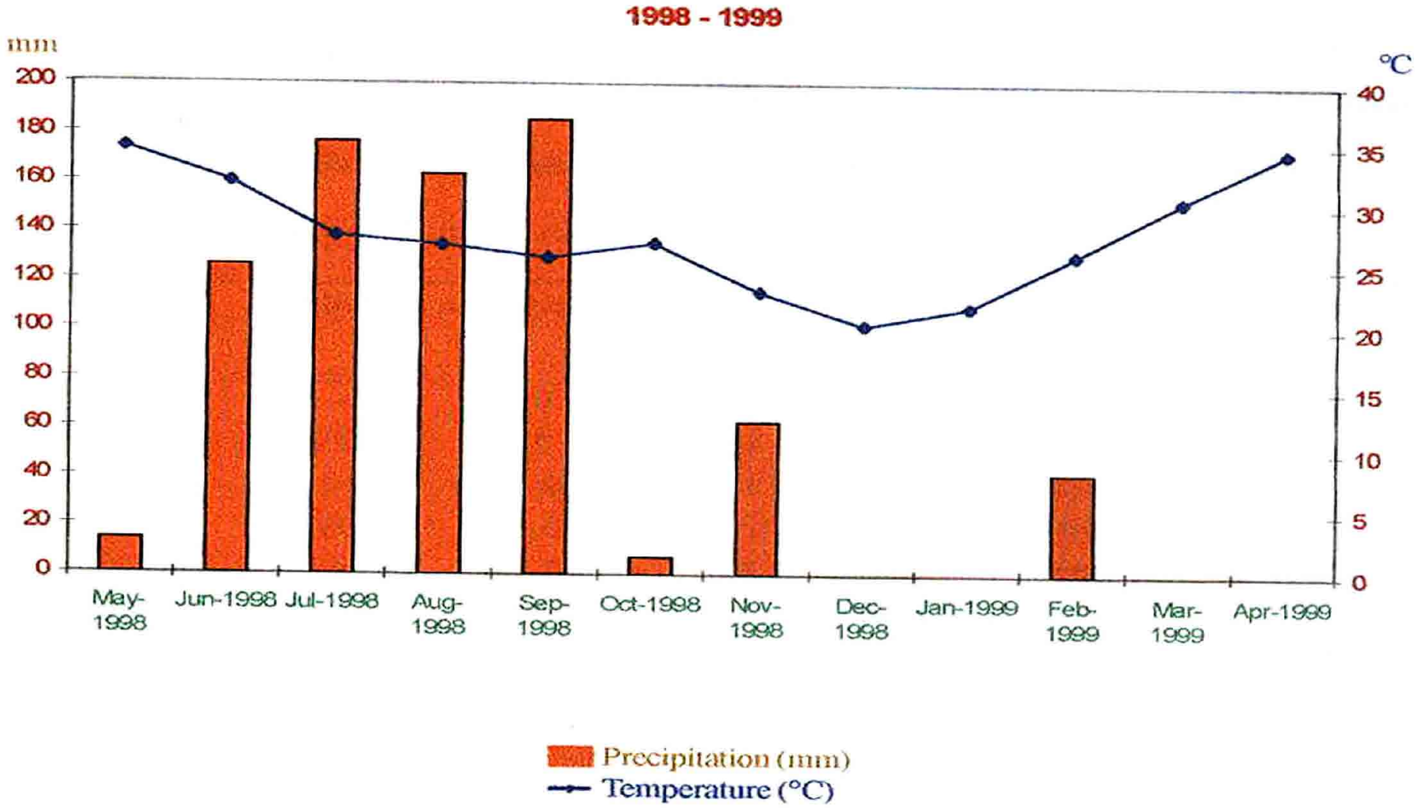


Figure 5 : Precipitation and temperature of Washim district



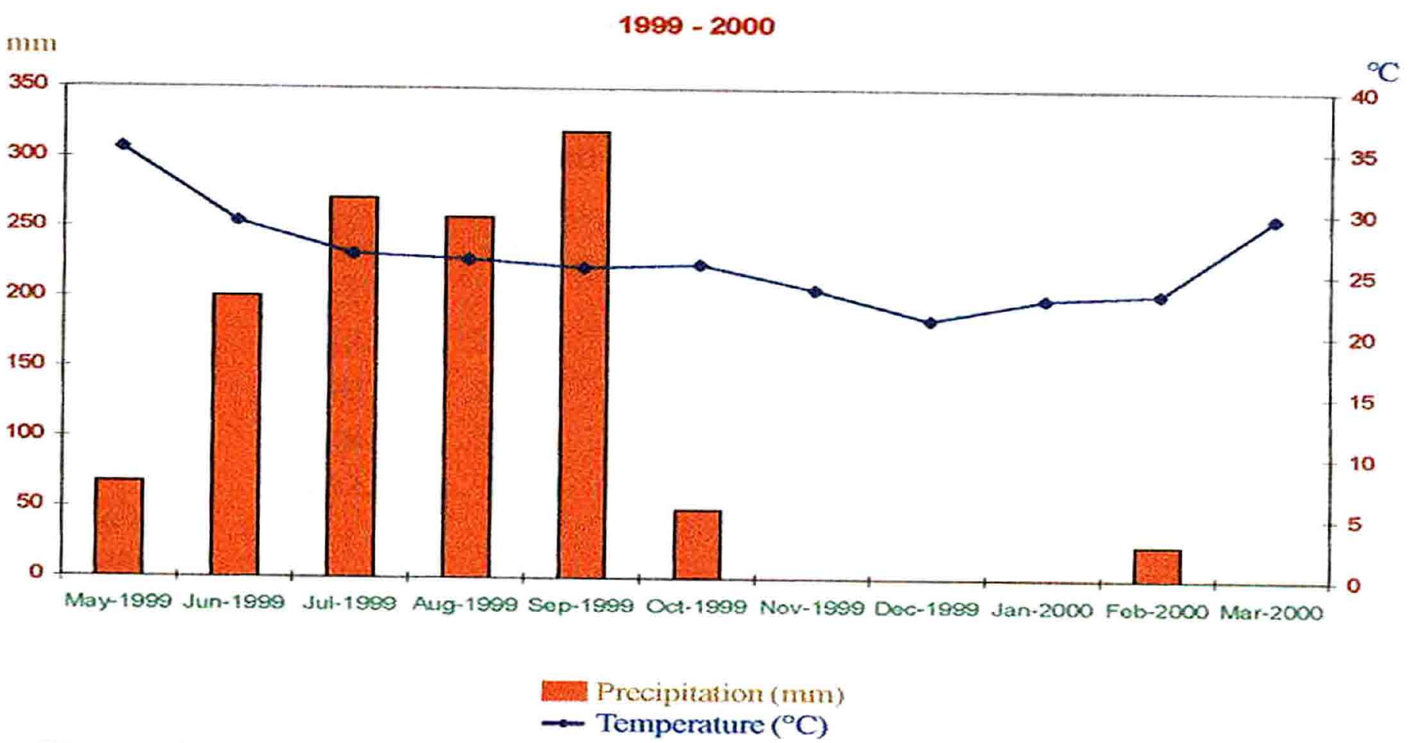


Figure 6 : Precipitation and temperature

Table 1 : **Monthly rainfall data collected from different locations of Western Vidarbha at meteorological observatory of Dr. PDKV Akola**

Table 1 (a) : Monthly rainfall data in mm during the year 1998-99

Month	Akola	Amravati	Buldana	Washim	Yavatmal	Average of five districts
May-1998	-	13.0	-	-	14.0	5.4
Jun-1998	95.9	85.0	246.0	305.2	126.2	171.7
Jul-1998	164.4	195.0	177.4	394.3	176.3	221.5
Aug-1998	160.2	283.0	216.6	273.8	163.0	219.3
Sept-1998	225.2	351.0	310.8	205.6	185.4	255.6
Oct-1998	80.3	28.0	112.8	65.4	7.0	58.7
Nov-1998	67.8	43.0	65.4	34.4	62.4	54.6
Dec-1998	-	-	-	-	-	-
Jan-1999	-	-	-	-	-	-
Feb-1999	46.2	40.0		8.0	41.4	27.12
Mar-1999	0.06	-	-	-	-	0.01
Apr-1999	-	-	-	-	-	-
Total	**840.1**	**1038**	**1129**	**1286.7**	**775.7**	**1013.9**

Table 1 (b) : Monthly rainfall data in mm during the year 1999-2000

Month	Akola	Amravati	Buldana	Washim	Yavatmal	Average of five districts
May-1999	29.6	19.0		39.8	68.0	31.3
Jun-1999	191.8	151.2	144.8	284.4	200.7	194.6
Jul-1999	138.2	329.7	138.8	283.0	271.3	232.2
Aug-1999	297.0	238.1	163.8	326.0	258.1	256.6
Sept-1999	188.4	225.9	122.6	206.4	319.5	212.6
Oct-1999	122.0	98.0	120.6	176.1	49.2	113.2
Nov-1999	-	-	-	-	-	-
Dec-1999	-	-	-	-	-	-
Jan-2000	-	-	-	-	-	-
Feb-2000	25.2	22.5			24.7	14.5
Mar-2000	-	-	-	-	-	-
Total	**992.2**	**1084.4**	**690.6**	**1315.7**	**1191.5**	**1054.9**

districts of Western Vidarbha during 1998-1999 and 1999-2000. The total average rainfall of Western Vidhrbha (average of five districts) during 1998-1999 and 1999-2000 was 1013.9 mm and 1054.9 mm,respectively. The total precipitation of Western Vidarbha during the *ambia* flush (Feb. 1999 to Dec. 1999) i.e. from *ambia* flowering to first maturation was 1082.1 mm and there was no precipitation during stress period (two months before flowering in Dec.1998). However, the total precipitation during *mrig* flush (June 1999 to March 2000) i. e. from *mrig* flowering to fruit maturation was 1023.1 mm and it was 31.3 mm during the stress period (May 1999) which was much less.

The precipitation received at Akola, Amravati, Buldana, Washim and Yavatmal districts during *ambia* flush was 1013.3, 1101.9, 690.6,1323.7 and 1208.2 mm respectively whereas during *mrig* flush it was recorded as 962.6, 1065.4, 690.6, 1275.9 and 1223.5 mm, respectively (Table 1). The condition of no or less rain fall during the stress period is favorable to mandarin crop for flowering. The rainfall is required during flower initiation, initial fruit setting and upto pea size fruit development for this crop. The amount of rainfall during the critical stages is of prime imporancre than the total amount of rainfall during the year for growth and yield of mandarin crop.

3.1.2.2 Temperature

The temperature data (Table 2 and Fig. 2 to 6) showed that the average of mean air temperature (MAT) of five districts during 1998-1999 and 1999- 2000 was 22.9^{0}C and 29.4^{0}C respectively. The hottest months in 1998-1999 and 1999-2000 were May 1998 and May 1999 with the MAT of 35.2^{0}C and 32.1^{0}C,respectively

Table 2 : Monthly temperature data collected from different locations of Western Vidarbha at meteorological observatory of Dr. PDKV Akola

Table 2 (a) : Monthly temperature data in °C during the year 1998-99

Month	Akola			Amravati			Buldana			Washim			Yavatmal			Average MAT of five districts
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	
May-1998	43.7	28.7	36.2	42.9	25.5	34.2	39.6	28.6	34.1	41.0	32.1	36.6	41.8	27.7	34.8	35.2
Jun-1998	38.5	27.1	32.8	38.3	26.4	32.4	33.1	25.9	29.5	34.9	28.1	31.5	36.9	27.0	32.0	31.6
Jul-1998	32.8	24.2	28.5	33.0	24.0	28.5	29.2	23.2	26.2	29.9	25.6	27.8	31.2	23.9	27.6	27.7
Aug-1998	31.3	23.8	27.6	32.1	24.5	28.3	28.8	23.1	26.0	28.2	24.8	26.5	29.8	23.9	26.9	27.0
Sep-1998	31.7	23.1	27.4	32.5	22.4	27.5	28.0	22.5	25.3	29.0	24.5	26.8	28.4	23.3	25.9	26.5
Oct-1998	32.3	20.9	26.6	32.9	21.2	27.1	29.9	21.5	25.7	29.8	24.5	27.2	30.9	23.1	27.0	26.7
Nov-1998	29.8	15.4	22.6	32.6	18.4	25.5	27.9	21.0	24.5	27.7	22.0	24.9	27.8	18.3	23.1	24.1
Dec-1998	28.8	8.5	18.7	26.5	13.1	19.8	22.0	13.1	17.6	27.6	19.5	23.6	27.0	13.7	20.4	20.0
Jan-1999	28.7	9.0	18.9	27.4	10.9	19.2	17.0	12.2	14.6	28.4	17.6	23.0	28.8	14.8	21.8	19.5
Feb-1999	32.2	15.1	23.7	30.4	16.3	23.4	20.0	15.5	17.8	30.0	21.5	25.8	32.5	19.7	26.1	23.3
Mar-1999	37.8	17.8	27.8	36.6	16.9	26.8	30.0	17.5	23.8	36.3	26.4	31.4	37.2	23.8	30.5	28.0
Apr-1999	42.9	23.3	33.1	41.9	18.8	30.4	28.9	18.0	23.5	40.3	21.1	30.7	41.8	27.3	34.6	30.4
Average	31.6	18.2	24.9	31.3	18.3	24.9	25.7	18.6	22.2	29.5	22.1	25.8	30.3	20.5	25.4	22.9

Table 2 (b) : Monthly temperature data in °C during the year 1999 - 2000

Month	Akola			Amravati			Buldana			Washim			Yavatmal			Average MAT of five districts
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	
May-1999	40.7	25.8	33.3	41.0	27.2	34.1	27.4	21.1	24.3	38.0	29.8	33.9	40.2	30.0	35.1	32.1
Jun-1999	34.6	24.4	29.5	34.1	25.3	29.7	29.5	22.7	26.1	31.1	26.6	28.9	33.4	24.8	29.1	28.7
Jul-1999	31.3	23.5	27.4	30.7	24.5	27.6	24.3	22.2	23.3	29.0	24.4	26.7	29.2	23.7	26.5	26.3
Aug-1999	30.0	22.7	26.4	29.2	23.1	26.2	23.1	21.3	22.2	27.3	23.6	25.5	28.9	23.2	26.1	25.2
Sep-1999	29.3	22.3	25.8	28.5	22.8	25.7	22.5	21.2	21.9	26.9	23.1	25.0	28.1	22.6	25.4	24.7
Oct-1999	31.2	19.1	25.2	30.7	20.5	25.6	22.6	19.1	20.9	28.7	23.7	26.2	30.3	21.0	25.7	24.7
Nov-1999	31.3	12.8	22.1	28.7	16.0	22.4	21.1	15.5	18.3	29.3	23.3	26.3	29.6	17.6	23.6	22.5
Dec-1999	28.8	9.8	19.3	27.0	10.6	18.8	17.8	12.9	15.4	27.2	19.4	23.3	27.4	14.9	21.2	19.6
Jan-2000	30.2	11.3	20.8	28.7	12.5	20.6	17.7	12.7	15.2	28.5	18.9	23.7	29.2	16.5	22.9	20.6
Feb-2000	30.0	13.5	21.8	29.8	12.4	21.1	20.3	15.8	18.1	29.8	21.1	25.5	29.1	17.5	23.3	21.9
Mar-2000	35.9	16.8	26.4	34.3	16.7	25.5	31.2	18.2	24.7	35.9	25.4	30.7	36.5	22.7	29.6	27.4
Average	29.4	16.8	23.2	28.6	17.6	23.1	21.5	16.9	19.2	27.6	21.6	24.6	28.4	19.5	24.0	29.4

whereas the coldest month was January 1999 in 1998-99 (Temp. 19.5^{0}C) and December 1999 in 1999-2000 (Temp. 19.6^{0}C). The MAT during *ambia* flush (Feb. 1999 to Dec. 1999) of Western Vidarbha (average of five districts) was 25.7^{0}C and during stress period (in Dec. 1998) it was 20.0^{0}C . The MAT during *mrig* flush (June 1999 to March 2000) was 24.2^{0}C and during the stress period (May 1999) it was 32.1^{0}C.

The mean air temperature recorded under report was 26.7, 26.4, 21.6, 22.7 and 27.6^{0}C during *ambia* flush and 24.5 24.3, 20.6, 26.2, and 25.3^{0}C during *mrig* flush at Akola, Amravati, Buldana, Washim and Yavatmal districts, respectively (Table 2).

3.2 Methods

The various methods followed during the present investigation are described in brief under the following heads.

3.2.1 Field methods

3.2.1.1 Selection of orchards

3.2.1.2 Crop parameters

3.2.2 Soil sampling and laboratory analysis

3.2.2.1 Collection of soil sample

3.2.2.2 Processing and storing

3.2.2.3 Soil analysis

3.2.3 Leaf sampling and analysis

3.2.3.1 Period of collection

3.2.3.2 Selection of leaf on shoot

3.2.3.3 Number of leaves.

3.2.3.4 Leaf processing and storing

3.2.3.5 Leaf analysis

3.2.4 Computation of DRIS norms

3.2.4.1 Diagnosis and Recommendation Integrated System

3.2.4.2 Development of DRIS norms

3.2.1 Field methods

The details of survey conducted and the field method adopted is described as under

3.2.1.1 Selection of orchards

The survey of mandarin was conducted for leaf and soil sampling as recommended by Srivastava (1997) for two different seasons. One hundred and fifty bearing orchards, seventy-five each from *ambia* flush and *mrig* flush of 10 to 13 years old were selected from Akola, Amravati, Buldana Washim and Yavatmal districts of Western Vidarbha region to study the nutritional status of soil and leaf of Nagpur mandarin.

3.2.1.2 Crop parameters

The number of Nagpur mandarin plants per hectare and yield per plant were recorded and presented in Appendix I. The plants per hectare ranged between 237 to 277. Yield of fruits in terms of number of fruits per plant was recorded in each orchard.

3.2.2 Soil sampling and laboratory analysis

The collection of soil samples and the further processing was carried out as described as below.

3.2.2.1 Collection of soil samples

The circular band of 30 to 40 cm wide underneath the perimeter of that tree from which leaf samples were to be collected was selected for the soil sampling. The surface (0-30 cm) samples were taken from the said circular band 30 to 40 cm away from stem and were kept separately.

3.2.2.2 Processing and storing

The collected soil samples were kept separately according to orchard and high or low yielding sub-population. These samples were air dried in shade, ground gently in pestle and mortar sieved through 2 mm sieve for determination of available nutrients and through 0.2 mm sieve for organic carbon and free calcium carbonate estimation. Thus processed samples of 2 mm and 0.2 mm size were duly labeled and stored in clean polyethylene bags for further analysis.

3.2.2.3 Soil analysis

The soil characteristics and different available nutrients determined through different methods in the laboratory are described as under.

Soil characteristics

a) Soil pH (1:2.5, soil:water suspension)

It was determined by pH meter after equilibrating soil with water for 60 minutes in the ratio of 1:2.5 soil water suspension (Jackson, 1967).

b) Electrical conductivity (EC) (1:2.5 soil:water suspension)

Electrical conductivity of the soil water suspension was determined using ELICO conductivity bridge (Richards, 1954).

c) Calcium carbonate

It was determined by rapid titration method (Piper, 1966). Soil was treated with strong acid (standard HCl) and the amount of acid was equivalent to the calcium carbonate present. The left over HCl was titrated with standard NaOH using phenolpthelene as an indicator.

d) Organic carbon

It was determined by Walkley and Black method (Piper, 1966). Ground soil sample of 0.2 mm size were used for estimation of organic carbon. Soil samples were oxidized by potassium dichoromate and concentrated sulphuric acid mixture and the amount of dichromate remaining were estimated by back titration with a standard ferrous ammonium sulphate solution using diphenylamine as an indicator.

Available nutrients

a) Nitrogen

The available nitrogen from soil was estimated by alkaline permanganate method of Subbiah and Asija (1956). The easily oxidizable organic nitrogen present in the soil was oxidized by potassium permanganate in the presence of NaOH by distillation. During oxidation, the released ammonia was absorbed in boric acid to convert the ammonia to ammonium borate, which was titrated with the standard sulphuric acid.

b) Phosphorus (P_2O_5)

The Olsen's method (Olsen *et al*, 1954) was used for determining plant available P in soil in which phosphorus was extracted from the soil using 0.5 M sodium bicarbonate ($NaHCO_3$), pH 8.5 as an extractant. Phosphorus was estimated colourimetrically by adding ammonium molybdate to aliquot and reducing the molybdenum phosphate complex in acidic medium. The intensity of blue color on reduction as a measure for concentration of P in extract was read on colourimeter using 730 nm red filter.

c) Potassium

The available potassium i.e. exchangeable and water soluble K in soil was determined in neutral normal ammonium acetate (N NH_4OAc) extract of soil. The extraction was carried out by shaking followed by filtration and the potassium in extract was estimated flame photometrically (Jackson, 1967).

d) Calcium and magnesium

Exchangeable (available) Ca and Mg were determined in the same ammonium acetate extracts of soil under K by direct titration with EDTA, suggested by Jackson (1967).

e) Sulphur

Sulphate sulphur in soil was extracted with Morgan's solution i.e. sodium acetate-acetic acid mixture Barium chloride was added to extract and barium sulphate was precipitated. Gum acacia was used to stabilize the fine colloidal suspension of barium sulphate. The resulting turbidity was measured colorimetrically using blue filter (Jackson, 1967).

f) Micronutrients

The soil was saturated and leached with Diethyl triamine penta acetic acid (DTPA) solution (pH 7.3); the leachate was analysed for available micronutrients Fe, Mn, Cu, and Zn using an Atomic Absorption Spectrophotometer (AAS) (Lindsay and Norvell, 1978).

3.2.3 Leaf sampling and analysis

Leaf samples of Nagpur mandarin from the selected orchards were collected, processed as per the standard procedure and analysed for their nutritional contents. The detail methodology adopted for sampling and chemical analysis is given below.

3.2.3.1 Period of collection

The leaf sampling was done at the leaf age of 7 months old during the month of October 1999 for *ambia* flush and 8 months old during January 2000 for *mrig* flush, separately. To distinguish leaves of right age, typical twigs were marked by tagging with suitable lable at the very young stage in advance for selecting the desired shoot as described by Munshi *et al.* (1978).

3.2.3.2 Selection of leaf on shoot

Only mature leaves characterized by dull green colour having rough surface were collected avoiding the immature leaves. The non-fruiting terminals were selected for collection of leaves from marked twigs. The samples were at height of 1.5 to 2.0 m from ground from all sides of tree i.e. North, South, East and West. Selected leaves were fully exposed to the atmosphere, to avoid shading effects. The sample covered minimum two per cent of the trees in the site selected for the purpose.

3.2.3.3 Number of leaves

The final sample consists of minimum 100 to 125 leaves, which were collected in brown paper bags and were brought to laboratory for analysis.

3.2.3.4 Leaf processing and storing

The collected leaf samples were subdivided into four parts and were washed sequentially with two per cent detergent, N/10 HCl, tap water and distilled water and immediately wiped out using ordinary filter paper. Then the samples were dried at 70°C and homogenized using grinder. The processed samples were preserved in brown paper bags with appropriate labels and used for chemical analysis.

3.2.3.5 Leaf analysis

The processed samples were analysed for different macro and micro-nutrients *viz.*, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, manganese and copper using standard procedures as follows.

a) Total nitrogen

Total nitrogen in plant samples was determined by Kjeldahl method in which complex nitrogenous compounds in plant samples were converted into ammonia and then to ammonium sulphate. The ammonia in the ammonium sulphate is released with NaOH during distillation and absorbed in a known excess of standard sulphuric acid. The unutilized excess of standard H_2SO_4 is determined by a back titration with standard sodium hydroxide. The total nitrogen is then calculated from amount of the standard H_2SO_4 neutralized by absorbed ammonia during distillation (Jackson, 1967).

b) Digestion of sample

For the nutrients other than nitrogen, the plant material was digested in a di-acid 9:4 mixture of HNO_3:$HClO_4$. The samples were predigested with 25 ml HNO_3 per gram sample to avoid explosion. Volume was made up with deionized water and the aliquots of this solution were used for the determination of P, K, Ca, Mg, S, Fe, Mn, Zn, and Cu.

c) Phosphorus in di-acid extract

Phosphorus contained in the extracts was estimated by reacting the extract with vanadomolybdate forming yellow colour complex in HNO_3 medium. The colour was developed in about 30 minutes and the transmittance or absorbance of solution was read at colourimeter using the blue filter (Jackson, 1967).

d) Potassium

The extract was diluted to appropriate concentration and was directly atomized to the flame photometer at 548 nm wavelength (Jackson, 1967).

e) Sulphur

The sulphate content in the digest was determined by barium sulphate turbidimetry method by reading the absorbance or transmittance of solution on colourimeter using blue filter.

f) Calcium and magnesium

For calcium and magnesium, the diacid digest was further diluted 50 times and was estimated by EDTA method (Jackson, 1967).

g) Micronutrients

Iron, manganese, copper and zinc content in diacid extract were determined using Atomic Absorption Spectrophotometer (AAS) (Jackson, 1967).

3.2.4 Computation of DRIS norms

Diagnosis and Recommendation Integrated System (DRIS) developed by Beaufils (1973) as outlined by Bhargava and Raghupathi (1996), was used for interpretation of results and soil fertility and leaf nutrient norms were developed to know the soil and leaf nutrient status and their relationship with yield parameter. The brief outline of the DRIS technique adopted in the study is mentioned as under.

3.2.4.1 Diagnosis and Recommendation Integrated System

DRIS is a holistic system in which as many yield determining factors as are capable of quantitative or qualitative expression are calibrated as a function of yield.

The interrelationship between plant, soil and environmental factors, as well as their relationship with yield are studied irrespective of whether any particular factor is known to have an influence on yield or not. This is essential because any one of these yield determining factors may become limiting in a particular case. Therefore to obtain as complete a picture as possible all factors must be studied for best results in diagnostic and recommendation purposes.

The DRIS system characterizes all the components like soil properties, climatic conditions, farming practices, plant response, yield in terms of indices which are derived as comparable functions of yield (Sumner, 1977-a). Not only do these indices allow one to classify yield factors in order of limiting importance, but they also give an indication of the intensity with which the plant requires a given nutrient. Because these indices rank the yield factor in order of limiting importance, the automatically incorporate the concept of balance into the system. These indices for soil, plant and environmental parameters constitute a set of calibrated norms that can be used for diagnosis and recommendation.

The indices for soil, climatic conditions and farming practices indicate what is offered or not offered to a particular plant at a given site. These indices are calibrated in terms of the nature and amount of a specified treatment, which is required. (Sumner, 1977-d).

On the other hand, the soil and plant nutrient indices to which this investigation will be confined simply indicate the nature and degree of nutrient balance in the plant at a given site. Soil and plant nutrient indices considered on their own do not give an automatic indication of the nature and amount of a particular element which must be added to the soil, as plant response is a function of soil properties and plant response to treatments.

Given a target yield under specified economic conditions the DRIS calibration system can be used to simultaneously bring the largest number of plant and environmental characters as close as possible to established optimum values.

It is therefore the correct and judicious use of the complete set of calibrated indices, which will enable one to establish the most appropriate practice or treatment for each particular case under consideration. Furthermore, although the application of the most appropriate treatment will increase the chances of obtaining a higher yield or production efficiency, one should bear in mind that uncontrollable factors can always play a part in limiting the chances of success.

DRIS norms are developed from a survey of Nagpur Mandarin in which soil and leaf samples were collected and yields were recorded. The most important advantages of DRIS approach are its ability to

i. make a diagnosis at any stage of crop development.

ii. list the nutrient elements in their order of limiting importance on yield.

iii. indicate not only the most limiting nutrient but also the order in which other nutrients are likely to limit yield (Bhargava and Chadha, 1988).

3.2.4.2 Development of DRIS norms

In the simples case, the norms of three selected nutrients can be related to one another in a so called DRIS chart in which specific circle is drawn and the degree of imbalance of nutrients is denoted by particular arrows. Although the use of this diagram enables one to make three nutrient diagnosis, DRIS also provides a method of development of norms.

Following is the procedure explained derived the norms for fertility status of soils and leaves.

The mean of high yield orchards constituted the mean for optimum. The standard deviation (SD) of high yielding population is associated with the particular parameter. The range of "Optimum" is the value derived from mean – 4/3 SD to mean + 4/3 SD. The range of "low" was obtained by calculating mean –4/3 SD to mean – 8/3 SD, and below the mean–8/3 SD was considered as deficient. The value from mean + 4/3 SD to mean + 8/3 SD was taken as high and the value above mean +8/3 SD was taken as toxic or excessive (Bhargava , 1995)

The steps adopted for development of DRIS norms are described below.

1. **Survey Technique**

In DRIS approach a survey technique was employed where total 150 orchards; 75 each in *ambia* and *mrig* flush randomly distributed through the study area were selected. Orchards were selected in such a way that these can represent general tree conditions of areas under study. In one site, an orchard which was centrally located and had similar topography (slope) with near by orchards of that site was taken for study.

2. **Establishment of data bank**

In this step the parameter to be improved and those factors likely to affect them defined. The parameter to be improved was yield per plant of each Nagpur mandarin orchard and other factors were soil fertility and leaf nutrient status.

The soil fertility factors were soil pH, EC, organic carbon content, free calcium carbonate ($CaCO_3$) content , available nutrients contents *viz.*, N, P, K, Ca, Mg, S, Fe, Mn, Cu. and Zn.

In case of leaf nutrients N, P, K, Ca, Mg, S, Fe, Mn, Cu. and Zn. were considered.

3. **Collection of reliable data**

All the reliable data available from filed and laboratory as mentioned above was collected.

4. **Dividation of population**

For a normal distribution of observations the mean of the all the values provides an accurate estimate of the peak or maximum value. Unfortunately, few populations of soil fertility status or foliar nutrient data collected in the field may not be normally distributed. Generally low yields are more frequently associated with the low than high soil or plant nutrient status. This should not be surprising because although excessive nutrient can certainly induce low yields, farmers producing low yields are more likely due to under than to over fertilize. Therefore, such type of poor distribution may be more indicative of agricultural practices than of plant responses.

Nevertheless, skewed distributions can represent a problem if such data are to be used for standard value generation.

In DRIS, this difficulty has been overcome by dividing data sets or populations of observations into high and low-yielding subgroups; then averaging values only from high-yielding group are used to obtain estimates of parameter optima have overcome this difficulty. In addition, the coefficients of variation (CVs) of the high yielding data provide a measure of the relative spread of breadth of the yield response surface at upper yield levels. The actual cut off value used to divide high and low yield groups is not critical as long as the high- yield data remain normally distributed. In practice, chosen cut off values usually represent yields that 'better' farmers routinely obtain (Walworth and Sumner, 1987).

In Vidarbha the Nagpur mandarin orchards are generally classified into three classes on the basis of yield *viz*., low (<400 fruits per tree), medium (400 to 700 fruits per tree) and high (>700 fruits per tree) yielder. For the purpose of dividation of data into two sets i.e. low and high yielding subpopulation, principle explained by Dey and Singha (1998) is adopted who categorized low yielders as declining and medium to high yielder as healthy orchard. In present investigation the whole population was divided in two groups based on "high" and "low" yield performance. The cut off value for dividing low and high yield was 400 fruits per tree for each orchard.

5. Formation of Expressions

For each pair of nutrients or parameters there are three forms of expression that may be considered. pH and EC, for example, can be related as the ratio pH/EC, as the inverse EC/ pH or as the product pH x EC. In DRIS caluclation only one expression is used to relate each nutrient pair. The form of expression (pH/EC, EC/pH or pH x EC) found best to discriminate between the high and low yielding subpopulations selected for use within DRIS calculations, are those with the largest variance ratio (Variance of low yielding ÷ Variance of high yielding population). As such as many nutrients/ parameters pairs as possible were expressed for each index. (Appendix II, III, IV, and V) separately for soil parameters and leaf nutrients.

6. Calibration of parameters

To study the relationship between yield and the parameters like soil composition, leaf composition etc, following steps were used.

a. The mean of each sub population was calculated for various forms of expression.

b. The variance ratios between yields of sub population for all forms of expressions were calculated together with the coefficients of variations (CVs) (Appendix II, III, IV, and V).

7. Calculation of DRIS index

Finally, based on significant variance ratios, formulae were worked out to calculate the DRIS indices for soil fertility and leaf nutrient status of Nagpur mandarin for all selected orchards.

Formulae to calculate DRIS indices developed are as follows.

A) For soil under *ambia* flush.

$$pH = \frac{1}{14}\left[-f\left(\frac{EC}{pH}\right) - f\left(\frac{OC}{pH}\right) + f(pH \times CC) + f\left(\frac{pH}{N}\right) + f\left(\frac{pH}{P}\right) + f\left(\frac{pH}{K}\right) + f\left(\frac{pH}{Ca}\right) + f\left(\frac{pH}{Mg}\right) + f\left(\frac{pH}{S}\right) + f\left(\frac{pH}{Fe}\right) + f\left(\frac{pH}{Mn}\right) + f\left(\frac{pH}{Cu}\right) + f\left(\frac{pH}{Zn}\right) + f\left(\frac{pH}{Y}\right)\right] \quad .....(1)$$

Equation (1) is solved in the following manner

In equation (1) –

a) $$f(\frac{EC}{pH}) = \left[\frac{EC/pH}{ec/ph} - 1\right]\frac{1000}{CV} \qquad ....(2)$$

When , $\frac{EC}{pH} > \frac{ec}{ph}$ and

$$f(\frac{EC}{pH}) = \left[1 - \frac{ec/ph}{EC/pH}\right]\frac{1000}{CV} \qquad ....(3)$$

When , $\frac{EC}{pH} < \frac{ec}{ph}$ and

b) $\frac{EC}{pH}$ is the value of ratio of the two parameter (EC and pH) in the soil being diagnosed.

c) $\frac{ec}{ph}$ is the actual value of the ratio (which is the mean value of high yielding orchards) of EC (dSm^{-1}) and pH.

d) CV is the coefficient of variation of high yielding orchards associated with the norm.

e) 14 is the number of functions comprising the nutrient index.

f) In either case 1000 multiplier in the function equations is 100 x 10 with the value 10 being included as a matter of practicability to give the resultant indices convenient magnitudes and having no actual functional purpose. The value 100 is the denominator of the coefficient of variation expressed as a per centage.

g) OC is used for organic carbon (%) and CC for calcium carbonate(%).

h) Y indicates the yield.

The need for two separate function equations, dependent on whether the sample ratio is smaller than or larger than the norm (mean value) can best be explained in the following manner.

The function of $\frac{EC}{pH}$ is used in the calculation of indices for both soil parameters EC and pH. When calculating the pH index, $f(\frac{EC}{pH})$ is added to the other functions prior to averaging (Equation 1). However, this same function $f(\frac{EC}{pH})$ is used with a reversed sign in calculation of the index for other parameter for example $f(\frac{EC}{pH})$ in equation (1) is negative which is used with positive sign in equation (4) for calculation of index EC. In other words, because the value of each ratio function was added to one index subtotal and subtracted from another, all indices were balanced around zero. Therefore nutrient indices sums up around zero (Bhargava and Raghupathi, 1996). The higher negative index showed that the corresponding nutrient parameter was relatively deficient. Alternatively, a large positive index indicated the nutrient was excessive in quantity. As such, the order of plant requirement is given by the most negative index being the most required and the most positive, the least. Each "function" is a comparison of the ratio found in the individual plant sample with the mean for that ratio. In the similar manner the indices were calculated for other parameters and/or nutrients for soil and leaf composition. These formulae are expressed as under.

$$EC = \frac{1}{14}[f(\frac{EC}{pH}) + f(EC \times OC) + f(EC \times CC) + f(\frac{EC}{N}) + f(\frac{EC}{P}) + f(\frac{EC}{K})$$
$$+ f(\frac{EC}{Ca}) + f(\frac{EC}{Mg}) + f(\frac{EC}{S}) + f(\frac{EC}{Fe}) + f(\frac{EC}{Mn}) + f(\frac{EC}{Cu}) + f(\frac{EC}{Zn}) + f(\frac{EC}{Y})] \quad \ldots (4)$$

$$OC = \frac{1}{14}[f(\frac{OC}{pH}) - f(EC \times OC) - f(\frac{CC}{OC}) + f(\frac{OC}{N}) + f(\frac{OC}{P}) + f(\frac{OC}{K})$$
$$+ f(\frac{OC}{Ca}) + f(\frac{OC}{Mg}) + f(\frac{OC}{S}) + f(\frac{OC}{Fe}) + f(OC \times Mn) + f(\frac{OC}{Cu}) + f(\frac{OC}{Zn}) + f(\frac{OC}{Y})] \quad \ldots (5)$$

$$CC = \frac{1}{14}[- f(pH \times CC) - f(EC \times CC) - f(\frac{CC}{OC}) + f(\frac{CC}{N}) + f(\frac{CC}{P}) + f(\frac{CC}{K})$$
$$+ f(\frac{CC}{Ca}) + f(\frac{CC}{Mg}) + f(CC \times S) + f(\frac{CC}{Fe}) + f(\frac{CC}{Mn}) + f(\frac{CC}{Cu}) + f(\frac{CC}{Zn}) + f(\frac{CC}{Y})] \quad \ldots (6)$$

$$N = \frac{1}{14}[- f(\frac{pH}{N}) - f(\frac{EC}{N}) - f(\frac{OC}{N}) - f(\frac{CC}{N}) + f(\frac{N}{P}) - f(\frac{K}{N})$$
$$+ f(\frac{N}{Ca}) + f(\frac{N}{Mg}) - f(\frac{S}{N}) - f(\frac{Fe}{N}) - f(\frac{Mn}{N}) - f(\frac{Cu}{N}) - f(\frac{Zn}{N}) + f(\frac{N}{Y})] \quad \ldots (7)$$

$$P = \frac{1}{14}[- f(\frac{pH}{P}) - f(\frac{EC}{P}) - f(\frac{OC}{P}) - f(\frac{CC}{P}) - f(\frac{N}{P}) - f(\frac{K}{P})$$
$$- f(\frac{Ca}{P}) - f(\frac{Mg}{P}) - f(\frac{S}{P}) - f(\frac{Fe}{P}) - f(\frac{Mn}{P}) - f(\frac{Cu}{P}) - f(\frac{Zn}{P}) + f(\frac{P}{Y})] \quad \ldots (8)$$

$$K = \frac{1}{14}[- f(\frac{pH}{K}) - f(\frac{EC}{K}) - f(\frac{OC}{K}) - f(\frac{CC}{K}) + f(\frac{K}{N}) + f(\frac{K}{P})$$
$$+ f(\frac{K}{Ca}) + f(\frac{K}{Mg}) - f(\frac{S}{K}) - f(\frac{Fe}{K}) - f(\frac{Mn}{K}) - f(\frac{Cu}{K}) - f(\frac{Zn}{K}) + f(\frac{K}{Y})] \quad \ldots (9)$$

$$Ca = \frac{1}{14}[- f(\frac{pH}{Ca}) - f(\frac{EC}{Ca}) - f(\frac{OC}{Ca}) - f(\frac{CC}{Ca}) - f(\frac{N}{Ca}) + f(\frac{Ca}{P})$$
$$- f(\frac{K}{Ca}) - f(\frac{Mg}{Ca}) - f(\frac{S}{Ca}) - f(\frac{Fe}{Ca}) - f(\frac{Mn}{Ca}) - f(\frac{Cu}{Ca}) - f(\frac{Zn}{Ca}) + f(\frac{Ca}{Y})] \quad \ldots (10)$$

$$Mg = \frac{1}{14}[- f(\frac{pH}{Mg}) - f(\frac{EC}{Mg}) - f(\frac{OC}{Mg}) - f(\frac{CC}{Mg}) - f(\frac{N}{Mg}) + f(\frac{Mg}{P})$$
$$- f(\frac{K}{Mg}) + f(\frac{Mg}{Ca}) + f(\frac{Mg}{S}) + f(\frac{Mg}{Fe}) - f(\frac{Mn}{Mg}) + f(\frac{Mg}{Cu}) - f(\frac{Zn}{Mg}) + f(\frac{Mg}{Y})] \quad \ldots (11)$$

$$S = \frac{1}{14}[- f(\frac{pH}{S}) - f(\frac{EC}{S}) - f(\frac{OC}{S}) - f(CC x S) + f(\frac{S}{N}) + f(\frac{S}{P})$$
$$+ f(\frac{S}{K}) + f(\frac{S}{Ca}) - f(\frac{Mg}{S}) - f(\frac{Fe}{S}) - f(\frac{Mn}{S}) + f(\frac{S}{Cu}) - f(\frac{Zn}{S}) + f(\frac{S}{Y})] \quad \ldots (12)$$

$$Fe = \frac{1}{14}[-f(\frac{pH}{Fe}) - f(\frac{EC}{Fe}) - f(\frac{OC}{Fe}) - f(\frac{CC}{Fe}) + f(\frac{Fe}{N}) + f(\frac{Fe}{P})$$
$$+ f(\frac{Fe}{K}) + f(\frac{Fe}{Ca}) - f(\frac{Mg}{Fe}) + f(\frac{Fe}{S}) - f(\frac{Mn}{Fe}) + f(\frac{Fe}{Cu}) - f(\frac{Zn}{Fe}) + f(\frac{Fe}{Y})] \quad \ldots (13)$$

$$Mn = \frac{1}{14}[-f(\frac{pH}{Mn}) - f(\frac{EC}{Mn}) - f(OC \times Mn) - f(\frac{CC}{Mn}) + f(\frac{Mn}{N})$$
$$+ f(\frac{Mn}{P}) + f(\frac{Mn}{K}) + f(\frac{Mn}{Ca}) + f(\frac{Mn}{Mg}) + f(\frac{Mn}{S}) + f(\frac{Mn}{Fe}) + f(\frac{Mn}{Cu}) + f(\frac{Mn}{Zn}) + f(\frac{Mn}{Y})] \quad \ldots (14)$$

$$Cu = \frac{1}{14}[-f(\frac{pH}{Cu}) - f(\frac{EC}{Cu}) - f(\frac{OC}{Cu}) - f(\frac{CC}{Cu}) + f(\frac{Cu}{N}) + f(\frac{Cu}{P}) + f(\frac{Cu}{K}) + f(\frac{Cu}{Ca}) - f(\frac{Mg}{Cu})$$
$$- f(\frac{S}{Cu}) - f(\frac{Fe}{Cu}) - f(\frac{Mn}{Cu}) - f(\frac{Zn}{Cu}) + f(\frac{Cu}{Y})] \quad \ldots (15)$$

$$Zn = \frac{1}{14}[-f(\frac{pH}{Zn}) - f(\frac{EC}{Zn}) - f(\frac{OC}{Zn}) - f(\frac{CC}{Zn}) + f(\frac{Zn}{N})$$
$$+ f(\frac{Zn}{P}) + f(\frac{Zn}{K}) + f(\frac{Zn}{Ca}) + f(\frac{Zn}{Mg}) + f(\frac{Zn}{S}) + f(\frac{Zn}{Fe}) - f(\frac{Mn}{Zn}) + f(\frac{Zn}{Cu}) + f(\frac{Zn}{Y})] \quad \ldots (16)$$

$$Y = \frac{1}{14}[-f(\frac{pH}{Y}) - f(\frac{EC}{Y}) - f(\frac{OC}{Y}) - f\frac{CC}{Y} - f(\frac{N}{Y}) - f(\frac{P}{Y})$$
$$- f(\frac{K}{Y}) - f(\frac{Ca}{Y}) - f(\frac{Mg}{Y}) - f(\frac{S}{Y}) - f(\frac{Fe}{Y}) - f(\frac{Mn}{Y}) - f(\frac{Cu}{Y}) - f(\frac{Zn}{Y})] \quad \ldots (17)$$

B) For soil under *mrig* flush

$$pH = \frac{1}{14}[f(pH \times EC) + f(\frac{pH}{OC}) + f(pH \times CC) + f(\frac{pH}{N}) + f(\frac{pH}{P}) + f(\frac{pH}{K})$$
$$+ f(\frac{pH}{Ca}) + f(\frac{pH}{Mg}) + f(\frac{pH}{S}) + f(\frac{pH}{Fe}) + f(\frac{pH}{Mn}) + f(\frac{pH}{Cu}) - f(\frac{Zn}{pH}) + f(\frac{pH}{Y})] \quad \ldots (18)$$

where, $f(pH \times EC) = [\frac{pH \times EC}{ph \times ec} - 1] \times \frac{1000}{CV} \ldots (19)$ When $pH \times EC > ph \times ec$

and $f(pH \times EC) = [1 - \frac{ph \times ec}{pH \times EC}] \times \frac{1000}{CV} \ldots (20)$ When $pH \times EC < ph \times ec$

pH X EC is the actual value of product of pH and EC (dsm-1) in sample under diagnosis and x ec is the mean value of high yielding sub-population. The other terms in the form of ratio or products *viz.* $f(\frac{pH}{OC})$, $f(pH \times CC)$ and so on are derived in a similar way using their mean values of high yielding subpopulation as ph / oc , ph x cc and likewise . CV is the coefficient of variation for high yielding orchards. The formulae for rest of the parameters are solved by the procedure described under equation (1).

$$EC = \frac{1}{14}[-f(pH \times EC) + f(EC \times OC) + f(EC \times CC) + f(\frac{EC}{N}) + f(\frac{EC}{P}) + f(\frac{EC}{K})$$
$$+ f(\frac{EC}{Ca}) + f(\frac{EC}{Mg}) + f(\frac{EC}{S}) + f(EC \times Fe) + f(\frac{EC}{Mn}) + f(\frac{EC}{Cu}) + f(\frac{EC}{Zn}) + f(\frac{EC}{Y})] \quad \ldots (21)$$

$$OC = \frac{1}{14}[-f(\frac{pH}{OC}) - f(EC \times OC) - f(\frac{CC}{OC}) + f\frac{OC}{N} + f(\frac{OC}{P}) - f(\frac{K}{OC})$$
$$+ f(\frac{OC}{Ca}) + f(\frac{OC}{Mg}) + f(\frac{OC}{S}) - f(\frac{Fe}{OC}) + f(\frac{OC}{Mn}) + f(\frac{OC}{Cu}) - f(\frac{Zn}{OC}) + f(\frac{OC}{Y})] \quad \ldots (22)$$

$$CC = \frac{1}{14}[-f(pH \times CC) - f(EC \times OC) + f\left(\frac{CC}{OC}\right) + f(\frac{CC}{N}) + f(\frac{CC}{P}) + f(\frac{CC}{K})$$
$$+ f(\frac{CC}{Ca}) + f(\frac{CC}{Mg}) + f(\frac{CC}{S}) + f\left(\frac{CC}{Fe}\right) + f(\frac{CC}{Mn}) + f(\frac{CC}{Cu}) + f(\frac{CC}{Zn}) + f(\frac{CC}{Y})] \quad \ldots (23)$$

$$N = \frac{1}{14}[-f(\frac{pH}{N}) - f(\frac{EC}{N}) - f(\frac{OC}{N}) - f(\frac{CC}{N}) + f(\frac{N}{P}) - f(\frac{K}{N})$$
$$- f(\frac{Ca}{N}) - f(\frac{Mg}{N}) - f(\frac{S}{N}) - f(\frac{Fe}{N}) - f(\frac{Mn}{N}) - f(\frac{Cu}{N}) - f(\frac{Zn}{N}) + f(\frac{N}{Y})] \quad \ldots (24)$$

$$P = \frac{1}{14}[-f(\frac{pH}{P}) - f(\frac{EC}{P}) - f(\frac{OC}{P}) - f(\frac{CC}{P}) - f(\frac{N}{P}) - f(\frac{K}{P})$$
$$- f(\frac{Ca}{P}) - f(\frac{Mg}{P}) - f(\frac{S}{P}) - f(\frac{Fe}{P}) - f(\frac{Mn}{P}) - f(\frac{Cu}{P}) - f(\frac{Zn}{P}) + f(\frac{P}{Y})] \quad \ldots (25)$$

$$K = \frac{1}{14}[-f(\frac{pH}{K}) - f(\frac{EC}{K}) + f(\frac{K}{OC}) - f(\frac{CC}{K}) + f(\frac{K}{N}) + f(\frac{K}{P})$$
$$+ f(\frac{K}{Ca}) + f(\frac{K}{Mg}) - f(\frac{S}{K}) - f(\frac{Fe}{K}) - f(\frac{Mn}{K}) + f(\frac{K}{Cu}) - f(\frac{Zn}{K}) + f(\frac{K}{Y})] \ldots (26)$$

$$Ca = \frac{1}{14}[-f(\frac{pH}{Ca}) - f(\frac{EC}{Ca}) - f(\frac{OC}{Ca}) - f(\frac{CC}{Ca}) + f(\frac{Ca}{N}) + f(\frac{Ca}{P}) \quad \ldots (27)$$
$$- f(\frac{K}{Ca}) - f(\frac{Mg}{Ca}) - f(\frac{S}{Ca}) - f(\frac{Fe}{Ca}) - f(\frac{Mn}{Ca}) + f(\frac{Ca}{Cu}) - f(\frac{Zn}{Ca}) + f(\frac{Ca}{Y})]$$

$$Mg = \frac{1}{14}[- f(\frac{pH}{Mg}) - f(\frac{EC}{Mg}) - f(\frac{OC}{Mg}) - f(\frac{CC}{Mg}) + f(\frac{Mg}{N}) + f(\frac{Mg}{P})$$
$$- f(\frac{K}{Mg}) + f(\frac{Mg}{Ca}) - f(\frac{S}{Mg}) - f(\frac{Fe}{Mg}) - f(\frac{Mn}{Mg}) + f(\frac{Mg}{Cu}) - f(\frac{Zn}{Mg}) + f(\frac{Mg}{Y})] \quad ...(28)$$

$$S = \frac{1}{14}[- f(\frac{pH}{S}) - f(\frac{EC}{S}) - f(\frac{OC}{S}) - f(\frac{CC}{S}) + f(\frac{S}{N}) + f(\frac{S}{P})$$
$$+ f(\frac{S}{K}) + f(\frac{S}{Ca}) + f(\frac{S}{Mg}) - f(\frac{Fe}{S}) - f(\frac{Mn}{S}) + f(\frac{S}{Cu}) - f(\frac{Zn}{S}) + f(\frac{S}{Y})] \quad ...(29)$$

$$Fe = \frac{1}{14}[- f(\frac{pH}{Fe}) - f(EC \times Fe) + f(\frac{Fe}{OC}) - f(\frac{CC}{Fe}) + f(\frac{Fe}{N}) + f(\frac{Fe}{P})$$
$$+ f(\frac{Fe}{K}) + f(\frac{Fe}{Ca}) + f(\frac{Fe}{Mg}) + f(\frac{Fe}{S}) - f(\frac{Mn}{Fe}) + f(\frac{Fe}{Cu}) - f(\frac{Zn}{Fe}) + f(\frac{Fe}{Y})] \quad ...(30)$$

$$Mn = \frac{1}{14}[- f(\frac{pH}{Mn}) - f(\frac{EC}{Mn}) - f(\frac{OC}{Mn}) - f(\frac{CC}{Mn}) + f(\frac{Mn}{N}) + f(\frac{Mn}{P})$$
$$+ f(\frac{Mn}{K}) + f(\frac{Mn}{Ca}) + f(\frac{Mn}{Mg}) + f(\frac{Mn}{S}) + f(\frac{Mn}{Fe}) + f(\frac{Mn}{Cu}) - f(\frac{Zn}{Mn}) + f(\frac{Mn}{Y})] \quad ...(31)$$

$$Cu = \frac{1}{14}[- f(\frac{pH}{Cu}) - f(\frac{EC}{Cu}) - f(\frac{OC}{Cu}) - f(\frac{CC}{Cu}) + f(\frac{Cu}{N}) + f(\frac{Cu}{P})$$
$$- f(\frac{K}{Cu}) - f(\frac{Ca}{Cu}) - f(\frac{Mg}{Cu}) - f(\frac{S}{Cu}) - f(\frac{Fe}{Cu}) - f(\frac{Mn}{Cu}) - f(\frac{Zn}{Cu}) + f(\frac{Cu}{Y})] \quad ...(32)$$

$$Zn = \frac{1}{14}[f(\frac{Zn}{pH}) - f(\frac{EC}{Zn}) + f(\frac{Zn}{OC}) - f(\frac{CC}{Zn}) + f(\frac{Zn}{N})$$
$$+ f(\frac{Zn}{P}) + f(\frac{Zn}{K}) + f(\frac{Zn}{Ca}) + f(\frac{Zn}{Mg}) + f(\frac{Zn}{S}) + f(\frac{Zn}{Fe}) + f(\frac{Zn}{Mn}) + f(\frac{Zn}{Cu}) + f(\frac{Zn}{Y})] \quad ...(33)$$

$$Y = \frac{1}{14}[- f(\frac{pH}{Y}) - f(\frac{EC}{Y}) - f(\frac{OC}{Y}) - f\frac{CC}{Y} - f(\frac{N}{Y}) - f(\frac{P}{Y})$$
$$- f(\frac{K}{Y}) - f(\frac{Ca}{Y}) - f(\frac{Mg}{Y}) - f(\frac{S}{Y}) - f(\frac{Fe}{Y}) - f(\frac{Mn}{Y}) - f(\frac{Cu}{Y}) - f(\frac{Zn}{Y})] \quad ...(34)$$

C) For leaves from *ambia* flush

$$N = \frac{1}{10}[-f(\frac{P}{N}) - f(\frac{K}{N}) - f(\frac{Ca}{N}) - f(\frac{Mg}{N}) - f(\frac{S}{N}) - f(\frac{Fe}{N}) - f(\frac{Mn}{N}) - f(\frac{Cu}{N}) - f(\frac{Zn}{N}) + f(\frac{N}{Y})] \quad \ldots (35)$$

Where,

$$f(\frac{P}{N}) = [\frac{P/N}{p/n} - 1] \times \frac{1000}{CV} \quad \ldots (36)$$

when $\frac{P}{N} > \frac{p}{n}$

and

$$f(\frac{P}{N}) = [1 - \frac{p/n}{P/N}] \times \frac{1000}{CV} \quad \ldots (37)$$

when $\frac{P}{N} < \frac{p}{n}$

P/N is the actual value of ratio of P (%) and N (%) in sample under diagnosis whereas p/n is the mean value of high yielding sub-population and CV is the coefficient of variation for high yielding population. Similarly, the other indices were calculated by using the formulae given below.

$$P = \frac{1}{10}[f(\frac{P}{N}) + f(P \times K) + f(\frac{P}{Ca}) + f(P \times Mg) + f(\frac{P}{S}) + f(P \times Fe) + f(\frac{P}{Mn}) + f(\frac{P}{Cu}) + f(P \times Zn) + f(\frac{P}{Y})] \quad \ldots (38)$$

$$K = \frac{1}{10}[f(\frac{K}{N}) - f(P \times K) + f(\frac{K}{Ca}) + f(K \times Mg) + f(\frac{K}{S}) + f(K \times Fe) + f(\frac{K}{Mn}) + f(\frac{K}{Cu}) + f(K \times Zn) + f(\frac{K}{Y})] \quad \ldots (39)$$

$$Ca = \frac{1}{10}[f(\frac{Ca}{N}) - f(\frac{P}{Ca}) - f(\frac{K}{Ca}) - f(\frac{Mg}{Ca}) + f(\frac{Ca}{S}) - f(\frac{Fe}{Ca}) - f(\frac{Mn}{Ca}) - f(\frac{Cu}{Ca}) - f(\frac{Zn}{Ca}) + f(\frac{Ca}{Y})] \quad \ldots (40)$$

$$Mg = \frac{1}{10}[f(\frac{Mg}{N}) - f(P \times Mg) - f(K \times Mg) + f(\frac{Mg}{Ca}) + f(\frac{Mg}{S}) + f(Mg \times Fe) + f(\frac{Mg}{Mn}) + f(\frac{Mg}{Cu}) + f(Mg \times Zn) + f(\frac{Mg}{Y})] \quad \ldots (41)$$

$$S = \frac{1}{10}[f(\frac{S}{N}) - f(\frac{P}{S}) - f(\frac{K}{S}) - f(\frac{Ca}{S}) - f(\frac{Mg}{S}) - f(\frac{Fe}{S}) - f(\frac{Mn}{S}) - f(\frac{Cu}{S}) - f(\frac{Zn}{S}) + f(\frac{S}{Y})] \quad \ldots (42)$$

$$Fe = \frac{1}{10}[f(\frac{Fe}{N}) - f(P \times Fe) - f(K \times Fe) + f(\frac{Fe}{Ca}) - f(Mg \times Fe) + f(\frac{Fe}{S}) + f(\frac{Fe}{Mn}) + f(\frac{Fe}{Cu}) + f(Fe \times Zn) + f(\frac{Fe}{Y})] \quad \ldots (43)$$

$$Mn = \frac{1}{10}[f(\frac{Mn}{N}) - f(\frac{P}{Mn}) - f(\frac{K}{Mn}) + f(\frac{Mn}{Ca}) - f(\frac{Mg}{Mn}) + f(\frac{Mn}{S}) - f(\frac{Fe}{Mn}) + f(\frac{Mn}{Cu}) - f(\frac{Zn}{Mn}) + f(\frac{Mn}{Y})] \quad \ldots (44)$$

$$Cu = \frac{1}{10}[f(\frac{Cu}{N}) - f(\frac{P}{Cu}) - f(\frac{K}{Cu}) + f(\frac{Cu}{Ca}) - f(\frac{Mg}{Cu}) + f(\frac{Cu}{S}) - f(\frac{Fe}{Cu}) - f(\frac{Mn}{Cu}) - f(\frac{Zn}{Cu}) + f(\frac{Cu}{Y})] \quad \ldots (45)$$

$$Zn = \frac{1}{10}[f(\frac{Zn}{N}) - f(P \times Zn) - f(K \times Zn) + f(\frac{Zn}{Ca}) - f(Mg \times Zn) + f(\frac{Zn}{S}) - f(Fe \times Zn) + f(\frac{Zn}{Mn}) + f(\frac{Zn}{Cu}) + f(\frac{Zn}{Y})] \quad \ldots (46)$$

$$Y = \frac{1}{10}[-f(\frac{N}{Y}) - f(\frac{P}{Y}) - f(\frac{K}{Y}) - f(\frac{Ca}{Y}) - f(\frac{Mg}{Y}) - f(\frac{S}{Y}) - f(\frac{Fe}{Y}) - f(\frac{Mn}{Y}) - f(\frac{Cu}{Y}) - f(\frac{Zn}{Y})] \quad \ldots (47)$$

D) For leaves from *mrig* flush

Following equations also should be solved as described in equation 35 , 36 and 37 under the norms from *mrig* flush.

$$N = \frac{1}{10}[-f(\frac{P}{N}) - f(\frac{K}{N}) - f(\frac{Ca}{N}) - f(\frac{Mg}{N}) + f(\frac{N}{S}) - f(\frac{Fe}{N}) + f(\frac{N}{Mn}) + f(\frac{N}{Cu}) + f(\frac{N}{Zn}) + f(\frac{N}{Y})] \quad \ldots (48)$$

$$P = \frac{1}{10}[f(\frac{P}{N}) + f(P \times K) + f(P \times Ca) + f(P \times Mg) + f(\frac{P}{S}) + f(P \times Fe) + f(\frac{P}{Mn}) + f(\frac{P}{Cu}) + f(\frac{P}{Zn}) + f(\frac{P}{Y})] \quad \ldots (49)$$

$$K = \frac{1}{10}[f(\frac{K}{N}) - f(P \times K) + f(K \times Ca) + f(K \times Mg) + f(\frac{K}{S}) + f(K \times Fe) + f(\frac{K}{Mn}) + f(\frac{K}{Cu}) + f(\frac{K}{Zn}) + f(\frac{K}{Y})] \quad \ldots (50)$$

$$Ca = \frac{1}{10}[f(\frac{Ca}{N}) - f(P \, X \, Ca) - f(K \, X \, Ca) + f(Ca \, X \, Mg) + f(\frac{Ca}{S}) + f(Ca \, X \, Fe) + f(\frac{Ca}{Mn}) + f(\frac{Ca}{Cu}) + f(\frac{Ca}{Zn}) + f(\frac{Ca}{Y})] \quad ...(51)$$

$$Mg = \frac{1}{10}[f(\frac{Mg}{N}) - f(P \, X \, Mg) - f(K \, X \, Mg) - f(Ca \, X \, Mg) + f(\frac{Mg}{S}) + f(Mg \, X \, Fe) + f(\frac{Mg}{Mn}) + f(\frac{Mg}{Cu}) + f(\frac{Mg}{Zn}) + f(\frac{Mg}{Y})] \quad ...(52)$$

$$S = \frac{1}{10}[- f(\frac{N}{S}) - f(\frac{P}{S}) - f(\frac{K}{S}) - f(\frac{Ca}{S}) - f(\frac{Mg}{S}) - f(\frac{Fe}{S}) + f(\frac{S}{Mn}) + f(\frac{S}{Cu}) - f(\frac{Zn}{S}) + f(\frac{S}{Y})] \quad ...(53)$$

$$Fe = \frac{1}{10}[f(\frac{Fe}{N}) - f(P \, X \, Fe) - f(K \, X \, Fe) - f(Ca \, x \, Fe) - f(Mg \, X \, Fe) + f(\frac{Fe}{S}) + f(\frac{Fe}{Mn}) + f(\frac{Fe}{Cu}) + f(\frac{Fe}{Zn}) + f(\frac{Fe}{Y})] \quad ...(54)$$

$$Mn = \frac{1}{10}[- f(\frac{N}{Mn}) - f(\frac{P}{Mn}) - f(\frac{K}{Mn}) - f(\frac{Ca}{Mn}) - f(\frac{Mg}{Mn}) - f(\frac{S}{Mn}) - f(\frac{Fe}{Mn}) - f(\frac{Cu}{Mn}) - f(\frac{Zn}{Mn}) + f(\frac{Mn}{Y})] \quad ...(55)$$

$$Cu = \frac{1}{10}[- f(\frac{N}{Cu}) - f(\frac{P}{Cu}) - f(\frac{K}{Cu}) - f(\frac{Ca}{Cu}) - f(\frac{Mg}{Cu}) - f(\frac{S}{Cu}) - f(\frac{Fe}{Cu}) + f(\frac{Cu}{Mn}) - f(\frac{Zn}{Cu}) + f(\frac{Cu}{Y})] \quad ...(56)$$

$$Zn = \frac{1}{10}[- f(\frac{N}{Zn}) - f(\frac{P}{Zn}) - f(\frac{K}{Zn}) - f(\frac{Ca}{Zn}) - f(\frac{Mg}{Zn}) + f(\frac{Zn}{S}) - f(\frac{Fe}{Zn}) + f(\frac{Zn}{Mn}) + f(\frac{Zn}{Cu}) + f(\frac{Zn}{Y})] \quad ...(57)$$

$$Y = \frac{1}{10}[- f(\frac{N}{Y}) - f(\frac{P}{Y}) - f(\frac{K}{Y}) - f(\frac{Ca}{Y}) - f(\frac{Mg}{Y}) - f(\frac{S}{Y}) - f(\frac{Fe}{Y}) - f(\frac{Mn}{Y}) - f(\frac{Cu}{Y}) - f(\frac{Zn}{Y})] \quad ...(58)$$

8. DRIS Index Interpretation

After calculating DRIS indices, one should know how the interpretation be made to obtain optimum yield. Following are ways to interpret the indices.

In first case, in general the more negative is an index, the more lacking in the nutrient or parameter it represents relative to other parameter used in the diagnosis. Alternatively, a large positive index indicates that the corresponding nutrients are present in relatively excessive quantity.

However, secondly, it is important to recognize that an individual nutrient is not necessarily present in optimum concentration if its index equals zero. If, for instance, results of a diagnosis were as follows.

Parameter	A	B	C	D	E
Index	-24	0	+8	+8	+8

One could accurately say that, of all nutrients tested, A having the most negative index, was relatively least abundant, and was likely to be yield limiting. Although B index equaled zero, it was relatively less abundant than C, D or E and was the second most needed parameter in this diagnosis. The C, D and E levels were excessive relative to A and B. In this example C, D and E may have actually been more yields limiting than B, for instance. However, because parameters can in practical terms be added but not taken away, the recommendations from such diagnosis include supplementing the supply of A and to a lesser extent B, even though the B index equals zero.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

Data generated during present investigation are presented and discussed in this chapter under following heads.

4.1 Location and general information of Nagpur mandarin orchards

4.2 Soil fertility status of Nagpur mandarin orchards

4.3 Leaf nutritional status of Nagpur mandarin orchards

4.4 DRIS norms for soil fertility status

4.5 DRIS norms for leaf nutrient status and yield

4.6 Computation of DRIS indices

4.1 Location and general information of Nagpur mandarin orchards

The study area covered Akot, Murtizapur and Patur tahsils of Akola district;Achalpur, Amravati, Anjangaon Surji, Chandur (Bazar), Chandur (Rly), Dhamangaon, Morshi and Tiwasa tahsils of Amravati district; Jalgaon and Sangrampur tahsils of Buldana district; Malegaon, Mangrulpir and Washim tahsils of Washim district and Babhulgaon, Digras, Kalamb, Ner Parsopant and Pusad tahsils of Yavatmal district of Western Vidarbha where mandarin crop is grown extensively. The details of the location and general information of Nagpur mandarin orchards are presented in Appendix-I.

The data indicated that the major study area (65 %) is covered by Amravati [redacted] limitation and limited area under productive cultivation. The selected orchards were in the productive age of 10 to 13 years. It was further observed that 51 and 49 per cent mandarin orchards were distributed in low and high yielding subpopulations respectively of *ambia* flush. This proportion in case of *mrig* flush was 48 and 52 per cent respectively for low and high yielding subpopulation.

Plate 1 : Low yielding Nagpur mandarin orchard

Plate 2 : Low yielding Nagpur mandarin tree

Plate 3 : High yielding Nagpur mandarin orchard

Plate 4 : High yielding Nagpur mandarin tree

4.2 Soil fertility status of Nagpur mandarin orchards

Nagpur mandarin is an important fruit crop of Western Vidarbha region. Supply of adequate nutrients and organic matter i.e., balanced supply of nutrients and ideal soil management system is required to get higher yields of good quality fruits over the years. Deficiency of important nutrient elements is wide spread and sometimes lead to huge crop losses. Soil characteristics like pH, electrical conductivity, organic carbon, and free calcium carbonate play important role in availability of nutrients in soil. The deficiencies of nutrients are associated with poor fruit set, heavy fruit drop, poor quality of produce and make the tree vulnerable to diseases and other disorders. To understand this problem in a better way, and to develop the standard nutrient norms for important elements, particularly in case of Nagpur mandarin it is necessary to investigate the soil and leaf nutritional status of the productive orchards in Western Vidarbha region. Results in this regard are discussed under this chapter.

4.2.1 Characteristics of soil

4.2.1.1 Soil reaction

The soil pH is indicative of the degree of acidity or alkalinity in soils. Soil acidity (indicated by low pH < 6.5) is due to the leaching of exchangeable bases and concentration of H^+ ion on the exchangeable complex. Soil alkalinity is indicated by pH more than 7.5. It is due to the accumulation of exchangeable bases on the exchangeable complex and the soil becomes alkali (pH > 8.5) when sodium dominates on exchange complex.

The data (Tables 3 and 4 and Fig. 7 and 8) showed that soils are neutral to moderately alkaline in reaction with pH values ranging from 7.28 to 8.06. However it is observed that average pH values were slightly higher in low yielding subpopulation (7.54) of Nagpur mandarin soils than that of high yielding soils (7.53) under *ambia* flush (Table 3). Similar pattern of low (7.57) and high (7.53) yielding subpopulations was observed under *mrig* flush (Table 4). Chapman (1960) considers a pH range of 5.5 to 7.5 to be ideal for optimum citrus growth.

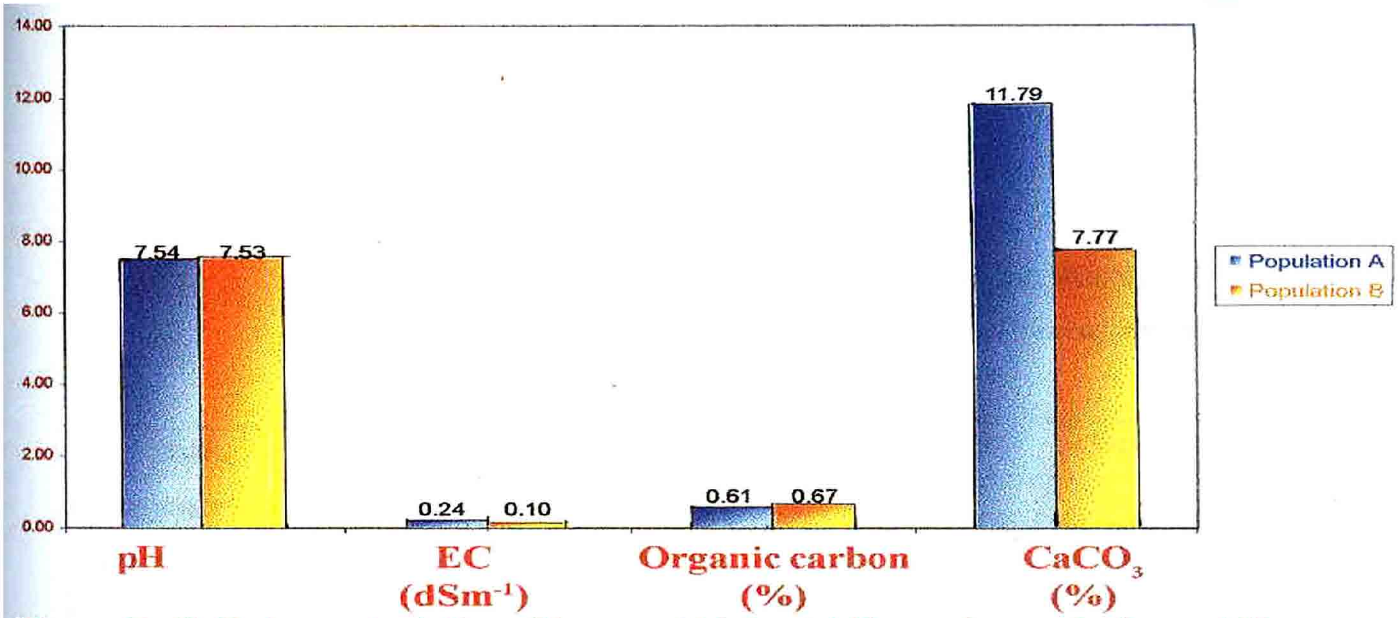


Figure 7 : Soil characteristics of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush

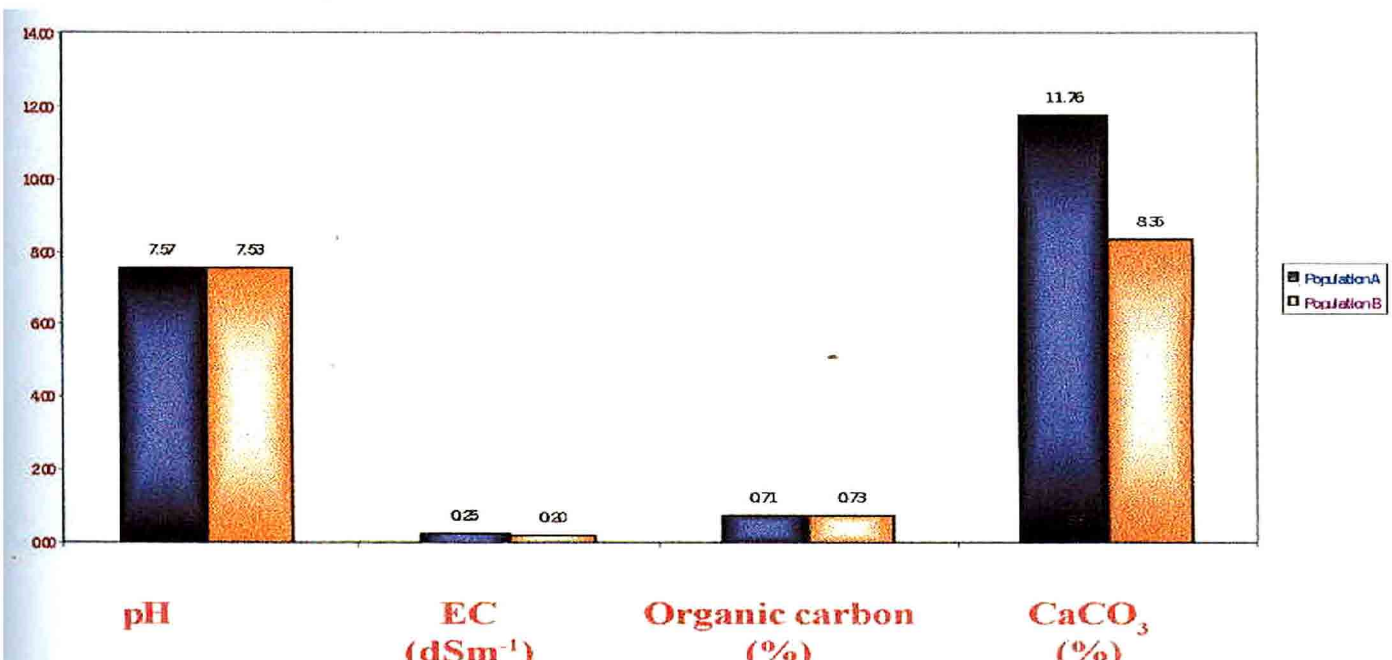


Figure 8 : Soil characteristics of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush

Table 3 : Soil characteristics and available nutrient status of low and high yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush *

Soil characteristic and nutrient	Unit	Population 'A' (Low yield)			Population 'B' (High yield)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
pH	-	7.28	8.03	7.54	7.37	8.06	7.53
EC	dSm^{-1}	0.10	0.48	0.24	0.10	0.38	0.20
Organic carbon	per cent	0.12	1.18	0.61	0.11	1.22	0.67
$CaCO_3$	per cent	4.23	23.97	11.79	4.07	14.01	7.77
N	kg ha^{-1}	73.76	291.96	207.77	219.52	577.02	391.92
P_2O_5	kg ha^{-1}	2.72	115.90	48.56	32.01	128.34	73.41
K_2O	kg ha^{-1}	89.28	840.80	436.86	300.16	882.24	588.58
Ca	c mol $(p^+)kg^{-1}$	10.05	33.15	22.28	34.10	56.10	44.24
Mg	c mol $(p^+)kg^{-1}$	1.59	16.85	8.10	6.18	29.30	14.37
S	kg ha^{-1}	2.10	60.90	15.03	11.20	28.00	19.35
Fe	ppm	1.39	10.36	6.49	5.64	9.59	7.29
Mn	ppm	8.28	29.09	13.20	9.25	23.48	13.75
Cu	ppm	1.50	6.85	3.05	1.82	10.24	5.44
Zn	ppm	0.58	0.86	0.65	0.51	0.93	0.70

* Table derived from appendix VI and VII

Table 4 : Soil characteristics and available nutrient status of low and high yielding subpopulation of Nagpur mandarin orchards of Western \ Vidarbha from *mrig* flush [*]

Soil characteristic and nutrient	Unit	Population 'A' (Low yield)			Population 'B' (High yield)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
pH	-	7.37	7.75	7.57	7.35	7.96	7.53
EC	dSm^{-1}	0.15	0.37	0.25	0.11	0.36	0.20
Organic carbon	per cent	0.26	1.26	0.71	0.36	1.05	0.73
$CaCO_3$	per cent	3.01	19.73	11.76	3.62	13.33	8.35
N	kg ha^{-1}	54.96	343.47	204.97	294.96	564.66	410.59
P_2O_5	kg ha^{-1}	3.30	125.91	54.30	35.24	86.87	57.97
K_2O	kg ha^{-1}	180.32	868.00	442.46	266.80	1001.52	547.12
Ca	c mol $(p^+)kg^{-1}$	13.80	46.25	26.51	30.25	53.35	42.87
Mg	c mol $(p^+)kg^{-1}$	2.08	15.35	8.18	4.35	13.80	9.58
S	kg ha^{-1}	5.60	35.00	17.58	9.80	31.57	18.44
Fe	ppm	5.40	8.21	6.89	5.16	10.33	7.78
Mn	ppm	8.15	21.22	10.20	7.72	21.25	11.47
Cu	ppm	0.98	4.25	2.18	2.47	8.32	4.36
Zn	ppm	0.43	0.92	0.71	0.41	0.96	0.70

[*] Table derived from appendix VIII and IX

Kanwar and Randhawa (1960), Dhingra and Kanwar (1963) and Kanwar *et al.* (1965) opined that the pH of soils should not be more than 8.5 for the successful growth of citrus. Dhawan *et al.* (1957) reported similarity in their findings that the safe limit of pH was 7.0 to 8.5 for citrus. In the present investigation, the results have conformity with the findings of Patil and Malewar (1998) who reported that the soils of Nagpur mandarin in Western Vidarbha are moderately alkaline in reaction (7.9 to 8.3).

A perusal of data presented in Appendix-VI and VII showed that the soils surveyed for *ambia* flush have highest pH value i.e. 8.03 for low yielding in site 24 and 8.06 for high yielding subpopulation in site 24 while the soils surveyed for *mrig* flush showed highest pH values of 7.75 in low yielding orchards and 7.96 in high yielding orchards in sites 13 and 15 respectively. Thus, soil pH of Nagpur mandarin orchards under study did not make any significant influence in terms of yields of mandarin since the pH range of 7.28 to 8.06 is in the safe limit as reported by Dhawan *et al.* (1957) and others.

4.2.1.2 Electrical conductivity

The electrical conductivity (EC) is a measure of soluble salt concentration in soils. Higher amounts of salts in soils (higher EC) restrict the nutrient uptake and thus affect plant growth. The EC of Nagpur mandarin orchard soils ranged from 0.10 to 0.48 dSm^{-1} (Table 3 and 4 and Fig. 7 and 8) which is within the acceptable limit ($<$ 0.5 dSm^{-1}) above which growth and production of citrus crop would be adversely affected as was suggested by Kanwar and Randhawa (1960). This range of EC values showed that all the soils were non-saline in nature. The EC of soils of low yielding orchards of *ambia* flush ranged from 0.10 to 0.48 dSm^{-1} (mean 0.24 dSm^{-1}) while for that of high yielding subpopulation, the values ranged from 0.10 to 0.38 dSm^{-1} (mean 0.20 dSm^{-1}) (Table 3 and Fig. 7). In case of soils surveyed from *mrig* flush the EC varied from 0.15 to 0.37 dSm^{-1} and 0.11 to 0.36 dSm^{-1} in low and high yielding subpopulation, respectively (Table 4 and Fig. 8). It was also observed that mean ECs of low yielding sub population were slightly higher than high yielding subpopulation

The similar trend was also observed by Nilangekar and Patil (1982) while studying the normal and chlorotic citrus soils of Marathwada region of Maharashtra.

Cooper and Peynado (1959) reported decrease in growth of young and old lime trees when treated with salts. Bhambota (1965) observed adverse effect in sweet orange when EC level was six mm hos cm^{-1}. Inhibitory effects of salts on the growth of citrus rootstocks and sweet orange have also been recorded by Joolka and Singh (1979). Patil (1979) suggested that EC should not exceed three mm hos cm^{-1} for orange fruit crop. The shoot growth, number of leaves and the leaf area of Nagpur mandarin were adversely affected as salinity levels increased in the soil (Khanna and Kumar, 1990). However, EC of mandarin orchards under study was within safe limits (< 0.5 dSm^{-1}).

4.2.1.3 Organic carbon

Soil organic matter contents is an indication of its general health. It helps in granulation of soil separates and maintain conductive acid water ratio in soil. Due to its high EC and water holding capacity, it improves soil fertility and crop productivity besides for soil microbes.

The data of Table 3 and 4 and Fig. 7 and 8 revealed that the organic carbon in low yielding subpopulation orchard soils was lower in both *ambia* and *mrig* flush (mean values 0.61 and 0.71 per cent respectively) than high yielding orchard soils of both flushes (0.67 and 0.73 per cent respectively). Organic carbon content was somewhat uniform at different locations in Nagpur mandarin growing soils of Western Vidarbha region. The organic carbon content of soils of *ambia* flush was ranging from 0.12 to 1.18 per cent under low yielding. Whereas under high yielding this range was 0.11 to 1.22 per cent (Table 3 and Fig. 7). Organic carbon was 0.26 to 1.26 per cent under low yielding and 0.36 to 1.05 per cent under high yielding of *mrig* flush soils (Table 4 and Fig. 9). It is interesting to note that although organic carbon content of most surface soils of low yielding subpopulation in both flushes was medium to high, the available nitrogen was found to be in low range. This may be due to more humified nature of organic carbon. It indicates that in these soils organic carbon content may not be considered as an index of available nitrogen. The soils of citrus growing belts of Dhaulakuan district in Himachal Pradesh, Raina (1988) observed the similar trend of organic carbon. More or less similar trend was observed in high fertility population. The organic carbon content of the soils depends upon the type, quantity and quality of organic matter and its stage of decomposition. Organic matter acts as a major parameter regulating the availability of organic forms of nitrogen, phosphorus, sulphur and trace elements in the soils (Stevenson, 1982). It also improves soil structure, infiltration rate nutrient retention and reduces soil erosion (Smith and Elliott, 1990). As such higher organic carbon content and correspondingly N content of orchards of high yielding population might have contributed to higher yields. High yielding orchards were supplemented with nutrients than low yielding orchards.

4.2.1.4 Free calcium carbonate

Calcium carbonate content (Tables 3 and 4 and Fig. 7 and 8) of low yielding subpopulation of soils surveyed during *ambia* flush is higher which varied from 4.23 to 23.97 per cent with mean value 11.79 per cent than that of high yielding subpopulation (4.07 to 14.01 per cent with mean value 7.77 per cent). This indicated that all the orchard soils were slightly calcareous to calcareous in nature excepting site number 7 and 18 in case of low yielding subpopulation, which were strongly calcareous soils.

The soils surveyed during *mrig* flush also showed slightly calcareous to calcareous nature of soils in both low yielding subpopulation of mandarin orchards containing $CaCO_3$, ranging from 3.01 to 19.73 per cent (mean 11.76 %) and 3.62 to 13.33 per cent (mean 8.35%), respectively. Similar results were obtained by Patil and Malewar (1988) while studying the mandarin soils of Amravati district of Western Vidarbha. This data further showed that the high yielding subpopulation orchard soils contain low $CaCO_3$ than that of the low yielding subpopulation.

Kanwar and Radhawa (1960) and Dhingra and Kanwar (1963) opined that a high $CaCO_3$ content in citrus soils of Punjab was an important factor towards decreased availability of iron and zinc in these soils. Harmful effects of excessive accumulation of $CaCO_3$ on citrus have been reported by Agarwala and Mohrotra

(1963), Nilangekar and Patil (1981). Kharkar *et al.* (1991) reported that free lime by adversely affecting availability of macro and micro nutrients besides its effect on soil physical condition, particularly aeration (Randhawa *et al.* 1966). Therefore in high yielding orchards $CaCO_3$ content (7.77 % and 8.35 % for *ambia* and *mrig*) may not be as adversely affecting factor as it is in low yielding orchards (11.79 and 11.76 for *ambia* and *mrig*) .

4.2.2 Primary available nutrient status

Results in respect of available primary major nutrients i.e. nitrogen, phosphorus and potassium content in different Nagpur mandarin orchards are presented in Tables 3 and 4 and Fig. 9 and 10.

4.2.2.1 Nitrogen

Nitrogen is referred as 'balance wheel' of citrus nutrition because of the fact that efficiency of other nutrients is based on it. Nitrogen requirement varies with different varieties of citrus. Higher available nitrogen status was observed in high yielding subpopulation of mandarin orchards of *ambia* flush, ranging from 219.52 to 577.02 kg ha^{-1} with mean value 391.91 kg ha^{-1} than the low yielding subpopulation in which it was ranged from 73.76 to 219.96 kg ha^{-1} with mean value 207.77 kg ha^{-1}. (Table 3 and Fig. 7). Soil surveyed during *mrig* flush showed the similar trend of available nitrogen in low and high yielding subpopulation orchards which is ranging from 54.96 to 343.47 kg ha^{-1} with mean 204.96 kg ha^{-1} and 294.96 to 564.66 kg ha^{-1} with mean 410.59 kg ha^{-1} respectively (Table 4 and Fig. 8). These results are in conformity with the research findings of Awasthi *et al.* (1984) who studied mineral nutrient status of mandarin orchards in Nurpur area of Himachal Pradesh. The present data similarly indicated that the low yielding orchards in both the flushes, the soils are rated as low in available N on the basis of mean values which can be attributed to low fertility status of soil.

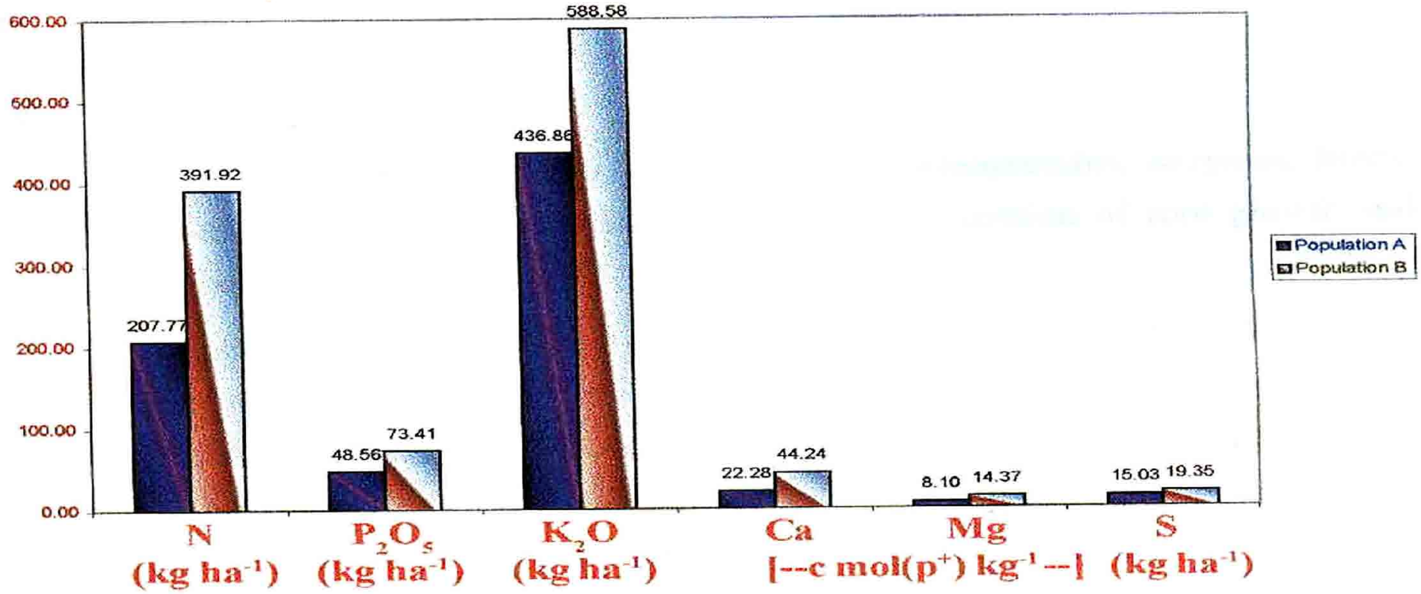


Figure 9 : Major nutrient status of soils from low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush

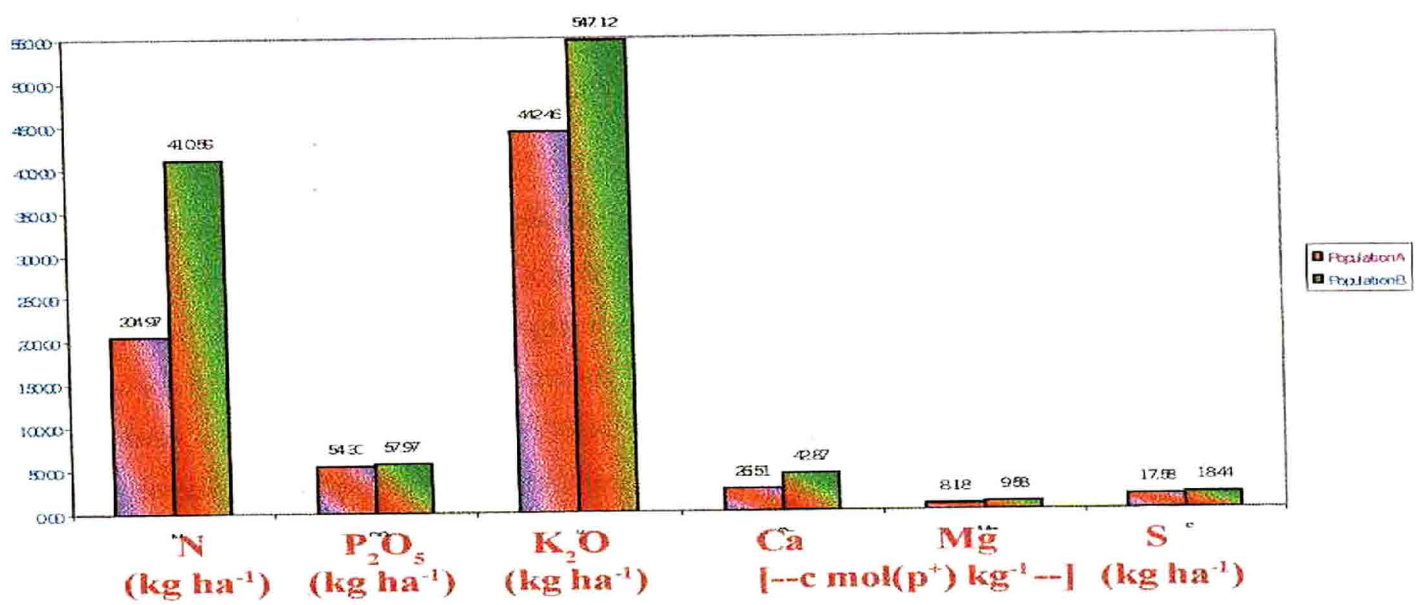


Figure 10

Major nutrient status of soils from low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush

4.2.2.2 Phosphorus

Phosphorus, being a constituent of various nucleoproteins, enzymes, lipids, plays important role in the formation of new cells, promotion of root growth and promotes maturity of plants.

Available phosphorus (P_2O_5) content of the soil ranged from 2.72 to 115.90 kg ha^{-1} (mean 48.56 kg ha^{-1}) under the low yielding subpopulation orchards and from 32.01 to 128.34 kg ha^{-1} (mean 73.41 kg ha^{-1}) under high yielding subpopulation of *ambia* flush (Table 3 and Fig 7). Soils collected from *mrig* flush showed that low yielding subpopulation orchards contained 3.30 to 125.91 kg P_2O_5 ha^{-1} (mean 54.30 kg ha^{-1}) which was lower than the range of 35.24 to 86.47 kg ha^{-1} (mean 57.97 kg ha^{-1}) in case of high yielding subpopulation orchard soils (Table 4 and Fig. 8).

Relatively high content of available phosphorus in high yielding subpopulation of mandarin orchards of this region may be attributed to the intermittent application organic manure with applied dose of phosphorus which helps in build up of high level of phosphorus (Malewar *et al.* 1978-a). Lower available phosphorus in low yielding subpopulation of mandarin orchards seems to be due to the fact that farmers might be applying less quantity of phosphorus and organic manure. Organic manure due to organic acids produced in decomposition makes native phosphorus available and keeps it in available form by reducing its fixation.

4.2.2.3 Potassium

Potassium serves metabolic functions in the growth and cell division of young tissues. It is necessary for carbohydrate, protein and oil synthesis in plants. It improves fruit quality. It regulates water economy of trees and greatly increases citrus yields not in term of number but in fruit size (Rajput and Sri Haribabu, 1995). The data of Table 3 indicated that the available soil potassium status was higher in high yielding subpopulation (mean 588.58 kg ha^{-1}) than the low yielding mandarin orchards (mean 436.86 kg ha^{-1}) under the soils surveyed from *ambia* flush. It would also be seen from the data in Table 4 that available potassium content of mandarin orchard soils surveyed from *mrig* flush was higher in high yielding (mean 547.12 kg ha^{-1}) the low yielding (mean 442.46 kg ha^{-1}). Awasthi *et al.* (1984) observed the similar results while studying the healthy and declined mandarin orchards in Himachal Pradesh. Potassium ranged between 300.16 to 882.24 kg ha^{-1} in soils supporting higher yield of *ambia* flush whereas in case of *mrig* flush the range of high yielding orchards was 266.80 to 1001.52 kg ha^{-1}. The soils bearing low yielding subpopulation of *ambia* and *mrig* flush were in range of 89.28 to 840.80 kg ha^{-1} and 180.32 to 868.00 kg ha^{-1}, respectively of available potassium. Potassium is rather a regulatory nutrient maintaining nutrient balance in plants .

4.2.3 Secondary available nutrient status

4.2.3.1 Calcium

Calcium has two fold importance as far as citrus is concerned *viz.* as a nutrient and as a soil improving agent. In many citrus growing regions of the world, calcareous soils are extensively used for citrus cultivation. Inspite of the beneficial role of calcium its high content in soils are posing a threat to citrus industry in India by way of inducing chlorosis. It occurs in soils as complex salts and as an exchangeable cation in vast majority of approximately neutral or slightly saline soil. Data regarding the exchangeable calcium content in the study area from different sites are presented in Tables 3 and 4.

The mean available (exchangeable) calcium content of soils of high yielding group in both flushes i.e. *ambia* and *mrig* are 44.24 and 42.87 cmol (p^+) kg $^{-1}$ which were much higher compared to that of low yielding orchard soils (mean values 22.28 and 26.51 cmol (p^+) kg^{-1} respectively) (Fig. 9 and 10). These results are in conformity with the findings of Nilangekar and Patil (1981 and 1982), Kalbande *et al.* (1983) and Awasthi *et al.* (1984).

The minimum and maximum values for exchangeable available calcium showed large variation. It varied from 10.05 to 33.15 cmol (p^+) kg $^{-1}$ and 34.10 to 56.10 cmol (p^+) kg $^{-1}$ in low and high yielding sub population respectively in soils of *ambia* flush while in case of *mrig* flush it was ranging from 13.80 to 46.25 cmol (p^+) kg $^{-1}$ and 30.25 to 53.35 cmol (p^+) kg $^{-1}$ in low and high yielding orchards, respectively. This large variation might have been due to the presence of free calcium carbonate in soils (Bhargava and Raghupathi, 1996).

4.2.3.2 Magnesium

Magnesium is a constituent of chlorophyll and also an enzyme activator. It helps in synthesis of organic acids e.g. citric and malic acid. This essential plant nutrient has not been observed to be deficient on a wide scale in any part of India. Analytical results as regards exchangeable (available) magnesium content in Nagpur mandarin growing soils of Western Vidarbha are presented in Tables 3 and 4.

The observations revealed that the exchangeable (available) magnesium was found to be higher in high yielding than the low yielding mandarin soils of both flushes. The results further showed that the exchangeable magnesium status in low yielding subpopulation soils varied from 1.59 to 16.85 cmol (p^+) kg $^{-1}$(mean 8.10 cmol (p^+) kg $^{-1}$) whereas it was from 6.18 to 29.30 cmol (p^+) kg $^{-1}$ (mean 14.37 cmol (p^+) kg $^{-1}$) in high yielding subpopulation soils of *ambia* flush (Table 3 and Fig. 9).

The identical results as regards to exchangeable magnesium were recorded in high yielding subpopulation having the range from 4.35 to 13.80 cmol (p^+) kg^{-1} with mean 9.58 cmol (p^+) kg $^{-1}$ which is slightly higher than low yielding subpopulation having the range of 2.08 to 15.35 cmol (p^+) kg $^{-1}$ with mean 8.18 cmol (p^+) kg^{-1} of *mrig* flush (Table 4 and Fig. 10).

Milad *et al.* (1975) observed that the growth of orange orchard was affected due to lower per centage of soluble magnesium. Nilangekar and Patil (1981 and 1982) also observed that exchangeable magnesium were some what low in chlorotic than that of in the profile of normal citrus garden. The magnesium indicated the similar trend as that of Ca in respect of high yielding and low yielding population.

4.2.3.3 Sulphur

Sulphur being the constitutent of proteins, it plays an important role in chlorophyll synthesis. Sulphur deficiency resemble somewhat N deficiency, but new growth is much yellower than old leaves (Rajput and Sri Haribabu, 1995). It is generally applied as sulphate through ammonium sulphate, super phosphate and potassium sulphate. Application of copper sulphate through Baurdex mixture is also a common practice followed in Vidarbha in Nagpur mandarin orchards.

Studies on the available sulphur status of selected Nagpur mandarin orchards of Western Vidarbha region indicated higher concentration in high yielding orchards than the low yielding orchards in *ambia* (Table 3 and Fig. 9) as well as *mrig* flush (Table 4 and Fig. 10). It was further observed that available sulphur ranged between 11.20 to 28.00 kg ha^{-1} (mean 19.35 kg ha^{-1}) in soils supporting higher yield of *ambia* flush. In case of *mrig* flush the range for high yielding orchards was 9.80 to 31.57 kg ha^{-1} available sulphur (mean 18.44 kg ha^{-1}).

The soils bearing low yielding subpopulation of *ambia* flush and *mrig* flush contain average 15.03 (range 2.10 to 60.90 kg ha^{-1}) and 17.58 (range 5.60 to 35.00 kg ha^{-1}) available sulphur respectively.

The trend of sulphur content in high yielding and low yielding orchards in both the flushes fall in the line of other nutrients and was also observed by Deshmukh (2000). High yielding orchards are probably well cared and manured by the farmers. Sulphur is also supplemented through superphosphate and micronutrient preparations containing sulphur (sulphates). Thus properly fertilized/manured orchards are well supplied with available sulphur to sustain high yields.

4.2.4 Available micronutrient status

Micronutrients play important physiological role in plant growth development; a common one is participation in enzyme systems. Zinc plays a role in protein synthesis formation of some growth hormones like auxins and in the reproductive process of certain plants. Copper is involved in both photosynthesis and respiration and in the use of iron. Copper and iron are capable of acting as "electron carriers" in enzyme systems that bring about oxidation-reduction reactions in plants. Manganese seems to be essential for photosynthesis, respiration, and nitrogen metabolism.

Data regarding the soil available iron, manganese, copper and zinc status of low and high yielding subpopulations of Nagpur mandarin orchards from *ambia* and *mrig* flush are presented in Tables 3 and 4,respectively.

4.2.4.1 Iron

Every micronutrient has its own specific importance in anabolism and catabolism of plant system. Iron defninciency cause interveinal yellow and ivory colour in citrus (Leonard and Stewart, 1952). Deficiency of iron is most common in calcareous soils where availability of iron is reduced by calcium carbonate. The resulting chlorosis is called "lime induced chlorosis".

It is evident from the data presented in Tables 3 and 4 that the available iron content of soils bearing high yielding subpopulation was higher than that of soils bearing low yielding subpopulation in *ambia* and *mrig* flushes. With regards to *ambia* flush in low yielding subpopulation available iron was observed between 1.39 to 10.36 ppm (mean 6.49 ppm) whereas in high yielding subpopulation it was ranged between 5.64 to 9.59 ppm (mean 7.29 ppm) (Fig. 11 and 12).

The Nagpur mandarin orchard soils from *mrig* flush showed the distribution of available Fe as 5.40 to 8.21 ppm (mean 6.89 ppm) in low yielding and 5.16 to 10.33 ppm (mean 7.78 ppm) in high yielding subpopulation. Such a trend similar to other nutrients is indicative of the fact that high yielding orchards are supplemented with nutrients well managed with improved soil physical conditions. The data further indicated that available Fe was distributed irregularly in all soils. Similar pattern of Fe distribution was observed by Malewar (1977), Chauhan *et al.* (1984) and Sharma and Mahajan (1990). Irregular distribution of iron may be because of impeded drainge conditions and differences in the degree of weathering (Nair and Cottenie, 1971).

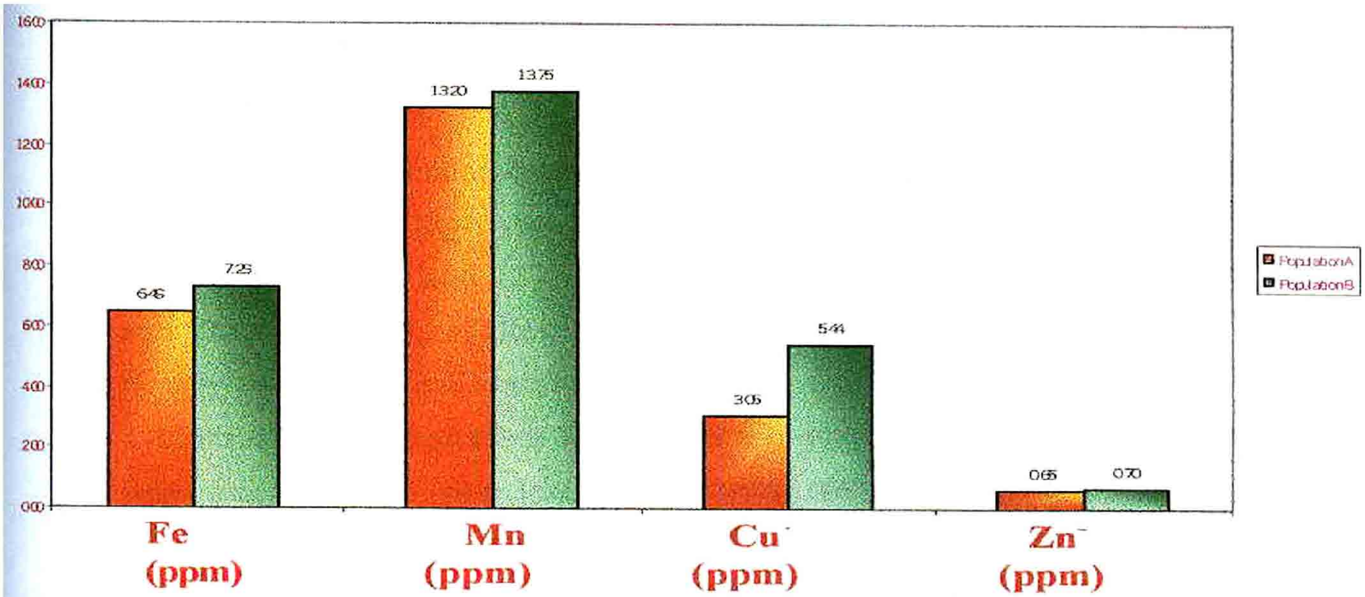


Figure 11: Soil micronutrient status of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush

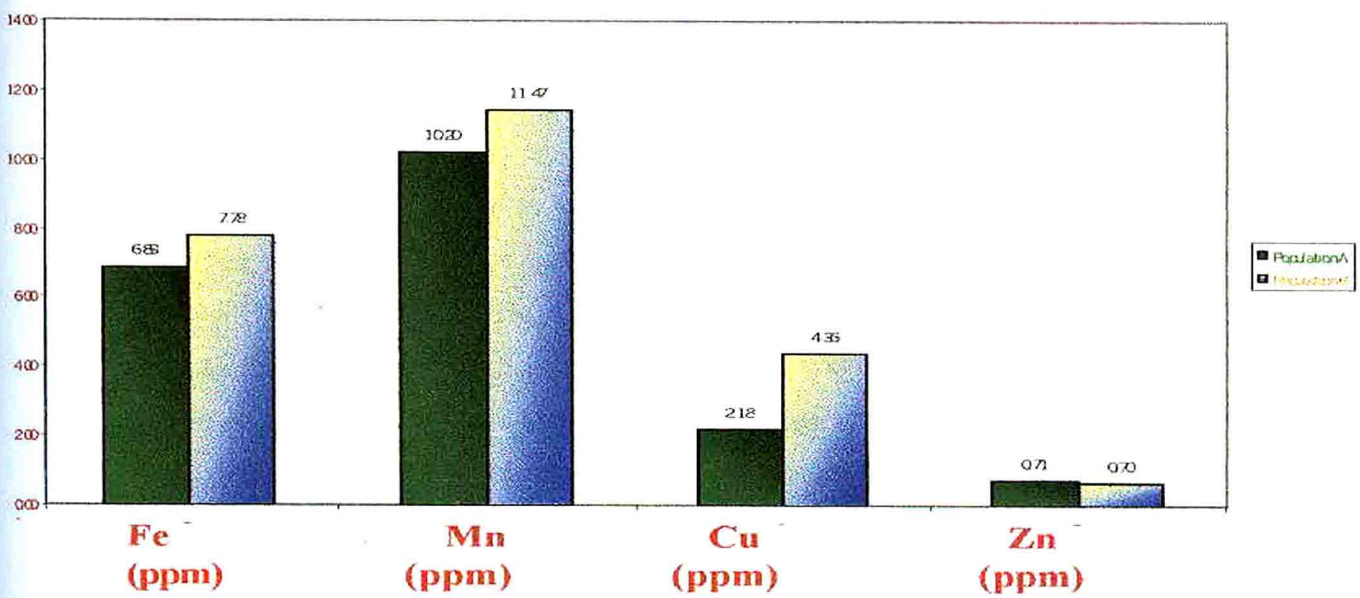


Figure 12: Soil micronutrient status of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush

4.2.4.2 Manganese

The data revealed that the available manganese content was invariably higher in the soils under high yielding than that of low yielding subpopulation soils(Table 3 and 4 and Fig. 11 and 12). These results are in agreement with the findings of Nijjar and Singh (1977), Malewar *et al.* (1978-a) and Awasthi *et al.* (1984) in case of healthy and declined conditions of citrus orchards. The data further showed that the available Mn ranged from 8.28 to 29.09 ppm (mean 13.20 ppm) and 8.15 to 21.22 ppm (mean 10.20 ppm) in low yielding subpopulation soils under *ambia* and *mrig* flush, respectively, whereas it was ranging from 9.25 to 23.48 ppm (mean 13.75 ppm) and 7.72 to 21.25 ppm (mean 11.47 ppm) in high yielding subpopulation sites.

4.2.4.3 Copper

In both flushes the available copper was found to be higher in high yielding than the low yielding orchard soils (Fig. 11 and 12). Under *ambia* flush, soils contained 1.50 to 6.85 ppm Cu (mean 3.05 ppm) and 1.82 to 10.24 ppm Cu (mean 5.44 ppm) in low and high yielding subpopulation respectively (Table 3), whereas the available copper status during *mrig* flush, was 0.98 to 4.25 ppm (mean 2.18 ppm) and 2.47 to 8.32 ppm (mean 4.36 ppm) (Table 4) in low and high yielding subpopulation, respectively. These observed values are in accordance with Malewar *et al.* (1978 –a and b), Singh and Tripathi (1983) and Patil and Malewar (1998).

4.2.4.4 Zinc

Zinc deficiency is next to nitrogen deficiency in citrus, which is widespread all over the world. The results indicate that the available zinc content was higher in the soil of high yielding sites as compared to that of low yielding sites in case of *ambia* flush (Fig. 11). Such observations were also reported by Malewar *et al.* (1978-a) and Awasthi *et al.* (1984). The reverse trend was observed in case of *mrig* flush. This low availability of available Zn may partly attributed to low organic carbon and partly attributed to high P build up (Malewar *et al.*, 1978-a)

The perusal of the data (Table 3 and 4) further indicated that the available Zn contents of low yielding subpopulation orchard soil was varied from 0.58 to 0.86

ppm (mean 0.65 ppm) and 0.43 to 0.92 ppm (mean 0.71 ppm) of *ambia* and *mrig* flush, respectively. It was ranged from 0.51 to 0.93 ppm (mean 0.70 ppm) and 0.41 to 0.96 ppm (mean 0.70 ppm) in the soils supporting high yielding subpopulation of *ambia* and *mrig* flush, respectively. The supporting results were also recorded by Nijjar and Singh (1971) and Chauhan *et al.* (1984) while studying the citrus growing soil of Punjab and Haryana,respectively.

From the results on micronutrients, it is concluded that high yielding population is well supported by higher status of available micronutrients in soils. Secondly requirement of *ambia* orchards was comparatively more than *mrig* orchards.

In general higher fertility status of macro and micro nutrients,higher organic matter content and low calcium carbonates in soils were favourable conditions for higher yields. In high yielding subpopulation particularly, the yields of *ambia* was comparatively more than *mrig* and so was the trend of available nutrients in soils. Soils with higher available nutrient status supported higher yields.

4.3 Leaf nutritional status of Nagpur mandarin orchards

Today the plant analysis technique is being applied to a variety of crops and plants. Much of the current interest in the plant analysis technique probably stems from the significant development in the methods of analysis. Atomic absorption and direct reading emission spectroscopy have greatly simplified analytical procedures, particularly for the micronutrients. The nutrient element content of the plant is a reflection of the soil's available nutrient status. The plants ability to absorb a nutrient in the established environment is reflected by the plant nutrient concentration at any time.

Leaf analysis as a guide to fertilization of fruit crop is based on the premise that "crop performance is related to concentration of essenti al minerals in this index tissues". Leaves are found best index tissue to indicate nutritional status of fruit tree.

The analytical data regarding nutritional status of low and high yielding subpopulation trees of Nagpur mandarin based on leaf analysis is discussed herewith.

4.3.1 Primary leaf nutrients status

Results on primary leaf nutrient status are presented in Tables 5 and 6.

4.3.1.1 Leaf nitrogen

The results indicated that in general, leaf nitrogen content of the low yielding sub-population of both flushes was lower than that of high yielding trees. This is in confirmily with findings of Smith *et al.* (1953), Ahlawat *et al.* (1982), Awasthi *et al.* (1984), Dhillon and Dhatt (1988), Mitra *et al.* (1988), Sharma and Mahajan (1990) and Kharkar *et al.* (1991) in different parts of India in case of healthy and declined condition of orchards.

The data further showed that leaves contained 1.55 to 2.65 per cent (mean 2.21 %) and 1.62 to 2.58 per cent (mean 2.29 %) nitrogen in *ambia* and *mrig* flush, respectively of low yielding subpopulation. However the difference was marginal. Soils under low yielding population were similarly lower in available N. Leaf N was 1.67 to 3.08 per cent (mean 2.54 %) and 1.82 to 2.67 per cent (mean 2.39 %) in *ambia* and *mrig* flush, respectively of high yielding sub-population trees (Fig. 13 and 14). Lower N content under low yielding population can be attributed to low fertility status of soil. Added fertilizers may not be adequate to meet the demand of plant (Sharma and Mahajan, 1990). On the contrary high yielding orchards might be well supplemented with nutrients through fertilizers besides higher native status. Irrespective of yield, so far high yielding subpopulation is concerned, more critical examination of the data indicated that nitrogen was found to be lower (mean 2.39 %) in the leaves of *mrig* flush (summer flush) when compared to the *ambia* flush (spring flush) (mean 2.54 %). Similar trend as regards to flush was earlier reported by Gururani and Singh (1983). It is known that more than any other element, N is spent by trees in leaf, flower and fruit production (Wallace *et al.*, 1951).

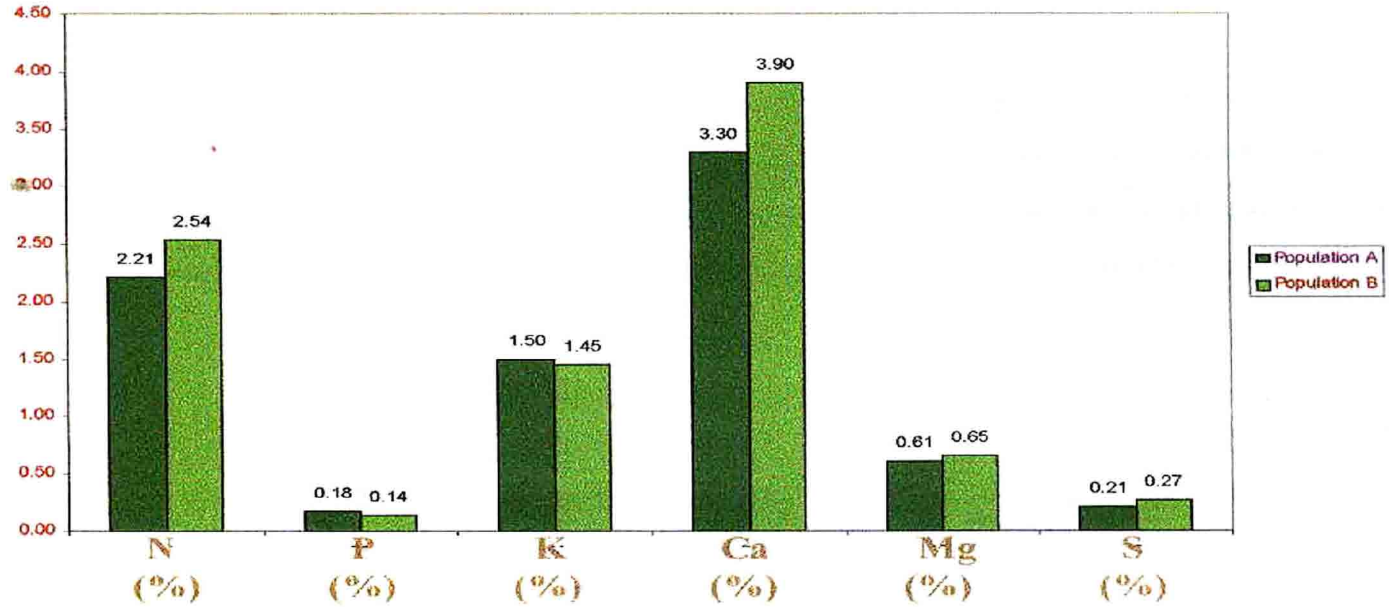


Figure 13: Major leaf nutrient status of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush

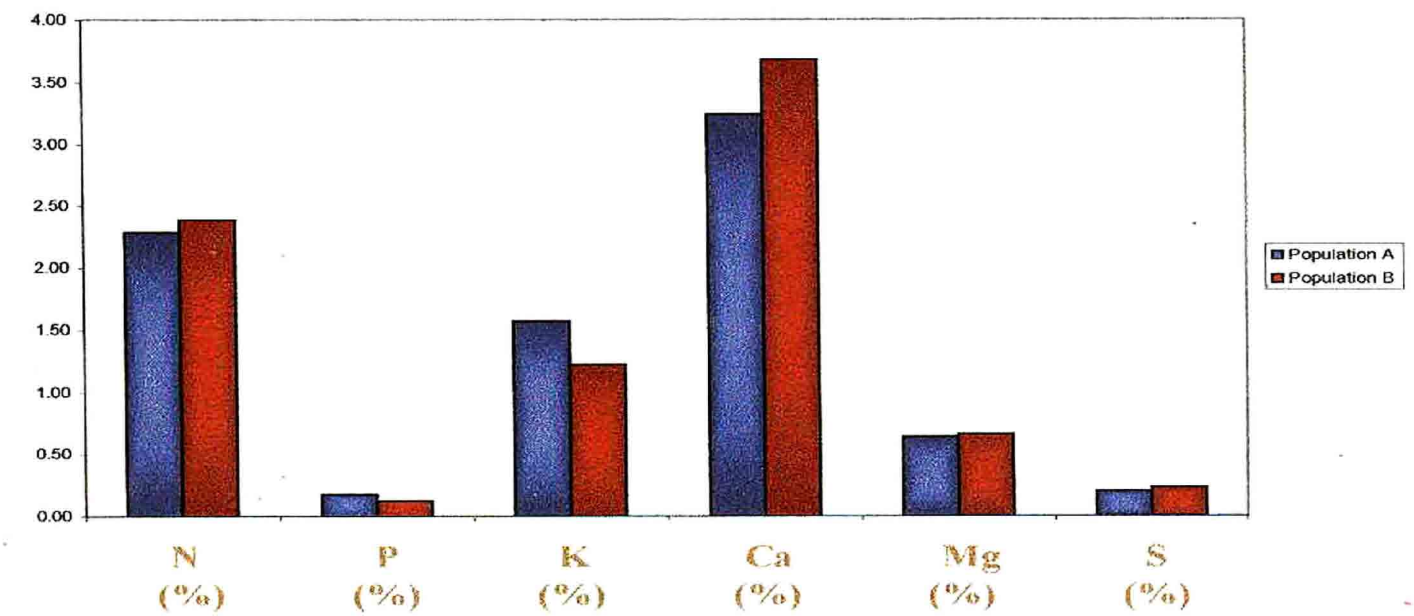


Figure 14: Major leaf nutrient status of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush

Table 5 : Leaf nutrient status of low and high yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush *

Leaf nutrients (oven dry basis)	Unit	Population 'A' (Low yield)			Population 'B' (High yield)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
N	per cent	1.55	2.65	2.21	1.67	3.08	2.54
P	per cent	0.08	0.38	0.18	0.03	0.27	0.14
K	per cent	0.52	3.33	1.50	0.96	1.86	1.45
Ca	per cent	2.61	4.10	3.30	2.50	5.20	3.90
Mg	per cent	0.37	0.88	0.61	0.49	0.78	0.65
S	per cent	0.14	0.32	0.21	0.19	0.43	0.27
Fe	ppm	50.00	199.60	102.90	71.32	190.73	121.50
Mn	ppm	18.45	63.15	30.67	26.62	70.95	39.82
Cu	ppm	8.44	34.85	15.41	11.35	41.40	24.74
Zn	ppm	10.97	49.28	27.94	16.51	47.66	30.91

* Table derived from appendix X and XI

Table 6 : Leaf nutrient status of low and high yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush **

Leaf nutrients (oven dry basis)	Unit	Population 'A' (Low yield)			Population 'B' (High yield)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
N	per cent	1.62	2.58	2.29	1.82	2.67	2.39
P	per cent	0.05	0.45	0.18	0.07	0.26	0.13
K	per cent	0.77	2.86	1.57	0.61	2.67	1.22
Ca	per cent	2.26	5.07	3.24	2.68	4.78	3.68
Mg	per cent	0.17	1.22	0.64	0.39	1.00	0.66
S	per cent	0.14	0.27	0.20	0.18	0.37	0.23
Fe	ppm	41.16	138.55	88.52	78.76	174.70	124.69
Mn	ppm	15.69	58.28	26.97	20.50	70.57	35.80
Cu	ppm	12.40	34.40	18.96	13.20	45.24	25.25
Zn	ppm	20.82	36.31	28.19	17.61	48.08	30.54

** Table derived from appendix XII and XIII

4.3.1.2 Phosphorus

Comparing the mean values in *ambia* and *mrig* flush P content was higher in low yielding trees (0.18% each) as compared to high yielding subpopulation (0.14 and 0.13%, respectively) (Fig. 13 and 14). It was ranged from 0.08 to 0.38 per cent and 0.03 to 0.27 per cent in leaves of low and high yielding orchards respectively, of *ambia* flush (Table 5). In case of *mrig* flush the range was 0.05 to 0.45 per cent and 0.07 to 0.26 per cent in low and high yielding orchards, respectively. Similar results were reported earlier by other workers (Nijjar and Singh 1971; Yamdagni *et al.,* 1983 and Dhillon and Dhatt,1988). Phosphorus content in leaves was comparatively higher in low yielding subpopulation in both the flushes. This might be due to the tendency of crop tree to accumulate the essential nutrients whenever there is apparent or latent deficiency as justified by Yamdagni *et al.* (1983) for P and K. This is further indicative of less utilization of P for fruiting in low yielding population. It was further observed that leaf P was not related to soil P which showed reverse trend with each other. Awasthi et al. (1984) who studied leaf and soil nutrients status of mandarin orchards in Punjab reported similar findings. Leaf P in *ambia* and *mrig* flush showed no much variation. While studying sweet orange of UP, Singh and Kunwar (1982) also reported similar relationship between spring(*ambia*)and summer (*mrig*) flush phosphorus.

4.3.1.3 Potassium

It is seen from the data that the potassium concentration in leaves of Nagpur mandarin of low yielding subpopulation varied from 0.52 to 3.33 per cent (mean 1.50 %) and 0.77 to 2.86 per cent (mean 1.57 %) in *ambia* and *mrig* flush respectively. In high yielding subpopulation the K concentration was observed between the range of 0.96 to 1.86 per cent (mean 1.45 %) in *ambia* flush (Table 5) and 0.61 to 2.67 per cent (mean 1.22 %) in *mrig* flush (Table 6). The mean values indicating the more accumulation of K in low yielding than high yielding trees (Fig. 13 and 14) in accordance with the findings of Sivaraman Nair *et al.* (1968), Nauriyal *et al.* (1970), Yamdagni *et al.* (1983), Awasthi *et al.* (1984), and Rana *et al.* (1984) for healthy and declining trees of citrus. Similar to P, K starts accumulating in the leaves under low yields probably when some growth factors or any nutrient becomes more limiting than K. The another probable reason for lesser amount of K in leaf from high yielder trees might be the fact that these trees were bearing fruit at the time of leaf sampling and comparatively higher amounts of this nutrient was utilized in fruit development process. On the contrary, low yielding trees carried poor load of crops.

As regards to flush differences taking high yielding subpopulation into consideration, the data revealed that the K concentration was found to be lower in the leaves of *mrig* flush when compared to the *ambia* flush. For low yielding orchards K in leaves, there was no much variation in *mrig* and *ambia* flush.

4.3.2 Secondary leaf nutrients status

Secondary major nutrients were analysed from the leaves of high and low yielding subpopulation of Nagpur mandarin orchards. The results are presented in Tables 5 and 6.

4.3.2.1 Calcium

Citrus plants contain more calcium than any other mineral plant nutrient. The sampling of leaves at *ambia* flush indicated a higher Ca concentration (mean 3.90 %) ranging from 2.50 to 5.20 per cent in high yielding subpopulation than low yielding (3.30 %) which ranged from 2.61 to 4.10 per cent (Table 5 and Fig. 13). The mean Ca concentration in leaves sampled at *mrig* flush low yielding subpopualtion was 3.24 per cent (ranging from 2.26 to 5.07 %). This was lower compared to the Ca status in leaves of high yielding subpopulation of the same flush where the mean Ca concentration was 3.68 per cent (range 2.68 to 4.78 %) (Table 6 and Fig. 14). This is probably due to higher available Ca in soils of corresponding areas. This supports the earlier observations by Kanwar *et al.* (1963), Mann *et al.* (1978 and 1979) and Awasthi *et al.* (1984) who reported lower Ca content in leaves of declining gardens than healthly. If looked into K content it was higher in low yielding population than high yielding population. Mann *et al.* (1978 and 1979) attributed such a lower Ca content in declining gardens is the antagonistic relationship of K and Ca.

The data also indicated that in both low and high yielding subpopulation, the Ca concentration was found to be higher in *ambia* flush leaves than the *mrig* flush. Gururani and Singh (1983) observed similar results for spring (*ambia*) and summer (*mrig*) flushes in Kinnow mandarin. Ca being less mobile in plant and due to its role in the formation of calcium pectate, its withdrawal from the leaves is restricted and thus it increases in the leaves as the season advances. (Gururani and Singh, 1983). Gonzalez-Sicilia and Koen Mosse (1963) also observed that Ca concentration gradually increased in mandarin Randhwa and Kar (1967) observed that Ca was the highest in the March (*ambia*) flush.

4.3.2.2 Magnesium

Magnesium is not only a constituent of chlorophyll, but also an enzyme activator. Magnesium deficiency is commonly characterized by bronzing. The need of citrus for magnesium is fairly small until the trees bear an appreciable crop load.

The mean magnesium concentration in leaf of Nagpur mandarin of low yielding subpopulation is slightly lower (0.61 %) compared to that from high yielding subpopulation (0.65 %) when sampled at *ambia* flush time (Table 5 and Fig. 13). It ranged from 0.37 to 0.88 per cent and 0.49 to 0.78 per cent in low and high yielding subpopulations, respectively. For *mrig* sampling it was observed that Mg content of low and high yielding subpopulation ranged from 0.17 to 1.22 per cent (mean 0.4%) and 0.39 to 1.00 per cent (mean 0.66%) respectively (Table 6 and Fig. 14).

The lower concentration of Mg in low yielding population could similarly (like Ca) be attributed to the antagonistic effects of K present in higher amount in low yielding population. Smith (1966) considered Mg to be a weak competitor against K. These results are in argument with the results reported by Mann *et al.* (1979). Considering the variation in nutrient content of leaves of different flushes, it was observed that the mean values showed no much differences between *mrig* (summer) and *ambia* (spring) flush. It agrees with the findings of Pennisi and Scuderi (1959), and Nadir (1967).

4.3.2.3 Sulphur

It plays an important role in chlorophyll synthesis. The sulphur content in leaves samples of *ambia* flush collected from low yielding trees ranged from 0.14 to 0.33 per cent (mean 0.21 %) whereas that of high yielding trees the range was 0.19 to 0.43 per cent (mean 0.27 %) (Table 5). A perusal of data further showed that the sulphur content in the leaves of *mrig* flush of low and high yielding trees ranged from 0.14 to 0.27 per cent (mean 0.20 %) and 0.18 to 0.37 per cent (mean 0.23 %), respectively (Table 6). The results indicate that high yielding subpopulation in general had higher values of S concentration in both flushes, as compared to leaves low yielding subpopulation (Fig. 13 and 14).

The increasing trend in sulphur content from high yielding mandarin leaves is in harmony with the results obtained by Saini *et al.* (1999), who showed that sulphur content in Kinnow mandarin leaves was higher in healthy trees than the declined one.

With respect to the flushes, sulphur was in higher quantity in *ambia* (spring) flush when compared with *mrig* (summer) flush. This may be due to the fact that during winter months, when the plant enjoyed the long rest period, there was an accumulation of sulphur in leaves and when *ambia* (spring) season advanced it was partly reduced to nourish the fruits of spring flush (Gururani and Singh, 1983). Similar trend, was also observed by Harding *et al.* (1962).

4.3.3 Micronutrient status in leaf

Minimum, maximum and average contents of micronutrients in the leaves of Nagpur mandarin plant are presented in Tables 5 and 6.

4.3.3.1 Iron

The content of iron in leaves of low yielding subpopulation from *ambia* and *mrig* flush ranged from 50.00 to 199.60 ppm (mean 102.90 ppm) and 41.16 to 138.55 ppm (mean 88.52 ppm) respectively. The mean leaf Fe concentration in high yielding Nagpur mandarin trees was 121.50 ppm (range from 71.32 to 190.73) and 124.69 ppm (range from 78.76 to 174.70 ppm) in *ambia* and *mrig* flush samples respectively.

A study of the data showed that leaf Fe content was higher in high yielding Nagpur mandarin trees as compared with the low yielding ones (Fig. 15 and 16). Similar results were reported by Nijjar and Singh (1977) and the values are in confirmation with the findings of Patil and Malewar (1998) for mandarin grown in Amravati District.

The data of low yielding subpopulatioon reagarding leaf Fe content indicated that iron was higher in leaves of *ambia* flush than *mrig* flush. Fe being less mobile is generally not removed from old leaves and thus an increasing trend was observed in spring (*ambia*) flush, (Wallihan *et al.*, 1974). The similar trend was also observed by Gururani and Singh(1983).

4.3.3.2 Manganese

Manganese deficiency is found in almost all citrus growing areas of India, which causes chlorosis of the new growth. It is evident from the data that the high yielding plants had more manganese in leaves compared to low yielding subpopulation. The range in low yielding subpopulation was 18.45 to 63.15 ppm (mean 30.67 ppm) in *ambia* flush (Table 5) and 15.69 to 58.28 ppm (mean 26.97 ppm) in *mrig* flush(Table 6) whereas it ranged from 26.62 to 70.95 ppm (mean 39.82 ppm) in *ambia* and 20.50 to 70.57 ppm (mean 35.80 ppm)) in *mrig* flush of in high yielding subpopulation. Malewar *et al.* (1978- a) recorded significantly higher leaf Mn in healthy than declined citrus trees.

It was further observed that leaves from *ambia* flush showed higher leaf Mn content compared to leaves of *mrig* flush. This may be due to accumulation of this nutrient in leaves during warmer months when the absorption is more (Roy and Gardens, 1946).

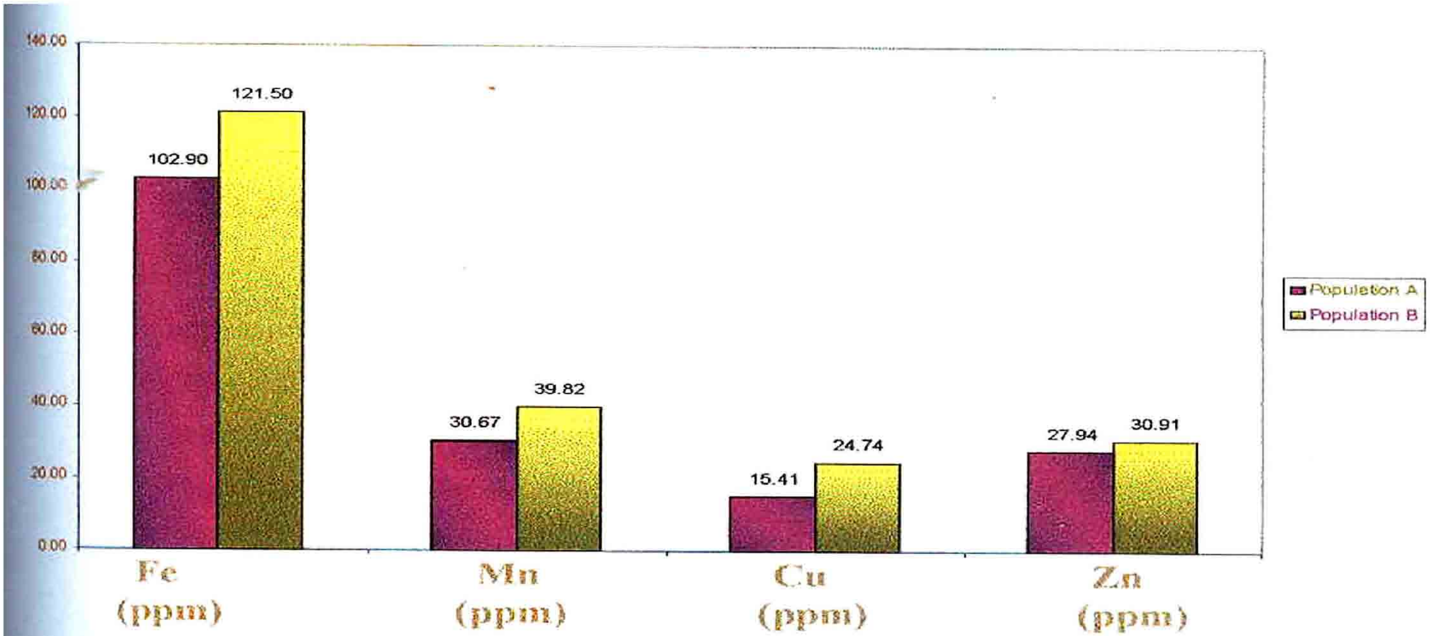


Figure 15 : Leaf micro-nutrient status of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush

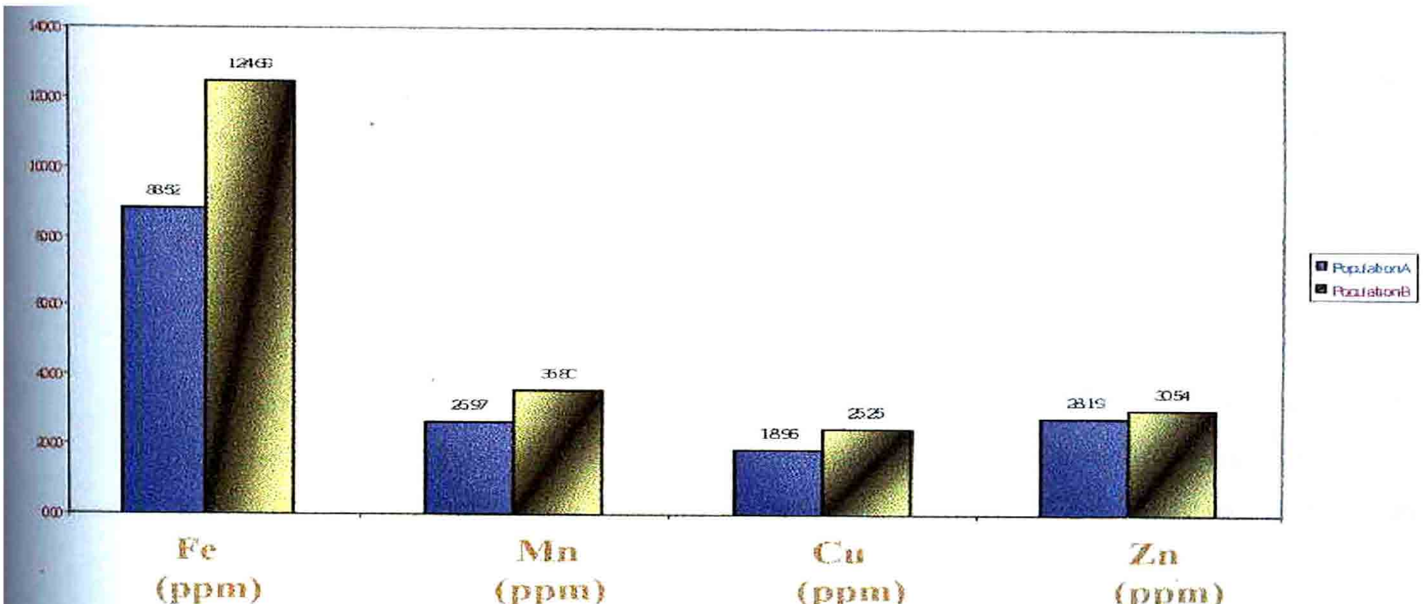


Figure 16 : Leaf micro-nutrient status of low and high yielding subpopulations of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush

4.3.3.3 Copper

The data of Tables 5 and 6 reflected that Cu in leaves low yielding subpopulation was lower than the high yielding population in both of the flushes. (Fig. 15 and 16) Malewar *et al.* (1978-a) have made similar observations for the lower concentration of Cu in unhealthy than healthy leaves. High yielding leaves contained Cu from 11.35 to 41.40 ppm (mean 24.74 ppm) and 13.20 to 45.24 ppm (mean 25.25 ppm) from *ambia* and *mrig* flush respectively. Whereas in leaves from low yielding subpopulation it was in range from 8.44 to 34.85 ppm (mean 15.41 ppm) and 12.40 to 34.40 ppm (mean 18.96 ppm) in *ambia* and *mrig* flush, respectively.

Cu content was higher in *mrig* (summer) flush than *ambia* flush. Gururani and Singh (1983) similarly recorded lower Cu and Zn content in spring flush (*ambia*) than other flushes.

4.3.3.4 Zinc

Zinc is involved in the biosynthesis of a plant harmone-Indole acetic acid and is a component of variety of enzymes. A number of names have been given to zinc deficiency such as "frenching" in Florida, "mottle leaf or little leaf of folliocellosis" in California and India. Zinc deficiency is next to nitrogen deficiency in citrus. The mean values of Zn concentration of low and high yielding population showed higher concentration in high yielding subpopulation (Fig. 15 and 16). The mean Zn concentration in high yielding orchards was 30.91 ppm in *ambia* (range 16.51 to 47.66 ppm) and 30.54 ppm in *mrig* (range 17.61 to 48.08 ppm). Whereas in low yielding subpopulation the range was 10.97 to 49.28 ppm (mean 27.94 ppm) in *ambia* flush and 20.82 to 36.31 ppm (mean 28.19 ppm) in *mrig* flush leaves (Fig. 15 and 16). This trend was similar to other micronutrients. Sharma and Mahajan (1990) and Kharkar *et al.* (1991) reported similar results.

Considering *ambia* and *mrig* flushes, it was observed that Zn content did not show any variation. This happened because available Zn in soil under both flushes was above critical level and hence it was not limiting.

The studies revelaed that maximum nutrients (excluding Mg, Cu and Zn) were having higher concentration in *ambia* flush than in *mrig* flush and so was the yield performance. This trend of nutrients was also observed in soil fertility status. Higher concentration of leaf nutrients performed higher yields.

4.4 DRIS norms for soil fertility status

Critical limits of soil nutrients that separate deficient from nondeficient soils vary with the soil, crop and the extractant used. These variations are to some extent related to their differential sensitivity to nutrient stress. Even for the same crop, critical limits are not universal for different soils since several factors modify availability of these nutrients. Therefore, critical limits or standards should be used with reference to a crop and established to match the local soil and environmental conditions.

Considering the precision of Diagnosis and Recommendation Integrated System (DRIS) described by Beaufils (1971, 1973) and others over the other methods, the norms for different soils parameters of Nagpur mandarin are developed. These norms are divided into five classes, *viz.* very low, low, optimum, high and excess and are reported and discussed below (Appendix XIV and XV). The evaluation and classification of the total orchards (low and high yielding together) was done based on the composition of individual soil nutrient or parameter with norm value in DRIS. The observed DRIS norms were compared with the nutrient standards or rating proposed by various workers for soil available in literature (Appendix XVIII and Table 7).

4.4.1 Soil characteristics

Soil reaction

The soils under study are neutral to slightly alkaline with pH ranging from 7.28 to 8.06 dSm^{-1}. The new norms developed for pH showed that the optimum pH for Nagpur mandarin ranges from 7.35 to 7.71 for *ambia* flush and 7.40 to 7.65 for

Table 7 : Comparison of soil fertility DRIS norms with conventional standard values

Parameter / nutrient (Unit)	Actual observed range		DRIS norms for *ambia* flush		DRIS norms for *mrig* flush		Conventional Range	
	Ambia flush	*Mrig* flush	Very Low (Less than)	Optimum	Very Low (Less than)	Optimum	Safe Limit (Less than)	Optimum
pH	7.28-8.06	7.35-7.96	7.16	7.35-7.71	7.27	7.41-7.65	8.5[a]	7.0-8.5[b]
EC (dSm^{-1})	0.10-0.48	0.11-0.37	0.01	0.12-0.29	0.05	0.14-0.28	0.5[c]	< 2.5[d]
Organic Carbon (%)	0.11-1.22	0.26-1.25	0.05	0.37-0.98	0.24	0.49-0.98	0.2[e]	0.41-0.8[e]
$CaCO_3$ (%)	4.06-23.97	3.01-19.73	0.74	4.26-11.29	1.09	4.73-11.98	10[f]	0-10[g]
N ($kg\ ha^{-1}$)	74-577	55-343	168	281-504	216	314-508	100[e]	201-400
P_2O_5 ($kg\ ha^{-1}$)	3-128	3-126	11	43-105	17	38-78	34[e]	70-149[e]
K_2O ($kg\ ha^{-1}$)	89-882	180-1002	141	366-812	148	348-747	120[e]	181-300
Ca (c mol (p^+)kg^{-1})	10-56	14-53	30	38-51	26	36-51	1.5[h]	-
Mg (c mol (p^+)kg^{-1})	1.59-29.30	2-15	2.62	8.51-20.24	2.4	6.01-13.20	1[h]	-
S ($kg\ ha^{-1}$)	2.10-60.90	6-35	5	13-26	4	12-26	-	-
Fe (ppm)	1.39-10.36	5.16-10.33	4.80	6.03-8.56	4.80	6.32-9.24	4.5[i]	-
Mn (ppm)	8.27-29.09	7.70-21.20	4.56	9.16-18.34	3.60	7.51-15.40	0.2[i]	-
Cu (ppm)	1.50-10.24	0.97-8.32	0.56	3.01-7.88	0.45	2.41-6.30	2[i]	-
Zn (ppm)	0.51-0.93	0.41-0.96	0.35	0.53-0.87	0.33	0.52-0.89	0.6[i]	-

a-Kanwar *et al.* (1965)
b-Dhawan *et al.* (1957)
c-Kanwar and Randhawa (1960)
d-Patil (1979)
e-Muhr *et al.* (1965)
f-Bhella (1996), Singh (1966)
g-Rajput and Sri Haribabu (1995),
h-Biswas *et al.* (1985),
i-Gupta (1993).

mrig flush soils.The optimum pH was observed in 89 per cent orchards of *ambia* and 88 per cent orchards *mrig* flush soils.

Electrical conductivity

The electrical conductivity of soils under study was ranging from 0.10 to 0.48 dSm^{-1}. The optimum EC varied from 0.12 to 0.29 dSm^{-1} and 0.14 to 0.28 dSm^{-1} for *ambia* and *mrig* flushes respectively indicating relatively much lower EC in Nagpur mandarin growing soils as compared to critical EC level (0.5 dSm^{-1}) (Kanwar and Randhava, 1960). Most of the soils under present investivation were optimum to high (> 90 %) in EC in both soils under *ambia* (81 +11 %) and *mrig* (73 + 20 %) flush.

Organic carbon

The organic carbon requirement ranged from 0.37 to 0.98 per cent in *ambia* flush and 0.49 to 0.98 per cent under *mrig* flush soils for optimum yield (Table 7). However Nagpur mandarin was observed to grown on soils of wide range of organic carbon i.e. 0.11 to 1.22 per cent and of 0.26 to 1.25 per cent in *ambia* and *mrig* flush, respectively. Majority of Nagpur mandarin orchards (79 % in *ambia* and 75 % in *mrig*) were in optimum range of organic carbon as per DRIS norms under both flushes.

The data showed that optimum values of DRIS norms are in low to high range according to Muhr *et al.* (1965) for critical soil limits. Higher values of organic carbon in these orchard soils might be due to the fact that the cultivators might be using high doses of FYM to mandarin orchards for getting higher yield. Similar observations were also made earlier by Malewar *et al.* (1978-a).

Free $CaCO_3$

The optimum ranges value of free $CaCO_3$ content of soils observed for Nagpur mandarin in Western Vidarbha were 4.26 to 11.29 per cent in *ambia* flush and 4.73 to 11.98 per cent in *mrig* flush. In *ambia* and *mrig* flush soils it was ranging from 4.06 to 23.97 per cent and 3.01 to 19.73 per cent respectively (Table 7). The majority of gardens (64 % *ambia* and 72 % *mrig*) were in the optimum range. However some orchards though on soils of high $CaCO_3$ range, produced higher yield in *ambia* and *mrig* flushes may because of some other factor such as higher organic matter content.

Bhella (1966) and Singh (1966) observed limit beyond which growth of citrus was adversely affected could be ten per cent. Rajput and Sri Haribabu (1995) reported that the optimum range of $CaCO_3$ for citrus 0 to 10 per cent.

4.4.2 Primary available nutrients

Nitrogen

It is observed from Table 7 that the available nitrogen content of soils under present investigation varied from 74 to 577 kg ha^{-1} for *ambia* flush and 55 to 343 kg ha^{-1} for *mrig* flush soils. The optimum range of available N in soils using DRIS for soils of *ambia* flush ranged from 281 to 504 kg ha^{-1} and that of *mrig* flush from 314 to 508 kg ha^{-1}.

In the present investigation, evaluation of orchards indicates that 44 and 48 per cent orchards in *ambia* and *mrig* flush, respectively were under optimum nitrogen status. Only four per cent in *ambia* and five per cent in *mrig* flush orchardswere under high N level. The optimum available N requirement for Nagpur mandarin is met at medium to high available N (Muhr *et al.*, 1965) indicating that the crop can be grown successfully in soils of medium to high fertility. But low level of N is a limiting factor under present investigation.

In case of *ambia* flush 52 (= 8 + 44) per cent orchards were under low in available N while in *mrig* flush this per centage was 47 (31 + 16) under in low available N. Such low yields were due to the low available N which is not adequate to meet the demand of plants. Most of the citrus growing soils of India are low to medium in available nitrogen (Nilangekar and Patil, 1982 and Raina, 1988). Diware and Kolte (1990) also observed the deficiency of available N in orange growing soils of Western Vidarbha.

Phosphorus

The observed range showed 3 to 128 kg ha^{-1} available phosphorus (P_2O_5 in *ambia* flush and 3 to 126 kg ha^{-1} P_2O_5in *mrig* flush soils. The optimum phosphorus varied from 43 to 105 kg ha^{-1} and 38 to 78 ka ha^{-1} in *ambia* and *mrig* flush respectively indicating that the P_2O_5 requirement of Nagpur mandarin is met from medium to high soil available P_2O_5 (Muhr *et al.*,1965) (Table 7). Orchards under low soil available P_2O_5 (24 % in *ambia* and 20 % in *mrig*) were low yielding and it may be a limiting factor for these orchards. However it was optimum in 69 and 60 per cent orchards in *ambia* and *mrig* flush respectively.

Potassium

Available potassium (K_2O) was ranging from 89 to 882 kg ha^{-1} and from 180 to 1002 kg ha^{-1} in *ambia* and *mrig* flush soils, respectively. The optimum norms for available K_2O for *ambia* and *mrig* flush were found to be 366 to 812 and 348 to 747 kg ha^{-1} respectively, indicating that the Nagpur mandarin growing soils of Western Vidarbha are very high in available K (Muhr *et al.*, 1965) (Table 7).The evaluation of orchards showed that the most of orchards (73%) come under optimum cateogory in both flushes. Kharkar *et al.* (1991) observed that the available K_2O was excess in Nagpur mandarin growing soils of Vidarbha.

4.4.3 Secondary available nutrients

Calcium

The minimum and maximum values of available calcium for *ambia* flush were from 10 to 56 cmol (p$^+$) kg^{-1} and for *mrig* flush this range was 14 to 53 cmol (p$^+$) kg^{-1} DRIS norms developed indicated 38 to 51 cmol (p$^+$) kg^{-1} soil and 36 to 51 cmol (p$^+$) kg^{-1} for *ambia* and *mrig* flush respectively. Fourty per cent *ambia* and 48 per cent *mrig* orchards were under optimum DRIS norms. The available Ca in these soils less than 30 cmol (p$^+$) kg^{-1} and 26 cmol (p$^+$) kg^{-1} for *ambia* and *mrig* flush respectively were observed in very low range and may be critical limits (Table 7).

Soils containing exchangeable Ca less than 1.5 cmol (p$^+$) kg^{-1} have usually been considered as Ca deficient (Biswas *et al.*, 1985). Fifty six per cent orchards in *ambia* and 51 per cent of *mrig* were growing on soils with low available calcium DRIS norms.

Magnesium

The available magnesium was ranging from 1.59 to 29.30 cmol (p$^+$) kg^{-1} in orchards from *ambia* flush, whereas it was recorded between 2 to 15 cmol (p$^+$) kg^{-1} in orchards from *mrig* flush. The optimum yield was recorded at 8.51 to 20.24 cmol (p$^+$) kg^{-1} and 6.01 to 13.20 cmol (p$^+$) kg^{-1} of available Mg in *ambia* and *mrig* flush soils respectively (Table 7). The evaluation of these orchards indicated that most of the soils (67 % in *ambia* and 63 % in *mrig*) were in optimum range. About 31 per cent sites from *ambia* flush were very low to low and the Mg concentration was less than 2.62 cmol (p$^+$) kg^{-1} whereas in *mrig* flush these concentration was less than 2.40 cmol (p$^+$) kg^{-1} and 21 per cent orchards observed under very low to low in available Mg. Hence 2.26 and 2.40 cmol (p$^+$) kg^{-1} may be considered as critical limits for ambia and mrig flush respectifely. Soils containing less than 1.00 cmol (p$^+$) kg^{-1} exchangeable Mg are considered deficient (Biswas *et al.* , 1985).

Sulphur

The available sulphur concentration in soils from *ambia* and *mrig* flush was ranged from 2.10 to 60.90 kg ha^{-1} and 6 to 35 kg ha^{-1} respectively.

The optimum available sulphur requirement ranged from 13 to 26 kg ha^{-1} in *ambia* flush. In *mrig* flush however this range was 12 to 26 kg ha^{-1} available S (Table 7). In case of *ambia* flush 57 per cent orchards and in *mrig* 71 per cent orchrds were in optimum range of available sulphur. Only 8 per cent gardens in *ambia* were under very low range indicating S critical level of 5 kg ha^{-1}.

4.4.4 Available micronutrients

Iron

The available iron concentration in soils showed wide variation from 1.39 to 10.36 ppm and from 5.16 to 10.33 ppm in *ambia* and *mrig* flush respectively. The optimum requirement of DTPA extractable Fe ranged from 6.03 to 8.56 ppm in *ambia* and from 6.32 to 9.24 ppm in *mrig* flush soils. The lowest yield was observed when available iron content of these soils was less than 4.8 ppm in both flushes and only 3 per cent orchards were found in this category of DRIS norms under *ambia* flush. Therefore 4.8 ppm available Fe can be considered as new critical limit for DTPA extractable Fe (Table 7). The most acceptable critical limit of available Fe is 4.5 ppm in soils (Lindsay and Norvell, 1978). The data regarding evaluation of orchards indicated that most of soils under *ambia* (76 %) and *mrig* (79 %) flushes were in optimum range of the DRIS norm.

The wide range (1.68 to 25.2 ppm) DTPA extractable of available Fe in surface soils under citrus cultivation was observed earlier by Singh and Tripathi (1983). For marathwada region of Maharashtra, Malewar *et al.* (1978-a) reported DTPA extractable Fe in range of 9.4 to 20.6 ppm.

Manganese

The wider range in available Mn was recorded in *ambia* (8.27 to 29.09 ppm) as well as in *mrig* flush (7.70 to 21.20 ppm) soils. The optimum DRIS norm range was 9.16 to 18.34 ppm for *ambia* and 7.51 to 15.40 for *mrig* flush soils which is considered as higher range (> 2.0 ppm) by Lindsay and Norvell (1978). Optimum range of exchangeable Mn for growing healthy citrus is considered to be 10 ppm (Ogata, 1967). The observed values are in conformity with the findings of Malewar *et al.* (1978 a and b), Singh and Tripathi (1983) and Patil and Malewar (1998). The orchards observed in optimum range were 88 per cent in *ambia* and 95 per cent in *mrig* flush. Data of optimum norms further indicated that Mn requirement of Nagpur mandarin is met at much higher Mn status than present critical limit.

Considering very low category of DRIS 4.56 ppm and 3.6 ppm can be critical limits for *ambia* and *mrig*, respectively since no orchards were available under this category.

Copper

The available copper was higher than critical limit (0.2 ppm) (Lindsay and Norvell, 1978) in all the soils ranging from 1.50 to 10.24 ppm in *ambia* and from 0.97 to 8.32 ppm in *mrig* flush. The optimum range of available Cu was 3.01 to 7.88 ppm and 2.41 to 6.30 ppm in soils under *ambia* and *mrig* flush respectively (Table 7) indicating that the Cu requirement of Nagpur mandarin was met at much higher Cu status than the present critical limit. This adequate Cu concentration of surface soils is supported by the findings of Malewar *et al.* (1978 a and b), Singh and Tripathi (1983), Raina (1988), Sharma and Mahajan (1990) and Patil and Malewar (1998) in different parts of the country.

From the evaluation of data it was observed that 60 per cent sites under *ambia* and 59 per cent sites under *mrig* flush were in optimum range in the new DRIS norms. Since no orchards were observed under very low category of DRIS norms 0.60 ppm and 0.45 can consider as new critical limits for *ambia* and *mrig* flush, respectively.

Zinc

The soils under present study showed that the available zinc was ranging from 0.51 to 0.93 ppm for *ambia* and 0.41 to 0.96 ppm for *mrig* flush soils. The requirement of available Zn for optimum yield recorded was in the range of 0.53 to 0.87 ppm in *ambia* flush and 0.52 to 0.89 ppm in *mrig* flush soils indicating that these optimum limits were nearer to critical limit (0.8 ppm) recommended by Lindsay and Norvell (1978). Chapman (1960) reported that the zinc less than 1.0 ppm in soils having pH above 7.0 were inadequate for citrus (Table 7). Most of the orchards (about 83 %) were found to be in optimum range in both flushes. However, there were no gardens in very low class of DRIS (< 0.35 ppm for *ambia* and 0.33 for *mrig* flush). Hence these limits can be considered as new critical limits of DRIS norms. The presence of higher lime with alkaline soil reaction is likely to pose problem of its availability in soil (Patil and Malewar, 1998).

4.5 DRIS norms for leaf nutrients and yield

Nutrition management of fruit crops is one of important practices to improve the productivity of fruits. Fertilizer requirement of the tree is determined by visual assessment of deficiencies, soil nutrient status and plant tissue nutrient status. Standardized norms for various soil nutrients or parameters as well as plant tissue nutrients for different crops are available.

Patil and Malewar (1998) observed that though leaf Zn and Fe values indicated relatively higher magnitude than critical limits the leaves expressed morphological deficiency symptoms of Zn and Fe in mandarin orchards of Western Vidarbha. Thus, presently established critical leaf Zn and Fe limits in mandarin failed to keep pace with their deficiencies. Therefore they further suggested that the present leaf nutrient standards need to be reassessed.

Therefore an approach was made to develop new DRIS norms for Nagpur mandarin in the present investigation. These norms were classified as deficient, low, optimum, high and excess and are presented in Appendix XVI and XVII for *ambia* and *mrig* flush respectively.

4.5.1 Major nutrients

Nitrogen

The nitrogen concentration in leaf ranged from 1.55 to 3.08 per cent and from 1.62 to 2.67 per cent in *ambia* and *mrig* flush, respectively. The optimum N concentration ranged from 2.06 to 3.02 per cent in *ambia* flush and 2.10 to 2.68 per cent in *mrig* flush leaves (Table 8). DRIS norms for optimum yields are more or less nearer to the ranges reported by other workers using other methods. DRIS indicated low to optimum range as described by Smith (1966). The optimum value suggested by Reuther *et al.* (1950) for citrus is in range of 2.4 to 2.8 per cent.Randhawa (1970) has suggested less than 2.2 per cent N in leaves from non fruiting terminals as deficient, 2.2 to 2.4 per cent as low, 2.5 to 2.7 per cent as optimum and more than 2.8 per cent as high. Hernandez (1983) considered that trees of Valencia late range

Table 8 : Comparison of leaf nutrient DRIS norms with conventional standard values

Nutrient (Unit)	Actual observed range		DRIS norms for *ambia* flush		DRIS norms for *mrig* flush		Standards of Smith (1966)	
	Ambia flush	*Mrig* flush	Very Low (Less than)	Optimum	Very Low (Less than)	Optimum	Critical limit (Less than)	Optimum
N (%)	1.55-3.08	1.62-2.67	1.57	2.06-3.02	1.79	2.10-2.68	2.2	2.5-2.7
P (%)	0.03-0.38	0.05-0.45	0.01	0.09-0.22	0.02	0.08-0.19	0.09	0.12-0.16
K (%)	0.52-3.33	0.61-2.86	0.62	1.05-1.87	0.09	0.66-1.79	0.7	1.2-1.7
Ca (%)	2.50-5.20	2.26-5.07	2.38	3.18-4.66	2.24	2.97-4.40	1.5	3.0-4.5
Mg (%)	0.37-0.88	0.17-1.22	0.49	0.58-0.73	0.25	0.47-0.87	0.20	0.30-0.49
S (%)	0.14-0.43	0.14-0.37	0.11	0.20-0.36	0.11	0.18-0.30	0.14	0.20-0.39
Fe (ppm)	50.00-199.60	41.16-174.70	25	74-170	58	92-158	35	50-120
Mn (ppm)	18.45-70.94	15.69-70.57	11	26-54	8	23-50	18	25-49
Cu (ppm)	8.43-41.40	12.40-45.24	5.73	15.25-34.25	2.36	13.82-36.70	3.6	5-12
Zn (ppm)	10.97-49.28	17.61-48.08	10	22-41	14	23-39	18	25-49

having less than 2.0 per cent leaf N as deficient. Chauhan *et al.* (1984) reported N content in citrus leaves ranged from 1.5 to 2.9 per cent as optimum.

The evaluation of the orchards showed that from *ambia* and *mrig* flush N was optimum in 87 and 85 per cent orchards respectively indicating that it was not limiting the yield in these orchards. However deficient limits of 1.57 per cent *ambia* and 1.79 per cent in *mrig* can be considered as real critical limits. Similar observations regarding DRIS norms were also made by Varlakshmi and Bhargava (1998) in acid lime.

Phosphorus

Leaf P concentration ranged from 0.03 to 0.38 per cent and from 0.05 to 0.45 per cent in *ambia* and *mrig* flushes respectively, indicating wide variation (Table 8). The optimum leaf P concentration ranged from 0.09 to 0.22 ppm in *ambia* flush and from 0.08 to 0.19 ppm in *mrig* flush leaves which indicated deficient to high range of leaf P as per standards of Smith (1966) for orange leaves. Randhawa (1970) reported the concentration of P in leaf of sweet orange higher than 0.17 per cent as high level. Mann *et al.* (1979) obtained P level in sweet orange leaves of Punjab orchards ranging from 0.04 to 0.17 per cent in healthy trees. P content ranging from 0.09 to 0.28 per cent in leaves of Nagpur mandarin in Vidarbha region was recorded by Kharkar *et al.* (1991). The optimum P was observed in 80 and 75 per cent orchards in *ambia* and *mrig* flush respectively as per DRIS norms. The deficient limit of 0.01 and 0.02 per cent in *ambia* and *mrig* flush can be considered as new critical limit for leaf P.

Potassium

The potassium concentration in mandarin leaves was found to be in the range of 0.52 to 3.33 per cent and 0.61 to 2.86 per cent in *ambia* and *mrig* flush respectively. The DRIS norms developed for orchards indicated K from 1.05 to 1.87 per cent and 0.66 to 1.79 per cent in *ambia* and *mrig* flush respectively as optimum (Table 8). Standards laid down by Smith (1966) showed that the requirement is low to high (0.70 to 2.30 %) in mandarin leaf for optimum yield as per DRIS. As reported by

Kharkar *et al.* (1991) K concentration ranged from 0.66 to 1.89per cent in healthy mandarin trees of Vidarbha region of Maharashtra.

The data indicated that potassium was optimum in 67 per cent orchards from *ambia* flush and 75 per cent from *mrig* flush. In respect of deficient level of K in leaves 0.62 per cent can be taken as critical level.

Calcium

The calcium availability was adequate in majority of the orchards ranging from 2.50 to 5.20 per cent and 2.26 to 5.07 per cent in *ambia* and *mrig* flush respectively, which was because of higher free $CaCO_3$ is soil and of neutral to alkaline nature of soils.

The optimum range of leaf Ca concentration ranged from 3.18 to 4.66 per cent in *ambia* flush and from 2.97 to 2.40 per cent in *mrig* flush orchards (Table 8). This optimum range is coincides with the optimum range established by Smith (1966). Awasthi *et al.* (1984) reported leaf Ca in the range above optimum level in both healthy and declined type of mandarin orchards in Himalchal Pradesh. Kharkar *et al.* (1991) recorded calcium concentration of Nagpur mandarin leaves in Vidarbha region of Maharashtra between 2.84 to 6.00 per cent in healthy trees. The leaf Ca was optimum in 76 and 73 per cent orchards from *ambia* and *mrig* flush, respectively in present study. The new critical limit for leaf Ca can be 2.38 per cent for *ambia* and 2.24 per cent for *mrig* flush which was observed as deficient as per new DRIS norms.

Magnesium

The magnesium concentration ranged from 0.37 to 0.88 per cent and 0.17 to 1.22 per cent in *ambia* and *mrig* flush respectively. The optimum norm for Mg ranged from 0.58 to 0.73 per cent for *ambia* and 0.47 to 0.87 per cent for *mrig* flush indicating these optimum Mg DRIS range in high level as per the standards of Smith (1966) (Table 8). The evaluation of orchards showed that most of the orchards are in optimum range in *ambia* (79 %) as well as in *mrig* flush (67 %) soils. The higher leaf Mg might have the refletion of soils, higher in Mg. The deficient limits for *ambia* and *mrig* flushes were 0.49 and 0.25 per cent respectively which can considered as new critical limits. However, there were sufficient numbers of fruiting orchards under deficient class. As such Mg may not be that critical as other nutrients.

Sulphur

Sulphur concentration of Nagpur mandarin leaves was ranged from 0.14 to 0.43 per cent in *ambia* flush leaves and 0.14 to 0.37 per cent in *mrig* flush. The DRIS norms showed that S concentration ranging from 0.20 to 0.36 per cent in *ambia* flush and from 0.18 to 0.30 per cent in *mrig* flush was found as optimum (Table 8). These optimum values are more or less similar to the optimum standard values suggested by Smith (1966) for orange leaves. However, the norms developed in present investigation for S are near to agreement with the DRIS norms developed by Varlakshmi and Bhargava (1998) for acid lime in Cuddapah district of Andhra Pradesh.

From evaluation of the data it is observed that 65 and 83 per cent orchards in *ambia* and *mrig* flush, were in optimum range. This trend of sulphur was also noted in soils. Critical limit observed for leaf S can be 0.11 per cent which was deficient value observed in both flushes according to DRIS.

4.5.2 Micronutrient status

Iron

Leaf iron concentration showed wide variation from 50.00 to 199.60 ppm in *ambia* flush and 41.16 to 174.70 ppm in *mrig* flush, which indicated adequacy of iron in leaves. The optimum concentration of Fe ranged from 74 to 170 ppm and 92 to 158 ppm in *ambia* and *mrig* flush respectively (Table 8). As per Smith (1966), these optimum ranges from DRIS were in optimum to high range of leaf Fe status. Malewar *et al.* (1978-a) reported higher concentration of iron in leaves, irrespective of healthy and unhealthy trees associated with high content of leaves, which immobilizes the iron in roots and younger leaves. The evaluation showed that 77 per cent orchards in *ambia* flush and 64 per cent orchards in *mrig* flush were found to be in optimum status. The deficient leaf Fe content less than 25 and 58 ppm in *ambia* and *mrig* flush respectively can be considered as new critical limits.

Manganese

The concentration of manganese in Nagpur mandarin leaves of *ambia* and *mrig* flush was varied from 18.45 to 70.94 ppm and 15.69 to 70.57 ppm respectively (Table 8). Most of the orcahrds were detected in optimum range of norms which ranged from 26 to 54 ppm in *ambia* (80 %) and 23 to 50 ppm in *mrig* (85 %) flush. These optimum values are very close to optimum ranges of leaf Mn (25 to 50 ppm) given by Smith (1966) for this crop. It might have been due to the adequacy of Mn in these orchards soil. These observations are confirmed with the findings of Malewar *et al.* (1978-a), Mann *et al.* (1979) and Singh (1982).

Copper

The copper concentration ranged from 8.43 to 41.40 ppm and from 12.40 to 45.24 ppm in *ambia* and *mrig* flush respectively. The optimum Cu status in mandarin leaf varied from 15.25 to 34.25 ppm and from 13.82 to 36.70 ppm in *ambia* and *mrig* flush respectively (Table 8). This optimum leaf Cu range when compared with nutrient standards given by Smith (1966) it comes under very high to excess level of Cu. In *ambia* 65 per cent orchards and in *mrig* 88 per cent orchards were in optimum DRIS range. However, sufficient numbers of orchards were fruiting at low level of available Cu in soils of both flushes and the same was reflected in leaves. Awasthi *et al.* (1984) from his studies observed optimum range of Cu in most of the citrus orchards. Sharma and Mahajan (1990) and Kharkar *et al.* (1991) also did not report deficiency of Cu in their studies. Deficient level of leaf Cu, 5.73 ppm for *ambia* and 2.36 ppm for *mrig* are the new critical limits.

Zinc

Zinc, the most important micronutrient in citrus nutrition showed deficient to high range in Nagpur mandarin trees varying from 10.97 to 49.25 ppm and 17.61 to 48.08 ppm in *ambia* and *mrig* flushes respectively. The optimum Zn concentration ranged from 22 to 41 ppm in *ambia* flush and from 23 to 39 ppm in *mrig* flush leaves of Nagpur mandarin (Table 8). Comparing these values with the standards of Smith (1966) it was observed that Nagpur mandarin produced the optimum yield with optimum leaf Zn content. Most of the orchards i.e. 77 per cent from *ambia* and 83 per cent from *mrig* flush indicated optimum range of the DRIS norms for leaf Zn. The similar trend was observed for Zn in soil (Table 8). However 10.0 ppm and 14.00 ppm concentration of leaf Zn in *ambia* and *mrig* are the deficient levels and so are the critical limits for Nagpur mandarin.

4.5.3 Yield level

In present investigation DRIS was expanded to establish the new categorization of yield from DRIS norms. To date the Nagpur mandarin orchards of Vidarbha region are generally classified into three classes on the basis of yield *viz.*, low (400 tree), medium (400 to 700 fruits per tree) and high (> 700 fruits per tree) yielder. Therefore the cutoff value taken for dividing high and low yield in present study was 400 fruits per tree for each orchard. DRIS norms established for yield level of Nagpur mandarin in Western Vidarbha showed that the yield level should be considered as 'low' when yield is less than 767 fruits per tree for ambia and 801 fruits per tree for *mrig* flush (Appendix XVI and XVII). Therefore the new cutoff value of yield level for dividation of population into low and high yielding orchards should be rouned off to 800 fruits per tree. The data further indicated that the yield was low to very low in 55 per cent and 53 per cent orchards of *ambia* and *mrig* flush respectively. It was optimum in 41 per cent of *ambia* flush and 47 per cent of *mrig* flush orchards.

4.6 DRIS indices

In order to know the effects on yield of Nagpur mandarin, the yield data at various locations from orchard growers were collected and yield (numbers of fruit per tree) was recorded from the randomly selected trees in each orchards. DRIS indices are derived for soil fertility and leaf nutrient status of low as well as high yielding Nagpur mandarin orchards, which have negative, positive and zero values. The relative order of ranking of soil parameters / nutrients and leaf nutrients in terms of requirement by the plant for optimum yield are established and reported here.

4.6.1 Low yielding subpopulation

DRIS indices are the quantitative evaluation of relative degree of imbalance of nutrient in low yielding orchards. These sets of diagnostic indices lead to sound recommendation of nutrient capable of obtaining higher yields.

4.6.1.1 Soil fertility indices for *ambia* flush

DRIS indices computed for low yielding orchards from *ambia* flush for soil fertility are presented in Table 9.

DRIS indices for soil are presented sequentially in order of requirement of nutrients or parameter for getting optimum yield. These indices are separated for each low yielding site. The more lacking is the nutrient, relative to other nutrients used in the diagnosis. Alternatively a large positive nutrient index indicates that the corresponding nutrient is present in relatively excessive quantity. In present investigation yield index (Y) is calculated with nutrient indices in both soil and leaf for more accuracy. As low yielding orchards are taken into consideration for indices, yield index (Y) is always negative (Table 9). While detecting the most limiting parameter / nutrient, yield index must be neglected. Therefore, most negative index i.e. most limiting parameter is be that which comes first in order of requirement.

This can be best illustrated from the example below.

At site number 19 from *ambia* flush (Table 9) N showed most negative value. (-51) and the order of requirement (limiting factor) was N > Ca > K > P > Cu > OC. This means that in terms of relative requirement to yield, N is the most limiting than Ca followed K and subsequaently by P,Cu,OC . In this case it further noted that the parameter organic carbon (OC) showing zero index is with optimal balance . From postive values of indices in the same site it can be concluded that sulphur is in optimum range and Mg, Fe, EC , Mn, Zn, pH, and $CaCO_3$ are relatievely excessive. Of the higher or excessive nutrients, one or other nutrient may also be yield lilmting. In this particular case (site 19) free $CaCO_3$ (higher +ve index) may be limiting, even more than the deficient factors. However, by correcting deficient factors, the excessive factors may come in proper nutrient balance ensuring optimum yields.

Table 9 : DRIS indices with order of requirement of soil parameters for low yielding Nagpur mandarin orchards in *ambia* flush

Site No.	Order of requirement from left to right														
1	Y	N	Cu	Mg	OC	S	EC	Ca	Mn	P	CC	K	Zn	Fe	pH
	-63	-36	-19	-11	-3	-1	3	4	7	10	10	14	27	27	31
2	Y	Ca	S	K	N	Fe	Cu	CC	Zn	Mn	P	OC	Mg	pH	EC
	-93	-17	-16	-13	-9	-8	-6	10	11	13	18	21	23	26	41
3	Y	Mg	S	K	Cu	N	Mn	Fe	Ca	Zn	OC	EC	CC	pH	P
	-53	-41	-12	-7	-5	-2	-2	1	1	8	10	11	21	25	46
4	S	P	Y	CC	Mg	Cu	Ca	N	Zn	OC	K	Fe	Mn	EC	pH
	-92	-64	-42	-26	-20	-2	14	15	23	26	28	32	32	36	40
5	Y	P	Mg	Cu	K	Ca	N	S	Mn	CC	OC	Zn	pH	Fe	EC
	-59	-54	-47	-22	-18	-5	5	8	12	24	27	27	30	31	41
6	P	Y	Mg	Ca	Cu	S	N	K	EC	CC	Mn	OC	pH	Zn	Fe
	-372	-73	-32	-5	1	10	10	12	28	41	61	64	72	79	105
7	Fe	Y	Cu	N	Ca	Mn	P	Mg	Zn	S	OC	K	EC	pH	CC
	-132	-63	-34	-32	-31	-6	-5	10	16	23	32	37	39	48	96
8	Y	Fe	Mg	N	S	Ca	Cu	Mn	OC	K	CC	Zn	P	pH	EC
	-49	-37	-37	-9	-5	-2	-2	7	9	12	14	21	21	29	30
9	Mg	Y	Ca	S	N	OC	Cu	CC	Mn	P	K	Fe	pH	EC	Zn
	-91	-45	-16	-14	-9	-6	-2	10	11	12	13	27	33	35	42
10	P	K	Y	N	Cu	Ca	Mg	S	CC	OC	Mn	EC	Zn	pH	Fe
	-145	-45	-44	-15	1	3	9	10	13	17	22	31	45	46	53
11	Ca	Y	N	P	Cu	Mn	K	OC	pH	Zn	EC	Fe	CC	S	Mg
	-131	-59	-57	-25	-22	2	5	17	28	30	31	33	40	48	59
12	S	Y	Ca	Cu	CC	N	Mn	Mg	OC	pH	P	Zn	EC	Fe	K
	-41	-40	-25	-24	-14	-8	4	7	12	16	17	17	24	24	32

...continued...

Site No.	Order of requirement from left to right														
13	Y	K	Mg	N	Ca	P	S	Mn	CC	Zn	Fe	Cu	pH	OC	EC
	-87	-84	-76	-2	2	5	6	6	9	10	18	24	34	34	101
14	Mg	Y	Cu	Zn	Ca	S	Mn	N	Fe	P	pH	K	OC	CC	EC
	-92	-83	-19	-9	-5	-4	0	2	5	12	22	30	39	50	52
15	Ca	Y	N	P	S	Fe	Cu	Zn	Mg	pH	Mn	CC	OC	K	EC
	-98	-90	-9	-8	-4	-1	1	1	3	23	26	30	30	30	65
16	S	Ca	Y	N	Mn	Zn	OC	K	Cu	CC	Mg	P	Fe	pH	EC
	-115	-68	-50	-3	3	4	6	9	10	13	16	25	30	45	74
17	Ca	Y	Mg	S	Cu	N	Mn	P	Zn	Fe	OC	pH	CC	K	EC
	-118	-109	-78	-4	-1	4	11	16	17	27	28	38	49	49	70
18	K	N	OC	Y	Cu	Ca	Mg	Mn	Zn	P	Fe	EC	pH	S	CC
	-113	-99	-67	-64	-39	-36	-16	20	25	29	36	40	58	83	143
19	Y	N	Ca	K	P	Cu	OC	S	Mg	Fe	EC	Mn	Zn	pH	CC
	-58	-51	-37	-19	-13	-10	0	1	3	9	28	30	33	35	48
20	Mg	Y	S	N	Ca	P	Cu	CC	OC	Mn	K	Zn	Fe	pH	EC
	-116	-46	-32	-8	-4	-2	2	8	11	18	20	22	37	41	49
21	Ca	Y	P	S	Cu	N	CC	OC	Zn	Fe	Mg	Mn	pH	EC	K
	-45	-40	-38	-34	-12	-2	6	9	11	12	14	16	33	33	38
22	K	Y	Ca	OC	N	EC	CC	S	Mn	P	Mg	Cu	Fe	pH	Zn
	-39	-27	-18	-15	-11	-3	-2	2	4	4	9	11	19	29	38
23	Y	Ca	N	Mg	K	EC	Cu	Mn	Fe	Zn	OC	S	P	pH	CC
	-63	-30	-14	-3	-3	-2	0	2	3	3	7	16	17	23	43
24	Y	Ca	K	N	P	S	OC	Cu	Zn	Fe	Mn	EC	Mg	CC	pH
	-64	-26	-19	-11	-10	-10	-3	0	12	17	18	22	22	22	29
25	Y	Ca	Mg	Cu	N	OC	P	EC	K	Zn	S	Mn	Fe	pH	CC
	-85	-42	-25	-24	-15	-7	-4	0	9	13	14	20	33	41	74

...continued...

Site No.	Order of requirement from left to right														
26	**Y**	**Ca**	**Cu**	**N**	**Mg**	**EC**	**K**	**OC**	**P**	**S**	**Mn**	**Fe**	**Zn**	**pH**	**CC**
	-104	-48	-20	-13	-10	1	5	6	6	12	22	26	38	39	41
27	**P**	**Y**	**Ca**	**EC**	**Cu**	**Mg**	**OC**	**N**	**S**	**K**	**Mn**	**Fe**	**CC**	**pH**	**Zn**
	-340	-108	-25	-3	7	19	20	21	25	29	47	60	70	80	98
28	**Y**	**Mg**	**Ca**	**N**	**OC**	**Cu**	**Mn**	**P**	**K**	**EC**	**S**	**Fe**	**Zn**	**pH**	**CC**
	-86	-86	-7	-6	-6	1	3	4	9	10	18	25	28	36	57
29	**Y**	**Mg**	**Cu**	**P**	**N**	**OC**	**Ca**	**Zn**	**S**	**K**	**Fe**	**Mn**	**EC**	**pH**	**CC**
	-102	-59	-24	-22	-3	4	13	14	14	15	15	17	17	40	62
30	**Y**	**K**	**Mg**	**N**	**EC**	**OC**	**Ca**	**P**	**Mn**	**Zn**	**Fe**	**Cu**	**pH**	**S**	**CC**
	-90	-72	-70	-13	-10	-1	9	13	17	18	31	37	40	42	48
31	**Y**	**Ca**	**K**	**P**	**N**	**Mg**	**Mn**	**OC**	**S**	**Cu**	**EC**	**Fe**	**Zn**	**pH**	**CC**
	-51	-42	-30	-10	-9	-8	-5	3	6	8	9	17	27	33	51
32	**Y**	**Cu**	**S**	**Zn**	**Mn**	**Mg**	**Ca**	**N**	**EC**	**Fe**	**K**	**pH**	**CC**	**OC**	**P**
	-66	-26	-19	-19	-8	-5	-4	-4	3	5	13	17	26	27	60
33	**Y**	**Ca**	**S**	**P**	**Cu**	**N**	**EC**	**Fe**	**Mg**	**pH**	**Zn**	**Mn**	**OC**	**K**	**CC**
	-123	-32	-18	-5	-2	-1	2	10	16	18	20	27	27	28	31
34	**Y**	**Ca**	**Cu**	**N**	**S**	**EC**	**OC**	**Fe**	**Mg**	**pH**	**Zn**	**CC**	**K**	**Mn**	**P**
	-61	-34	-17	-15	-9	4	5	6	11	14	16	17	17	20	24
35	**Ca**	**Y**	**N**	**OC**	**Fe**	**Cu**	**Zn**	**K**	**Mn**	**P**	**Mg**	**pH**	**EC**	**CC**	**S**
	-119	-100	-12	-8	-5	-2	0	1	1	9	11	27	47	72	77
36	**Mg**	**Y**	**N**	**Cu**	**Ca**	**K**	**P**	**S**	**CC**	**Mn**	**Zn**	**OC**	**pH**	**Fe**	**EC**
	-91	-64	-9	-8	-7	2	4	4	8	9	19	29	30	35	38
37	**P**	**S**	**Y**	**Zn**	**Cu**	**CC**	**Mg**	**Ca**	**N**	**K**	**EC**	**Fe**	**OC**	**pH**	**Mn**
	-109	-107	-95	-9	-6	10	11	12	17	19	38	39	43	49	89
38	**Y**	**Mg**	**K**	**S**	**EC**	**Ca**	**N**	**CC**	**P**	**Cu**	**pH**	**Fe**	**Mn**	**Zn**	**OC**
	-51	-24	-9	-8	-6	-6	-3	-1	3	11	13	14	15	23	28

Since the excessive nutrient can not be withdrawn, it can be balanced by supplimenting limitilng nutrients.

In first low yielding orchard of *ambia* flush, soil fetility DRIS indices inferred that nitrogen is the most insufficient nutrient by Cu>Mg>OC>S, whereas others were in sufficient (+ve) range in the order of sufficiency as EC < Ca < Mn < P < CC < K < Zn < Fe < pH. In second orchard DRIS indices showed the most required nutrient as Ca followed by S > K >N > Fe > Cu whereas sufficiency requirement was as CC < Zn < Mn < P < OC < Mg < pH < EC. Similarly order of requirement can be interpreted in other low yielding orchards.

Among major nutrients, nitrogen, phosphorus, calcium, magnesium and sulphur showed insufficiency in majority of orchards. It is interesting to note that site No. 10 reflects the requirement of only primary nutrients in order P > K > N expressing yield 254 fruits per tree. It means that though the other nutrients are in balanced condition yield is mostly affected when these primary nutrients are deficient. Likewise indices can be interpreted for individual gardens.

Among micronutrients, copper was found to be deficient in most soils orchards with very low yield level. Zinc was limiting in two sites only i.e. sites 14 and 37. Fe was deficient in five orchards and Mn was limiting in three sites.

Though negative indices showing nutrients affecting yield, the excess of some soil parameters may also result in low yield. Free calcium carbonate is such important factor for citrus. In some of the sites $CaCO_3$ showing most positive index might have resulted in low yield rather than some limiting nutrient in the particular case. Site numbers 7, 18, 19, 23, 25, 26, 28, 30, 31 and 33 showed most postive index of $CaCO_3$.

4.6.1.2 Soil fertility indices for *mrig* flush

Soil fertility DRIS indices for low yielding subpopulation from *mrig* flush are presented in Table 10. All the orchards indicated requirement of N (negative indix)

Table 10 : DRIS indices with order of requirement of soil parameters for low yielding Nagpur mandarin orchards in *mrig* flush

Site No.	Order of requirement from left to right														
1	Y	N	Cu	K	P	CC	Ca	OC	Mn	S	EC	Fe	pH	Zn	Mg
	-45	-18	-15	-8	-6	-2	-1	1	2	7	8	8	15	26	27
2	P	Y	N	Cu	OC	Ca	Mn	CC	Fe	EC	Mg	S	pH	K	Zn
	-185	-49	-39	-11	-6	2	17	24	30	30	32	32	35	44	44
3	Y	N	Ca	K	Cu	Fe	P	Mn	OC	Mg	S	EC	pH	Zn	CC
	-29	-23	-21	-20	-20	-6	-5	1	6	12	14	16	21	23	31
4	Y	Cu	N	Ca	P	S	EC	Mn	CC	K	pH	Fe	Zn	OC	Mg
	-48	-34	-31	-19	-7	1	10	11	12	13	14	14	14	21	31
5	Y	Ca	N	K	CC	S	Cu	Mg	OC	Fe	pH	Mn	Zn	EC	P
	-76	-43	-28	-19	1	2	4	6	8	10	13	16	17	30	60
6	Y	N	Ca	Mg	K	S	Mn	Fe	P	Cu	Zn	OC	pH	CC	EC
	-61	-47	-20	-20	-11	-3	-1	1	10	12	24	24	28	32	33
7	Y	Cu	CC	Ca	N	Mg	Mn	Zn	Fe	OC	S	P	pH	K	EC
	-60	-28	-20	-9	-5	-4	1	7	9	11	11	11	15	30	33
8	Y	Mg	Ca	P	Cu	Zn	Mn	N	OC	CC	K	Fe	EC	pH	S
	-55	-14	-13	-9	-2	-2	2	4	5	7	8	9	10	14	36
9	Y	Cu	Ca	N	Mg	OC	Fe	EC	P	Mn	S	Zn	pH	CC	K
	-42	-31	-30	-28	-26	-8	-1	4	8	13	13	17	23	36	53
10	N	Y	S	Mg	Cu	OC	Ca	K	Fe	Mn	CC	EC	pH	Zn	P
	-191	-87	-25	-16	-13	8	12	14	21	22	44	49	50	52	61
11	Y	N	Cu	Ca	K	Mn	Fe	P	S	Zn	OC	Mg	pH	CC	EC
	-103	-50	-31	-17	-2	-2	12	15	16	20	24	25	27	30	35
12	N	Y	K	Cu	Ca	P	Mn	Fe	OC	Mg	EC	Zn	pH	S	CC
	-61	-37	-27	-14	-7	-3	5	6	11	12	16	19	20	24	37

...continued...

Site No.	Order of requirement from left to right														
13	N	P	Y	Cu	Ca	Mn	K	CC	Zn	Fe	OC	pH	Mg	S	EC
	-129	-67	-65	-28	-9	13	18	23	25	25	29	35	40	44	46
14	Y	Ca	Cu	K	P	CC	N	Mn	Fe	pH	Zn	Mg	OC	EC	S
	-47	-36	-26	-25	-13	-7	-6	4	11	12	18	25	26	30	34
15	N	Cu	Y	S	Mg	Ca	Fe	Mn	Zn	CC	pH	P	K	EC	OC
	-64	-56	-51	-43	-13	4	6	9	18	20	30	31	31	38	39
16	N	Cu	Y	Ca	S	P	Fe	Mn	Mg	EC	CC	OC	K	pH	Zn
	-44	-43	-36	-33	-24	-6	8	10	11	13	23	24	29	31	37
17	Y	N	Cu	P	K	Mn	Ca	Mg	Fe	Zn	EC	pH	CC	OC	S
	-109	-62	-53	-27	0	7	8	10	12	17	26	32	44	44	50
18	Y	N	CC	Ca	EC	P	Fe	OC	K	Cu	pH	Mn	S	Zn	Mg
	-94	-25	-10	-3	-2	1	4	7	12	12	13	17	20	22	26
19	P	Y	K	Ca	N	EC	CC	Fe	OC	Cu	pH	Mg	S	Zn	Mn
	-84	-72	-48	-39	-19	-1	2	5	15	22	28	34	38	43	75
20	Mg	Y	Cu	S	N	Zn	Fe	Ca	K	Mn	pH	EC	OC	CC	P
	-76	-48	-31	-22	-11	0	5	10	19	20	22	22	23	24	43
21	Y	Mg	Ca	Cu	N	S	Mn	Fe	Zn	OC	K	pH	P	EC	CC
	-48	-14	-10	-4	-4	-1	4	4	4	5	9	12	12	15	16
22	Mg	Cu	Y	Ca	S	N	K	OC	Fe	Zn	Mn	EC	pH	CC	P
	-66	-62	-44	-26	-18	-7	6	6	7	8	16	34	35	43	68
23	Y	Cu	K	Ca	Mg	S	OC	Mn	N	Fe	Zn	pH	CC	EC	P
	-90	-40	-37	-36	-32	-8	2	2	8	11	33	33	38	39	76
24	Y	N	Mg	Cu	OC	Mn	K	Fe	P	Zn	Ca	pH	EC	S	CC
	-38	-29	-23	-8	-6	-5	-2	5	5	6	15	17	17	21	27
25	P	N	Y	K	OC	Cu	Mg	Zn	CC	Mn	Ca	S	Fe	EC	pH
	-343	-45	-41	-17	-7	12	12	27	46	47	54	54	62	65	72

...continued...

Site No.	Order of requirement from left to right														
26	**N**	**Mg**	**Y**	**K**	**Cu**	**S**	**EC**	**Mn**	**OC**	**Zn**	**Ca**	**Fe**	**CC**	**pH**	**P**
	-96	-64	-40	-25	-13	2	6	16	16	17	21	22	25	31	81
27	**Y**	**OC**	**N**	**S**	**Cu**	**Mg**	**Ca**	**CC**	**EC**	**Mn**	**Fe**	**Zn**	**pH**	**K**	**P**
	-62	-34	-21	-13	-11	-9	-3	1	5	11	14	15	18	25	64
28	**Y**	**N**	**OC**	**Cu**	**EC**	**Ca**	**Mn**	**Fe**	**Mg**	**CC**	**S**	**pH**	**Zn**	**K**	**P**
	-50	-37	-22	-21	-8	-5	-2	0	1	2	4	15	23	31	71
29	**Ca**	**Y**	**Cu**	**N**	**P**	**K**	**Mn**	**Fe**	**S**	**Mg**	**CC**	**Zn**	**pH**	**EC**	**OC**
	-60	-59	-31	-29	-12	-10	7	9	11	15	19	26	27	34	53
30	**P**	**Y**	**Cu**	**Ca**	**N**	**Mg**	**Zn**	**K**	**S**	**Fe**	**CC**	**Mn**	**pH**	**EC**	**OC**
	-174	-87	-57	-43	-4	0	4	21	30	30	35	38	54	65	86
31	**Y**	**Cu**	**N**	**Ca**	**Zn**	**Fe**	**S**	**CC**	**Mg**	**Mn**	**OC**	**K**	**pH**	**P**	**EC**
	-54	-48	-33	-5	3	6	8	8	9	12	12	14	17	25	26
32	**Y**	**S**	**Ca**	**Mg**	**Mn**	**K**	**Cu**	**N**	**Zn**	**OC**	**CC**	**Fe**	**EC**	**pH**	**P**
	-67	-11	-9	-5	-5	-4	-4	0	2	7	9	12	13	13	49
33	**Y**	**N**	**Cu**	**Ca**	**S**	**Mn**	**Mg**	**K**	**Fe**	**Zn**	**EC**	**CC**	**pH**	**P**	**OC**
	-105	-60	-22	-5	-2	3	5	7	15	19	27	27	28	30	33
34	**Y**	**P**	**Cu**	**K**	**S**	**N**	**Ca**	**Zn**	**Fe**	**CC**	**OC**	**pH**	**Mn**	**Mg**	**EC**
	-53	-25	-23	-22	-20	-5	-3	0	7	13	15	23	23	30	38
35	**P**	**Ca**	**Y**	**S**	**N**	**Cu**	**Mg**	**Zn**	**Mn**	**Fe**	**CC**	**pH**	**K**	**OC**	**EC**
	-445	-57	-49	-27	12	13	26	28	38	48	63	64	90	96	101
36	**Y**	**Ca**	**N**	**Cu**	**Mn**	**S**	**Fe**	**K**	**Zn**	**P**	**pH**	**CC**	**Mg**	**OC**	**EC**
	-68	-20	-16	-12	-11	-6	-2	-1	6	7	17	19	24	31	32

excepting sites 8, 22, 32 and 35. Indices also showed insufficiency of Ca, Mg and S in majority of the soils under *mrig* flush.

Regarding micronutrients, Cu indicates negative index in most of the orchards. Howerver Zn, was in sufficiency (positive index) in all the orchards except site No. 8 in which it was mean to balance.

In site 17 DRIS reflects most required nutrient as N followed by Cu > P > K only. Other nutrients showed positive indices. As such N is most yield-limiting nutrient in this case.

Besides yield limiting effect of negative index showing nutrients low yield might have been contributed by excess $CaCO_3$ which showed most positive index in sites 3, 12, 21 and 24. Likewise nutrient indices can be interpreted. Nutrients with positive indices are in sufficient ranges and may not be limiting in terms of quantity. But the nutrient insufficiency may result in luxury consumption and may disturb nutrient balance causing low yield. However, such effects need to be quantified with further studies of parameter such as $CaCO_3$ may definitely cause other nutrients such as P and micronutrients unavailable and limiting.

The nutrient diagnosis made by DRIS indices indicated that more than two nutrients were limiting for yield in low yielding orchards. The orchards suffering from inadequacy of nutrients can be diagnosed from indices and order of limiting can be fixed.

The fertilizer recommendation is then made on the basis of order of requirement of particular nutrient.

4.6.1.3 Leaf nutrient indices for *ambia* flush.

The data regarding the DRIS indices for leaf nutrient status in low yielding orchards from *ambia* flush are presented in Table 11. In first low yielding orchard DRIS indices for *ambia* leaf inferred that Cu was the most yield limiting followed by Fe > Mn. Other nutrients showed positive indices and as such are in balanced or excess quantity. In second low yielding orchard, DRIS reflected least requirement of nitrogen and only iron and copper were most yield limiting. All other nutrients

Table 11 : DRIS indices with order of requirement of leaf nutrient for low yielding Nagpur mandarin orchards in *ambia* flush

Site No.	Order of requirement from left to right										
1	Y	Cu	Fe	Mn	Ca	S	K	N	P	Zn	Mg
	-5711	-344	-226	-131	417	650	757	772	898	1044	1874
2	Y	Fe	Cu	Zn	Mn	K	S	P	Mg	Ca	N
	-5695	-161	-11	161	231	412	427	611	1204	1309	1511
3	Y	Cu	S	Mn	Ca	Fe	Zn	K	N	P	Mg
	-4500	-1797	-70	100	131	171	445	450	625	923	3522
4	Y	S	Ca	Cu	Fe	Zn	N	P	K	Mn	Mg
	-3329	-484	-167	-125	426	427	556	559	589	591	957
5	Y	Cu	K	Mn	Ca	S	Fe	Zn	N	Mg	P
	-5190	-1463	-370	-92	-88	194	417	600	851	2129	3012
6	Y	Cu	Fe	Ca	Mn	K	N	S	Zn	P	Mg
	-6743	-1281	-406	-169	255	562	830	1029	1458	2123	2342
7	Y	Cu	Ca	Mn	Fe	S	N	Zn	P	K	Mg
	-4881	-901	-363	-294	86	348	555	610	1098	1679	2063
8	Y	Cu	Mn	S	Fe	P	Ca	N	Zn	K	Mg
	-4170	-805	-185	47	164	180	538	616	869	1249	1498
9	Y	Cu	Mn	S	Ca	Fe	Zn	N	Mg	P	K
	-3319	-283	-82	-39	9	356	412	584	722	753	885
10	Y	K	Ca	Mn	S	Cu	N	P	Zn	Fe	Mg
	-4726	-18	6	49	56	86	569	596	639	978	1765
11	Y	Cu	Mn	Ca	N	S	P	Zn	Fe	K	Mg
	-4134	-887	-223	-17	353	360	690	834	956	968	1101
12	Y	Cu	S	Ca	Mn	N	Fe	Zn	Mg	P	K
	-3745	-1856	-645	-544	-3	402	414	738	1131	1941	2168

...continued...

Site No.	Order of requirement from left to right										
13	Y	Mn	Ca	Fe	S	K	Zn	Mg	Cu	P	N
	-5114	-213	154	270	373	418	459	576	807	1108	1163
14	Y	Cu	Mn	S	Ca	Zn	N	Fe	P	K	Mg
	-4658	-655	-220	127	160	331	566	615	695	1235	1803
15	Y	Fe	Ca	S	Zn	N	Mn	Cu	K	P	Mg
	-5244	-431	122	131	195	589	724	756	992	1004	1162
16	Y	Mn	S	Zn	Fe	P	Cu	N	Ca	K	Mg
	-3798	-762	81	123	152	238	365	558	716	753	1573
17	Y	S	Mn	Zn	Cu	Ca	Fe	N	K	P	Mg
	-7157	141	245	345	397	547	737	868	1252	1284	1341
18	Y	Cu	K	P	Mn	Zn	Fe	N	Ca	Mg	S
	-4544	-997	-464	85	199	520	562	836	1110	1288	1405
19	Y	Cu	Fe	S	Mn	K	P	N	Ca	Zn	Mg
	-4666	-236	-129	30	89	217	378	527	776	1315	1698
20	Y	Cu	Mn	S	P	Zn	Ca	N	Fe	K	Mg
	-3920	-805	-683	-345	82	330	352	623	763	1172	2430
21	Y	Cu	S	Ca	Mn	Fe	Zn	N	P	Mg	K
	-3898	-707	-399	-248	30	55	337	526	917	1340	2048
22	Y	Mn	Ca	S	K	Fe	Cu	N	Zn	P	Mg
	-3140	-664	-293	-261	-115	-37	16	298	747	977	2472
23	Y	Mn	Cu	Zn	Fe	P	S	N	K	Ca	Mg
	-4543	-259	-185	-35	284	368	574	601	709	734	1752
24	Y	Cu	S	K	Ca	Mn	Zn	Fe	N	Mg	P
	-5359	-184	-124	60	182	241	333	436	826	1305	2285

...continued...

Site No.	Order of requirement from left to right										
25	Y	Cu	Mn	Ca	S	Zn	Fe	N	K	P	Mg
	-7252	-1567	65	99	342	623	825	1181	1293	2182	2209
26	Y	Cu	Ca	Mn	S	Fe	K	N	Zn	P	Mg
	-8422	-1011	328	354	611	720	772	1151	1205	1435	2857
27	Y	Cu	Mn	S	K	Ca	Fe	N	Zn	Mg	P
	-8960	-98	-87	569	777	862	883	1174	1268	1802	1811
28	Y	Ca	Cu	Mn	Zn	S	Fe	P	K	N	Mg
	-7000	-101	-61	242	537	564	610	984	1013	1052	2160
29	Y	Cu	Fe	Ca	S	Mn	Zn	P	N	K	Mg
	-7976	-1169	-109	374	464	512	615	1400	1464	1591	2834
30	Y	Ca	K	Zn	Mn	Fe	N	S	Mg	Cu	P
	-7246	-463	-284	26	263	340	892	1040	1458	1641	2333
31	Y	Ca	K	Mn	Fe	S	Cu	Zn	N	Mg	P
	-4114	-433	-223	-114	107	216	294	473	601	1524	1669
32	Y	Cu	S	Fe	Zn	P	N	K	Ca	Mn	Mg
	-3682	-1436	-362	144	277	294	667	700	907	944	1544
33	Y	S	Cu	P	Fe	Zn	N	Ca	Mn	K	Mg
	-7619	-181	154	356	421	730	929	1004	1223	1360	1622
34	Y	Cu	S	Ca	Fe	N	Zn	P	Mn	Mg	K
	-4105	-957	-151	-11	245	343	528	751	909	1042	1406
35	Y	Ca	Cu	Mn	Fe	Zn	N	S	K	Mg	P
	-6331	-655	-260	-152	350	491	680	1012	1192	1526	2145
36	Y	Cu	Ca	Mn	Zn	K	S	N	Fe	P	Mg
	-5307	-651	-93	-13	207	288	482	773	1238	1519	1559
37	Y	Zn	S	Cu	N	Ca	Fe	K	P	Mg	Mn
	-7580	-570	21	155	263	696	708	1051	1394	1806	2056
38	Y	Ca	S	Fe	Mn	N	K	Cu	Zn	Mg	P
	-3904	-331	-246	-160	184	256	270	329	599	921	2084

showed positive indices. In third orchard also only copper and sulphur were found to be most yield limiting. Likewise, the order of requirement of fourth and subsequent low yielding orchards can easily be detected. In site 13 only Mn showed negative index and other showed higher positive indices. The excess of some of these nutrients might have also limited yield. Site 17 showed that all the nutrients were in optimum to excess. In relation to soil (Table 9) for site 17, all the nutrients were found to be balanced in soil excepting Ca and Mg. In spite of deficiency of Ca and Mg in soil, their absorption in plants was not affected since $CaCO_3$ was in excess. In this case yield might have been reduced because of excess nutrients or other factor like soil and weather condition, disease, insects, plant physiological condition, etc. In sosme orchards only single nutrient showed yield limiting effect. Such orchards were 10, 13, 15, 16, 25, 26, 33 and 37 indicating negative indices of K, Cu, Fe, Mn, Cu, Cu, S and Zn respectively. In such cases the yield might have also been lowered by one or more excess nutrient and/or other environmental and uncontrollable factors. In rest of orchards more than two nutrients were found to be yield limiting which also carried the nutrient imbalance in plant.

To improve the nutritional balance and to increase the chances of obtaining higher fruit yield, it is necessary to increase the amount of those nutrients showing negative index and should be recommended for citrus under *ambia* flush soils.

4.6.1.4 Leaf nutrient indices for *mrig* flush

DRIS indices for low yielding orchards from *mrig* flush (Table 12) showed the similar pattern as described under *ambia* flush. DRIS indices of mandarin leaf in first and second orchard inferred most relatively insufficiency of Mn followed by Cu. Other nutrients showed positive indices. DRIS indices for third and fourth orchards reflected that Cu and Mn were the first and second limiting nutrients whereas the order of requirement Cu > Mn > Fe in third and Cu > Mn > S in fourth orchard. In this way order of requirement of all low yielding orchards is presented in Table 12. Orchard site number 11 showed that only Cu was yield limiting and remaining nutrients were in adequate amount in leaves. The low yield of this orchard might have also been due to some excessive nutrients.

Table 12 : DRIS indices with order of requirement of leaf nutrient for low yielding Nagpur mandarin orchards in *mrig* flush

Site No.	Order of requirement from left to right										
1	**Y**	**Mn**	**Cu**	**Ca**	**P**	**S**	**Mg**	**K**	**Fe**	**Zn**	**N**
	-2028	-158	-125	51	70	136	158	163	213	713	809
2	**Y**	**Mn**	**Cu**	**Mg**	**K**	**S**	**P**	**Ca**	**Fe**	**Zn**	**N**
	-2363	-184	-154	93	113	145	148	164	234	829	976
3	**Y**	**Cu**	**Mn**	**Fe**	**S**	**K**	**Mg**	**Ca**	**P**	**Zn**	**N**
	-1528	-650	-64	-14	84	114	122	207	224	666	840
4	**Y**	**Cu**	**Mn**	**S**	**Mg**	**Zn**	**P**	**Ca**	**Fe**	**K**	**N**
	-2470	-1458	-500	-120	208	487	505	580	632	988	1149
5	**Y**	**Mn**	**S**	**Mg**	**Ca**	**Zn**	**Fe**	**K**	**N**	**Cu**	**P**
	-3454	-1904	-44	105	314	425	569	592	903	981	1512
6	**Y**	**Fe**	**Mn**	**S**	**Ca**	**P**	**K**	**Mg**	**N**	**Zn**	**Cu**
	-2943	-539	-414	27	69	148	355	532	741	762	1262
7	**Y**	**Mn**	**Cu**	**Fe**	**S**	**K**	**Zn**	**Mg**	**P**	**Ca**	**N**
	-2490	-301	-275	-143	-132	79	85	339	665	695	1478
8	**Y**	**Mn**	**P**	**Zn**	**Mg**	**Fe**	**Cu**	**N**	**Ca**	**S**	**K**
	-2271	-433	-297	-98	29	165	457	459	488	707	795
9	**Y**	**Cu**	**Mg**	**P**	**Mn**	**S**	**Fe**	**Zn**	**Ca**	**K**	**N**
	-2249	-691	-513	31	97	119	161	324	516	997	1208
10	**Y**	**Cu**	**Mn**	**Fe**	**K**	**S**	**Mg**	**Ca**	**Zn**	**N**	**P**
	-4803	-276	-13	99	184	279	482	698	875	1047	1429
11	**Y**	**Cu**	**S**	**Mn**	**K**	**Mg**	**Zn**	**Fe**	**P**	**Ca**	**N**
	-4681	-114	96	192	226	304	443	577	679	759	1518
12	**Y**	**Cu**	**S**	**Mn**	**Ca**	**Fe**	**P**	**K**	**Zn**	**Mg**	**N**
	-2103	-234	-83	5	31	115	143	312	335	698	781

...continued...

Site No.	Order of requirement from left to right										
13	Y	Mn	Cu	P	K	Ca	Fe	S	Mg	N	Zn
	-2842	-478	-459	-72	70	89	412	578	828	925	949
14	Y	Mg	Mn	Cu	P	Fe	K	S	Ca	N	Zn
	-2201	-203	-79	139	143	183	207	379	383	508	542
15	Y	Cu	Mg	Fe	Mn	S	Zn	P	Ca	K	N
	-2367	-739	-636	-483	-174	71	657	685	704	786	1496
16	Y	Cu	Mn	Fe	S	Ca	P	Zn	N	K	Mg
	-2348	-1274	-527	-145	56	247	527	552	735	1052	1124
17	Y	Cu	Mg	Fe	P	S	K	Mn	Zn	Ca	N
	-4442	-853	-710	235	349	548	570	772	807	1044	1680
18	Y	Mn	Fe	K	Mg	S	P	Ca	Zn	N	Cu
	-4107	-521	-486	248	300	318	377	688	728	1180	1274
19	Y	Fe	P	N	S	K	Zn	Ca	Cu	Mg	Mn
	-3811	-1374	-219	111	388	416	470	594	605	992	1829
20	Y	Cu	Zn	Mg	S	N	Mn	Fe	K	Ca	P
	-2251	-347	-130	-56	45	109	129	171	608	640	1081
21	Y	Zn	Cu	Mn	S	Fe	Ca	P	N	K	Mg
	-2564	-233	-146	42	78	180	334	488	489	570	762
22	Y	Cu	Fe	S	Zn	K	Mn	Mg	Ca	P	N
	-2567	-754	-367	-256	-69	120	240	363	656	1233	1402
23	Y	Cu	Mn	S	Ca	Fe	K	Mg	Zn	N	P
	-5139	-1002	-465	-279	277	282	446	753	800	1858	2469
24	Y	Mn	Cu	Ca	Fe	K	Zn	P	S	N	Mg
	-1969	-1563	-895	31	118	195	340	534	726	1191	1292

...continued...

Site No.	Order of requirement from left to right										
25	Y	P	Mn	K	Mg	Zn	Cu	Fe	Ca	S	N
	-2263	-427	-91	56	128	130	288	295	429	693	761
26	Y	Cu	Mn	S	Zn	K	Fe	Mg	Ca	N	P
	-2769	-268	-171	-73	94	279	365	372	444	608	1119
27	Y	K	Cu	S	Mn	Fe	Zn	Ca	N	Mg	P
	-3373	-224	-203	-141	29	286	461	508	767	801	1091
28	Y	Cu	Mn	Fe	K	S	Mg	Ca	Zn	P	N
	-2591	-747	-560	-255	-32	313	564	609	630	938	1130
29	Y	Cu	Mn	Fe	P	Mg	S	N	Zn	Ca	K
	-2811	-856	-464	64	97	389	532	605	702	720	1023
30	Y	Cu	Fe	Zn	P	Mn	Ca	S	K	Mg	N
	-4837	-970	-154	-23	74	133	274	581	1401	1614	1908
31	Y	Cu	Mn	Mg	Zn	Fe	Ca	S	K	N	P
	-2927	-1484	-511	-464	149	237	368	469	814	1115	2234
32	Y	Cu	Zn	Mn	S	Ca	Fe	K	N	Mg	P
	-3915	-756	-231	-149	48	369	472	730	1006	1157	1269
33	Y	Mg	Mn	Cu	Fe	K	S	Ca	P	Zn	N
	-4637	-829	-31	45	478	529	537	652	653	709	1894
34	Y	Fe	Cu	P	Mn	Zn	Mg	S	K	Ca	N
	-2748	-240	-234	58	165	180	195	218	509	724	1174
35	Y	Mn	Cu	S	P	Fe	Zn	Mg	N	K	Ca
	-2845	-549	-149	-32	-10	221	266	427	659	754	1258
36	Y	Cu	Mn	Mg	Fe	Zn	S	Ca	P	N	K
	-3327	-700	-664	-33	51	169	472	747	851	1178	1256

The data revealed that the yield is affected due to the imbalance condition of leaf nutrient status in Nagapur mandarin. The application of fertilizer containing the yield limiting i.e. negative index showing nutrients is expected to increase the yield. In all orchards two or more elements are to be needed for increasing the yield excepting site 11.

4.6.2 High yielding subpopulation

High yields can only be obtained when all controllable and incontrollable yield factors are favourable or optimal. As one or more of the yield factors become unfavourable, crop performance will decrease and in general the more unfavourable the factor or the greater the numbers of unfavourable factors, the lower will be the yield. Despite the fact that all nutritional factors may be favourable in a given situation, high yields will not necessarily be obtained because a single factor such as a severe pest infestation, can render the crop barren. In present investigation the data are used to illustrate the ability of the DRIS approach to make meaningful diagnosis at high yield levels.

While dividing population into two categories *viz.* low and high yielding single cut off value was used. High yielding orchards having yield nearer to this cut off value can sorted out in which further increase in yield is possible using DRIS. In present investigation DRIS has been expanded to include nutrient ratios with yield (Y). In this case yield was considered as additional constituent and an index was calculated for yield as for other parameters. In fact, yield index is precisely used for sorting the high yielding orchards in which yield level can further increased economically. In case of high yielding subpopulation positive 'Y' index was observed in most cases with balanced nutritional status. In some cases one or other parameter showed limiting or excess. Since yield index was positive, correction of these factors were not going to contribute for further increase in yield. However, where yield indices are negative or nearer to optimum there is some scope of increasing yields further even under high yielding situations. This can be achieved by providing the limiting nutrients so that better utilization of nutrients in higher amount can be effected resulting in still higher yield.

Data regarding DRIS indices for high yielding orchards is presented in Tables 13 and 15 for *ambia* flush for soil and leaf respectively. For *mrig* flush DRIS indices for soil and leaf are presented in Tables 14 and 16 respectively. Orchard site showing negative index values or values nearer to zero, where chances for increase in yield are possible are presented in Table 17. The number of orchards found in such situation were 15 under *ambia* and 14 under *mrig* flush.

Table 13 : DRIS indices with order of requirement of soil parameters for high yielding Nagpur mandarin orchards in *ambia* flush

Site No.	Order of requirement from left to right														
1	Mg	Ca	EC	Mn	Cu	pH	N	CC	Fe	Y	S	Zn	K	P	OC
	-31	-10	-3	-2	-2	-2	-1	0	1	4	4	6	9	11	16
2	N	S	Mn	Zn	EC	Cu	Y	CC	pH	Ca	P	OC	Fe	Mg	K
	-22	-12	-9	-6	-4	-1	0	0	3	3	4	6	11	13	14
3	Cu	Zn	S	Mn	EC	P	N	OC	CC	Y	Fe	pH	Ca	Mg	K
	-35	-10	-5	-5	-2	-1	1	2	2	4	5	6	6	12	19
4	N	Cu	OC	CC	Y	EC	P	Mg	pH	Mn	Ca	K	Fe	S	Zn
	-18	-7	-6	-5	-5	-3	-2	-2	0	3	5	5	5	7	20
5	EC	CC	Mg	pH	Mn	Cu	Zn	S	Y	OC	N	Fe	Ca	P	K
	-12	-12	-11	-4	-3	-3	-2	1	2	2	6	6	8	10	14
6	CC	Mn	Mg	pH	Cu	Zn	EC	OC	Fe	K	N	Ca	P	S	Y
	-15	-7	-6	-5	-5	-4	-1	1	3	3	4	5	6	9	10
7	Cu	P	S	Mn	Fe	CC	N	pH	K	Y	Mg	Zn	OC	Ca	EC
	-18	-9	-8	-4	-4	-3	-2	1	4	4	4	7	8	9	11
8	Cu	CC	P	S	pH	Mn	Fe	EC	Mg	OC	Y	Ca	Zn	N	K
	-17	-7	-5	-4	-3	-1	-1	-1	2	2	3	3	8	10	11
9	EC	Mn	OC	Zn	CC	N	Ca	Y	Fe	pH	P	Cu	S	Mg	K
	-13	-9	-8	-7	-6	-5	-5	-2	0	2	5	7	10	14	16
10	Mg	Y	N	K	P	OC	S	EC	Zn	pH	Cu	Ca	CC	Fe	Mn
	-19	-14	-10	-10	-9	-7	-5	-3	4	6	7	12	15	15	19
11	P	Zn	Fe	CC	N	Ca	OC	Y	pH	EC	K	S	Mn	Cu	Mg
	-16	-15	-14	-12	-8	-6	-6	-5	-4	-1	3	11	17	24	31
12	Fe	Y	S	Mg	pH	P	Cu	Ca	N	K	CC	Zn	Mn	OC	EC
	-8	-6	-6	-4	-3	-3	0	1	1	2	2	3	4	7	9

...continued...

Site No.	Order of requirement from left to right														
13	Ca	Zn	pH	CC	OC	Mn	K	S	Y	Fe	Cu	P	N	Mg	EC
	-8	-7	-5	-4	-2	-1	0	0	0	2	3	3	3	7	11
14	P	S	Mn	Zn	pH	Mg	CC	Ca	OC	Cu	N	Y	Fe	K	EC
	-28	-10	-5	-5	-4	-2	-1	0	2	3	3	4	11	15	17
15	S	P	Cu	Mn	Ca	CC	Mg	pH	OC	Y	N	Fe	EC	K	Zn
	-14	-10	-7	-6	-5	-2	0	0	2	3	4	7	9	9	10
16	Mg	CC	EC	Cu	pH	OC	Mn	S	N	Fe	Y	P	Zn	Ca	K
	-17	-10	-7	-6	-5	-5	-4	-1	3	4	5	9	9	10	14
17	OC	K	CC	Mg	EC	Mn	pH	Fe	N	S	Y	Ca	Cu	P	Zn
	-22	-14	-14	-8	-8	-4	-1	2	3	7	9	10	10	14	14
18	EC	Mg	Mn	CC	OC	K	Zn	pH	Fe	S	Ca	Y	N	Cu	P
	-18	-10	-9	-8	-7	-5	-5	-2	3	3	4	6	7	19	20
19	OC	P	EC	K	S	Zn	CC	Mg	Mn	Cu	Fe	N	pH	Ca	Y
	-96	-14	-13	-2	3	6	6	8	8	8	9	14	14	22	28
20	S	Fe	Zn	Mn	pH	EC	Ca	OC	P	Y	Cu	CC	Mg	N	K
	-17	-7	-6	-5	-2	-1	0	2	4	5	5	5	5	6	8
21	S	Fe	Ca	Mn	pH	P	OC	Cu	CC	Y	N	Zn	K	Mg	EC
	-12	-8	-7	-6	-6	-3	1	2	2	5	6	6	6	7	8
22	EC	OC	K	N	Mn	Ca	pH	CC	Cu	P	S	Mg	Fe	Y	Zn
	-17	-10	-9	-9	-4	-3	1	2	3	3	5	7	9	10	11
23	EC	CC	OC	K	P	Ca	pH	Cu	N	Mg	Fe	Mn	Zn	Y	S
	-23	-13	-11	-5	-4	-3	1	2	3	6	6	8	8	10	14
24	K	CC	OC	S	EC	Fe	Ca	Y	Zn	pH	N	Mn	Cu	Mg	P
	-23	-15	-10	-9	-8	-6	-2	-1	-1	3	7	7	8	20	29
25	Cu	Mg	N	OC	K	Zn	EC	Fe	Y	CC	Mn	Ca	pH	S	P
	-17	-13	-11	-10	-8	-8	0	4	5	5	7	7	8	15	15

...continued...

Site No.	Order of requirement from left to right														
26	EC	OC	Zn	K	Mg	N	Mn	Fe	CC	pH	P	Ca	Cu	Y	S
	-23	-6	-5	-5	-4	-2	-2	0	3	4	6	7	8	9	10
27	Mg	Zn	OC	K	P	N	pH	Fe	Ca	Mn	CC	EC	Y	S	Cu
	-24	-14	-8	-8	-7	-6	-3	0	3	4	6	7	7	17	26
28	K	Zn	Ca	OC	EC	Mn	CC	Mg	pH	N	Fe	P	S	Cu	Y
	-16	-10	-9	-7	-5	-5	-5	-2	0	3	3	8	11	13	21
29	Y	EC	Fe	K	S	Cu	Mn	P	Mg	pH	Zn	N	Ca	OC	CC
	-23	-15	-10	-6	-3	-2	2	4	4	4	5	6	8	11	15
30	EC	Fe	K	CC	Ca	pH	Cu	Zn	N	Mg	P	S	OC	Mn	Y
	-17	-12	-11	-7	-6	-5	-5	-2	0	2	6	11	11	12	24
31	EC	Ca	Zn	Fe	pH	Cu	CC	K	P	OC	S	Mn	N	Mg	Y
	-16	-12	-11	-9	-6	-6	-5	0	1	3	6	6	12	17	19
32	Y	Mg	Mn	Zn	N	Ca	Fe	pH	OC	CC	K	Cu	P	S	EC
	-22	-14	-6	-6	-6	-5	-3	-3	2	4	6	7	10	13	22
33	Mn	Fe	Zn	Ca	P	K	pH	Y	Mg	CC	OC	N	Cu	S	EC
	-19	-9	-8	-7	-6	-3	-2	2	3	3	4	6	11	11	15
34	Mg	OC	S	Fe	pH	Mn	Zn	N	Y	EC	CC	K	P	Ca	Cu
	-12	-6	-6	-4	-3	-3	-1	2	3	4	4	4	4	6	7
35	S	Fe	Mn	Zn	Y	P	EC	pH	Mg	OC	CC	N	Cu	Ca	K
	-15	-8	-4	-4	-2	-1	0	0	0	2	5	6	7	7	7
36	Mg	K	CC	Y	pH	EC	Cu	OC	Mn	Ca	Zn	Fe	N	S	P
	-11	-10	-10	-6	-5	-3	-3	0	0	4	6	7	9	10	12
37	S	K	EC	Mg	pH	Zn	Fe	Mn	CC	Y	Ca	Cu	N	OC	P
	-21	-9	-7	-7	-6	-4	-3	-2	0	1	3	9	13	14	18

Table 14 : DRIS indices with order of requirement of soil parameters for high yielding Nagpur mandarin orchards in *mrig* flush

Site No.	Order of requirement from left to right														
1	CC	Y	Mg	K	N	pH	Zn	OC	S	Mn	EC	Fe	Ca	Cu	P
	-15	-13	-11	-8	-8	-5	-4	0	4	5	7	8	8	17	17
2	Y	CC	K	N	OC	Ca	Fe	Mn	pH	Zn	S	EC	Mg	Cu	P
	-22	-18	-13	-9	-8	-1	0	1	1	3	6	6	9	18	26
3	K	OC	S	CC	N	Fe	Ca	Zn	pH	EC	Y	Mn	P	Mg	Cu
	-14	-9	-8	-7	-7	-5	-4	-3	-1	4	5	7	10	14	18
4	OC	K	CC	Zn	Ca	Fe	N	pH	S	EC	Cu	Y	Mn	Mg	P
	-19	-9	-7	-5	-4	-4	-4	-2	2	5	5	5	7	14	17
5	Mn	Mg	S	Fe	pH	K	P	OC	Ca	N	EC	CC	Y	Zn	Cu
	-16	-10	-10	-4	-2	-2	-1	-1	1	5	5	6	7	8	15
6	S	Mg	Mn	Fe	K	N	OC	Cu	Y	pH	P	Zn	Ca	CC	EC
	-15	-8	-7	-6	-2	-2	-1	0	1	3	4	7	7	9	10
7	K	CC	EC	Mg	pH	Zn	OC	Fe	Ca	Mn	N	Cu	S	Y	P
	-28	-14	-13	-13	-2	-2	-1	0	1	5	7	11	11	15	22
8	Mg	Mn	CC	OC	K	Fe	EC	N	Cu	pH	Ca	S	Zn	P	Y
	-15	-11	-7	-7	-3	-1	-1	-1	0	1	4	4	11	11	13
9	EC	Cu	Zn	P	Mg	K	pH	OC	Mn	CC	Fe	Ca	S	Y	N
	-17	-7	-6	-4	-3	-3	-1	0	2	3	4	5	8	8	10
10	Zn	EC	pH	Cu	Mg	CC	P	Fe	Y	Mn	OC	K	Ca	N	S
	-22	-12	-2	-2	-1	-1	-1	1	1	3	3	4	4	9	15
11	Y	S	EC	OC	N	P	Cu	Mn	pH	Fe	Ca	Zn	CC	Mg	K
	-14	-12	-9	-9	-8	1	1	2	2	2	3	6	8	13	14
12	Y	Cu	P	K	CC	Fe	Mn	Mg	pH	Zn	S	EC	Ca	N	OC
	-23	-16	-4	-3	-3	-2	0	1	1	3	5	7	9	11	13

...continued...

Site No.	Order of requirement from left to right														
13	Cu	EC	OC	Mn	P	Fe	N	K	Ca	pH	CC	Y	Zn	Mg	S
	-11	-11	-9	-7	-6	-4	-4	-3	-2	2	9	10	10	11	17
14	Cu	P	K	OC	Ca	EC	Mn	Zn	N	pH	Fe	Y	CC	Mg	S
	-17	-9	-4	-4	-3	-3	-2	-1	0	1	2	3	8	12	18
15	K	OC	P	Cu	CC	EC	Fe	N	Mg	Y	Mn	pH	Ca	Zn	S
	-13	-8	-8	-2	-2	-2	-1	0	2	3	3	3	5	9	10
16	CC	pH	EC	Cu	Fe	P	OC	Zn	Ca	N	Y	Mn	K	Mg	S
	-15	-7	-7	-6	-6	-5	-3	-2	1	2	6	6	7	12	18
17	Mg	Fe	CC	P	Mn	pH	EC	Cu	OC	Ca	Zn	N	Y	K	S
	-15	-5	-4	-4	-4	-2	0	1	1	1	3	4	5	7	10
18	CC	Cu	pH	S	Mn	Ca	Fe	Mg	EC	OC	P	Zn	Y	K	N
	-21	-10	-6	-4	-3	-3	-3	2	3	4	4	7	7	11	11
19	Fe	EC	pH	CC	N	OC	S	Ca	Y	Zn	Mg	P	K	Mn	Cu
	-23	-15	-12	-11	-10	-9	-1	0	1	6	11	11	12	18	23
20	OC	CC	Cu	K	P	EC	Mn	Zn	N	pH	Y	Ca	Fe	S	Mg
	-21	-10	-10	-5	-4	-4	-3	-2	1	3	4	8	9	12	22
21	CC	EC	pH	S	Fe	Mn	Cu	Mg	Zn	Y	OC	Ca	N	P	K
	-28	-25	-12	-9	-6	-5	-1	2	2	8	9	11	15	17	23
22	S	Mn	EC	pH	Cu	Fe	Zn	CC	Mg	Y	OC	N	P	Ca	K
	-22	-13	-12	-6	-2	-2	-1	0	3	4	5	7	8	8	21
23	Cu	Mn	EC	Fe	Ca	P	pH	Zn	OC	Y	N	CC	K	Mg	S
	-16	-10	-10	-8	-8	-5	-5	0	2	5	5	8	8	12	22
24	Zn	Mn	S	N	P	Mg	Cu	pH	EC	Y	CC	K	OC	Fe	Ca
	-16	-8	-7	-6	-3	-2	-1	1	3	4	5	7	7	7	11
25	EC	S	Mn	P	K	Ca	OC	Y	Zn	Mg	pH	CC	N	Fe	Cu
	-10	-10	-9	-3	-3	-2	0	1	2	3	4	5	6	7	9

...continued..

Site No.	Order of requirement from left to right														
26	Zn	Ca	Cu	Mn	EC	OC	K	CC	N	pH	Fe	Y	Mg	S	P
	-12	-9	-8	-4	-3	-3	-2	-1	2	3	3	3	10	10	12
27	Ca	Mn	Zn	N	OC	Mg	pH	EC	Cu	P	K	CC	S	Fe	Y
	-8	-4	-4	-3	-2	-2	-1	-1	0	0	1	4	5	6	9
28	N	Zn	P	S	Y	Mn	Mg	K	EC	OC	Ca	CC	Cu	Fe	pH
	-15	-10	-7	-6	-5	-2	-1	0	2	4	5	5	6	12	13
29	Zn	Mg	N	S	EC	Mn	pH	Y	OC	Fe	Cu	CC	Ca	P	K
	-12	-7	-7	-4	-2	-1	-1	0	1	1	2	2	9	9	10
30	P	CC	Y	pH	Fe	Mn	Mg	Cu	Zn	K	OC	Ca	S	EC	N
	-17	-7	-5	-5	-4	-1	-1	2	2	2	6	6	6	7	7
31	S	Cu	Mn	CC	P	pH	Fe	Ca	OC	Zn	N	EC	Mg	K	Y
	-14	-13	-9	-7	-6	-5	-5	2	3	3	6	8	11	13	13
32	Ca	Mg	pH	CC	N	S	Fe	EC	Zn	Y	Cu	OC	P	K	Mn
	-15	-13	-12	-12	-9	-6	-5	-5	2	8	9	9	10	18	22
33	OC	S	N	EC	K	pH	P	Fe	CC	Ca	Mg	Y	Zn	Mn	Cu
	-18	-18	-14	-11	-8	-3	-2	-1	6	7	8	8	9	15	23
34	S	Ca	pH	Fe	Zn	P	Y	CC	Mn	Cu	OC	Mg	N	EC	K
	-20	-14	-10	-9	-6	-5	-4	-3	5	6	6	6	9	13	25
35	Ca	S	Mn	pH	K	Mg	Zn	EC	N	Y	Cu	CC	Fe	OC	P
	-14	-13	-8	-4	-3	-2	-2	-2	2	2	4	5	7	10	17
36	Mg	P	Zn	K	Mn	S	pH	CC	Fe	EC	OC	Ca	N	Y	Cu
	-27	-16	-4	-3	-2	1	1	4	4	6	6	7	7	7	8
37	N	Mg	Fe	Zn	K	Cu	S	P	Ca	EC	CC	Y	Mn	OC	pH
	-16	-10	-10	-7	-7	-6	-4	-1	1	3	5	7	8	12	25
38	N	Mg	Cu	P	Y	Zn	K	EC	S	CC	Fe	Mn	Ca	OC	pH
	-22	-17	-13	-8	-5	-5	-3	2	2	5	5	6	7	12	34
39	N	Zn	P	S	Y	Mn	Mg	K	EC	OC	Ca	CC	Cu	Fe	pH
	-37	-5	-5	-4	-3	-2	0	0	2	3	4	5	7	7	29

Table 15 : DRIS indices with order of requirement of leaf nutrient for high yielding Nagpur mandarin orchards in *ambia* flush

Site No.	Order of requirement from left to right										
1	Ca	Mn	Zn	K	Fe	Cu	Y	S	N	Mg	P
	-585	-390	-137	-137	-74	-42	30	170	198	338	628
2	N	S	Mn	Mg	Y	Cu	P	Zn	K	Fe	Ca
	-525	-302	-209	-141	-108	-20	37	61	193	253	760
3	Mn	K	P	Y	S	Fe	N	Zn	Ca	Mg	Cu
	-268	-235	-150	-118	-114	-89	-47	-44	228	235	602
4	Y	Mg	Cu	Zn	Fe	N	P	K	S	Ca	Mn
	-511	-304	-263	-158	-60	-6	2	109	280	388	522
5	Cu	N	Ca	S	Y	Mn	Fe	K	Mg	P	Zn
	-973	-602	-460	-126	24	64	313	339	452	480	489
6	Cu	Ca	N	Mn	S	K	Fe	P	Zn	Y	Mg
	-956	-765	-273	-148	113	150	283	360	370	378	486
7	Cu	S	Mn	P	Fe	N	Mg	Y	Zn	K	Ca
	-556	-142	-129	-91	-46	55	60	90	170	290	300
8	Cu	K	Mn	S	Fe	N	P	Y	Zn	Ca	Mg
	-408	-170	-79	-68	-18	-11	36	113	117	242	246
9	Y	Ca	Fe	Zn	K	Mg	Mn	N	S	P	Cu
	-370	-358	-346	-77	-13	17	32	46	93	421	556
10	Y	S	P	Cu	K	Ca	N	Mg	Zn	Fe	Mn
	-1578	-292	-230	-20	45	74	159	358	363	432	688
11	Fe	Mg	Y	K	N	P	Zn	Ca	S	Cu	Mn
	-621	-474	-451	-349	-340	-145	-123	311	439	829	924
12	Zn	Fe	Y	K	P	Mg	N	S	Ca	Cu	Mn
	-407	-246	-200	-176	10	71	109	122	153	217	347

...continued...

Site No.	Order of requirement from left to right										
13	**K**	**N**	**Mg**	**Y**	**Cu**	**S**	**P**	**Mn**	**Zn**	**Ca**	**Fe**
	-273	-139	-70	-67	-64	-34	-5	131	148	184	190
14	**P**	**S**	**Mn**	**Cu**	**Ca**	**Zn**	**N**	**Y**	**K**	**Mg**	**Fe**
	-1161	-414	-177	-22	19	80	177	207	231	299	760
15	**P**	**S**	**Mn**	**Ca**	**Y**	**Cu**	**Zn**	**N**	**Mg**	**K**	**Fe**
	-328	-263	-193	2	7	33	36	75	112	221	298
16	**Cu**	**Ca**	**Y**	**S**	**N**	**Fe**	**K**	**Mg**	**Mn**	**Zn**	**P**
	-646	-478	-158	-27	48	128	133	149	154	162	536
17	**Ca**	**Mn**	**Fe**	**Cu**	**N**	**Zn**	**S**	**Y**	**K**	**Mg**	**P**
	-1523	-639	-53	-30	-16	53	78	198	234	246	1454
18	**Ca**	**Mn**	**Zn**	**Fe**	**Mg**	**Y**	**N**	**S**	**K**	**Cu**	**P**
	-926	-668	-64	-38	-34	21	59	70	182	399	999
19	**Mn**	**P**	**S**	**Cu**	**N**	**Fe**	**Ca**	**K**	**Mg**	**Zn**	**Y**
	-384	-270	-226	-165	-127	-78	51	111	161	370	557
20	**S**	**Ca**	**N**	**Zn**	**Fe**	**K**	**Mn**	**Y**	**Mg**	**Cu**	**P**
	-416	-241	-137	-136	-16	-7	23	121	152	186	471
21	**Zn**	**N**	**S**	**P**	**Fe**	**Mn**	**Mg**	**K**	**Cu**	**Ca**	**Y**
	-217	-196	-184	-71	-42	-15	-6	84	88	229	331
22	**Mn**	**Cu**	**Ca**	**P**	**N**	**S**	**Mg**	**K**	**Y**	**Zn**	**Fe**
	-530	-256	-161	-47	9	73	138	159	160	173	284
23	**P**	**Cu**	**Ca**	**K**	**Zn**	**N**	**Mg**	**Y**	**Fe**	**S**	**Mn**
	-310	-249	-192	-21	-14	38	40	85	107	188	328
24	**N**	**Y**	**Ca**	**S**	**Fe**	**Cu**	**Zn**	**Mg**	**Mn**	**K**	**P**
	-597	-297	-297	-290	-19	30	86	128	136	138	983

...continued...

Site No.	Order of requirement from left to right										
25	Cu	Ca	Mn	Fe	N	Zn	Y	S	K	P	Mg
	-1213	-460	-304	-168	5	36	40	340	444	619	662
26	Ca	Fe	Mn	Zn	K	N	S	Mg	Y	Cu	P
	-476	-265	-219	-188	-107	89	95	130	194	370	376
27	K	P	Ca	N	Mg	Zn	Fe	Mn	Cu	Y	S
	-413	-192	-168	-97	-96	2	113	122	148	151	429
28	Ca	Mn	Mg	N	Fe	K	Zn	S	Cu	P	Y
	-824	-305	-226	-195	-98	-47	-31	170	304	458	795
29	Y	Cu	Fe	K	S	N	Zn	P	Ca	Mg	Mn
	-1531	-324	-199	-82	-41	33	146	205	512	628	653
30	Fe	Ca	Cu	Mg	N	K	Zn	S	Mn	P	Y
	-527	-514	-463	-326	-309	-83	-46	82	490	540	1157
31	Mg	K	Fe	Zn	N	Cu	P	Ca	S	Mn	Y
	-564	-550	-432	-162	-145	-66	-31	127	307	507	1009
32	Y	Ca	Mn	Fe	Zn	N	Mg	K	Cu	S	P
	-1517	-643	-219	-90	-74	55	196	364	425	696	807
33	Zn	N	K	Fe	Mg	Mn	P	Y	Ca	S	Cu
	-453	-425	-314	-283	-276	-122	20	238	286	488	841
34	Mn	Zn	K	N	S	Fe	Y	P	Mg	Ca	Cu
	-249	-249	-242	-155	-101	36	73	85	107	218	476
35	S	Mg	Mn	Y	Zn	P	N	K	Fe	Ca	Cu
	-334	-271	-153	-150	-117	-47	-4	43	151	337	545
36	Y	Cu	Ca	K	Zn	Mn	N	Mg	S	Fe	P
	-641	-630	-267	-193	-33	3	181	187	197	339	856
37	S	Ca	Y	K	Zn	N	Fe	Mg	Mn	Cu	P
	-578	-516	-55	-8	-6	16	39	71	124	224	690

Table 16 : DRIS indices with order of requirement of leaf nutrient for high yielding Nagpur mandarin orchards in *mrig* flush

Site No.	Order of requirement from left to right										
1	Y	Mn	N	K	S	Mg	Zn	Fe	Ca	P	Cu
	-771	-412	-250	-195	-91	-62	68	148	233	352	982
2	Y	K	Mg	Ca	Fe	Zn	S	N	P	Mn	Cu
	-1086	-292	-268	-124	-44	15	29	55	64	417	1234
3	K	Ca	S	Zn	Fe	N	Mg	Y	Mn	P	Cu
	-523	-293	-284	-244	-199	-189	-87	84	84	122	1530
4	Fe	Zn	Mg	Ca	K	N	Mn	S	P	Y	Cu
	-258	-220	-83	-35	-18	22	27	54	118	160	232
5	Mn	Fe	P	S	Mg	N	K	Ca	Y	Zn	Cu
	-512	-368	-211	-141	-106	-40	-27	0	303	383	720
6	Mn	Cu	Fe	S	Y	P	K	Mg	Ca	N	Zn
	-378	-356	-260	-162	-23	-20	23	140	284	327	425
7	Zn	Mn	Fe	K	Mg	Ca	P	S	N	Y	Cu
	-316	-304	-238	-226	-85	-59	77	127	231	335	457
8	Cu	Mn	Fe	K	Ca	P	N	S	Mg	Y	Zn
	-430	-305	-192	-30	17	32	59	62	82	314	390
9	Zn	Mn	K	P	Cu	Mg	Fe	Y	Ca	N	S
	-907	-215	-36	-24	-18	68	96	158	161	327	392
10	Zn	Y	P	Cu	Mn	K	Mg	Fe	Ca	S	N
	-141	-132	-88	-67	-66	-6	19	38	40	168	235
11	Y	P	N	Fe	Cu	Mg	S	Ca	Mn	K	Zn
12	Cu	Y	P	Mn	K	Fe	Zn	N	Mg	Ca	S
	-1311	-914	-205	61	71	150	184	194	371	558	842

...*continued*...

Site No.	Order of requirement from left to right										
13	**Cu**	**Mn**	**K**	**Fe**	**Ca**	**P**	**N**	**Y**	**Mg**	**Zn**	**S**
	-1150	-313	-278	-137	-38	39	209	265	285	427	691
14	**Cu**	**Zn**	**Mg**	**K**	**Ca**	**P**	**Y**	**Mn**	**Fe**	**N**	**S**
	-1470	-393	-133	-55	81	123	143	176	226	415	887
15	**Mn**	**K**	**N**	**P**	**Y**	**Cu**	**Ca**	**Mg**	**Fe**	**S**	**Zn**
	-385	-325	-165	-157	11	69	89	92	96	269	407
16	**Cu**	**P**	**Zn**	**Mg**	**Fe**	**Ca**	**K**	**Y**	**N**	**S**	**Mn**
	-1057	-249	-123	-51	-22	5	87	163	239	487	521
17	**Mn**	**S**	**Cu**	**Ca**	**Fe**	**Y**	**K**	**P**	**Zn**	**Mg**	**N**
	-298	-293	-242	-4	2	11	88	107	139	189	301
18	**Cu**	**N**	**Ca**	**P**	**S**	**K**	**Mn**	**Mg**	**Fe**	**Zn**	**Y**
	-812	-280	-25	-16	55	159	161	169	174	178	237
19	**N**	**Mg**	**S**	**P**	**Fe**	**Ca**	**Y**	**K**	**Zn**	**Cu**	**Mn**
	-783	-458	-309	-272	-233	-84	-64	29	98	892	1184
20	**Cu**	**Mn**	**Zn**	**K**	**Y**	**P**	**Mg**	**Ca**	**S**	**Fe**	**N**
	-1211	-266	-199	-79	-56	63	120	277	310	502	540
21	**Cu**	**Mn**	**S**	**Fe**	**Zn**	**Y**	**Mg**	**N**	**K**	**Ca**	**P**
	-432	-321	-219	-135	-130	71	80	227	260	279	318
22	**S**	**N**	**Mn**	**Fe**	**Zn**	**P**	**Mg**	**Y**	**K**	**Ca**	**Cu**
	-412	-332	-205	-108	-31	16	99	112	183	252	427
23	**Cu**	**Mn**	**Fe**	**N**	**Ca**	**Zn**	**P**	**K**	**Mg**	**Y**	**S**
	-643	-280	-206	-190	-149	13	24	103	143	264	921
24	**Cu**	**Mn**	**Mg**	**Zn**	**Y**	**S**	**K**	**P**	**N**	**Fe**	**Ca**
	-329	-271	-86	-72	-9	3	32	96	180	200	256

...continued...

Site No.	Order of requirement from left to right										
25	Mn	Zn	S	Y	K	P	Ca	Mg	Cu	Fe	N
	-813	-279	-124	-95	-65	-22	43	60	315	457	524
26	Cu	Zn	Ca	Mg	K	P	Mn	Y	S	Fe	N
	-529	-177	-104	-98	-8	17	20	102	112	205	462
27	Ca	Mn	S	Mg	Zn	K	N	P	Cu	Fe	Y
	-224	-192	-185	-132	-70	-32	89	128	132	240	246
28	S	Zn	Ca	Cu	Mn	Y	N	K	Fe	Mg	P
	-489	-430	-222	-169	-113	60	145	179	260	304	475
29	Cu	Y	S	N	Mn	Fe	Zn	K	Ca	P	Mg
	-410	-234	-171	-107	35	40	55	131	149	253	259
30	Y	Cu	Zn	P	Fe	K	Mn	Ca	S	N	Mg
	-243	-202	-173	-143	-2	3	42	140	144	205	229
31	Cu	S	Mg	Mn	P	Fe	K	Zn	Ca	N	Y
	-1097	-242	-236	-143	-101	93	169	192	258	518	588
32	Fe	Ca	N	P	S	Mg	K	Zn	Y	Cu	Mn
	-568	-550	-435	-370	-329	79	112	165	238	408	1250
33	N	S	P	K	Mg	Fe	Ca	Y	Zn	Mn	Cu
	-718	-397	-350	-343	-337	-277	-211	110	502	957	1063
34	S	Ca	Zn	Y	Fe	P	N	Mn	Cu	Mg	K
	-467	-196	-189	-116	-76	-7	103	133	157	226	432
35	Mn	Ca	S	Mg	K	Y	P	N	Fe	Zn	Cu
	-505	-318	-299	-95	-55	45	97	112	302	312	404
36	K	S	P	Zn	Mg	N	Ca	Fe	Y	Mn	Cu
	-109	-106	-90	-85	-43	-9	10	20	59	83	272
37	N	Mg	P	K	S	Fe	Ca	Cu	Zn	Y	Mn
	-593	-456	-108	-105	9	32	64	81	274	363	438
38	Cu	Y	P	Mg	Zn	K	Mn	S	Ca	Fe	N
	-715	-276	-143	-55	-29	-11	106	144	244	265	471
39	Mg	Y	P	S	K	N	Ca	Fe	Mn	Zn	Cu
	-296	-252	-146	-74	-40	-15	20	121	161	177	345

Table 17 : Orchard sites of high yielding subpopulation showing yield (Y) indices where yield can further increase

Site No.	*Ambia* flush			Site No.	*Mrig* flush		
	Soil Y index	Leaf Y index	Yield (fruits per tree)		Soil Y index	Leaf Y index	Yield (fruits per tree)
2	0	-141	1033	1	-13	-771	718
3	+4	-118	1058	2	-22	-1081	512
4	-5	-511	836	6	+1	-23	1015
9	-2	-370	968	10	+1	-132	1011
10	-14	-1578	635	11	-14	-110	632
11	-5	-451	1045	12	-23	-914	558
12	-6	-200	948	19	+1	-64	1218
13	0	-67	1265	24	+4	-72	1113
16	+5	-158	1217	25	+1	-95	893
24	-1	-297	1061	29	0	-234	988
29	-23	-1531	568	30	-5	-243	932
32	-22	-1517	672	34	-4	-116	1104
35	-2	-334	1052	38	-5	-276	865
36	-6	-641	927	39	-3	-252	913
37	+1	-55	1312	-	-	-	-

In case of *ambia* flush the orchard (site 29) showing lowest yield (568 fruits per tree) showed yield index –23 under soil and –1531 under leaf. Highest yield level which can further increase was 1312 fruits per tree and was observed in site 37 with Y index +1 under soil and –55 under leaf.

Under *mrig* flush the lowest yield was 512 fruits per tree in site 2 with highest negative indices in soil (-22) as well as in leaf (-1081). The highest yield level was 1218 fruits per tree in site 19 with yield index +1 in case of soil and –64 in case of leaf.

Fertilizer recommendation is to be made as described under low yielding orchards. Supplying the limiting nutrients through fertilizers will resulted in still increase of yield level of these orchards.

4.6.3 Interpretation for fertilizer recommendation

DRIS i.e. Diagnosis and Recommendation Integrated System is the procedure of diagnosing the yield limiting factors and making recommendation for getting the optimum yield. For making recommendation one should know two important points i.e. what is to be recommended and how much to be recommended. Therefore it is necessary to recognize the limiting factor to make the recommendation of that needed nutrient in diagnosis. DRIS provides the advantage of nutrient balance and ranking nutrients in order of most insufficient or most limiting to most relatively excessive or least limiting nutrient. The nutrient with most negative index is considered relatively the most limiting. The increasing indices in same line represent the order of limitation. Hence what is to be recommended can be decided from these indices in case of soil as well as leaf.

4.6.3.1 Soil indices

Soil indices established from *ambia* and *mrig* flushes for low yielding (Table 9 and 10) and for high yielding (Table 13 and 14) are used for fertilizer recommendation to an orchard for increasing the yield.

In particular orchard nutrient status of limiting nutrient is compared with ranges of DRIS norms. In *ambia* flush of low yielding subpopulation site 2 is taken as an example to quantify the fertilizer requirement using DRIS. DRIS indices (Table 9) showed the order of requirement as Ca > S > K > N > Fe > Cu. In this case Ca is most required. The soil Ca status of this particular orchard is 22.70 cmol $(p^+)kg^{-1}$ (Appendix VI) which comes under very low category as per DRIS norms for *ambia* flush (Appendix XIV). Therefore fertilizer recommendation for Ca should 50 per cent more than the recommended dose for Nagpur mandarin. Similarly N content in this soil was 215.13 kg ha^{-1} (Appendix VI) which is in low range (169 - 280 kg ha^{-1}) according to DRIS norms. The recommended amount of fertilizer for N should be more than 25 per cent of the recommended dose. In the same way Fe and Cu can be recommended. Indices showing positive values in the orchard in question is considered as optimum to high or excess. These nutrients should similarly be compared with corresponding DRIS norms and recommendation be fixed on the basis of recommended dose for this crop. Required amount of fertilizer for optimum range is as per recommended dose for high range it is less than 25 per of recommended dose and for very high range excess it should be less than 50 per cent of recommended dose. The set of recommendation based on indices *vis-a-vis* DRIS norms for the orchard if applied will result in increase of yield of subsequent crop.

In case of *mrig* flush of low yielding subpopulation site 1 is taken into consideration for deciding fertilizer dose. In this case according to DRIS norms (Table 10) order requirement of nutrients is N > Cu > K > P > Ca. N status of this orchard soil was 211.76 kg ha^{-1} (Appendix VIII) which was detected as very low (< 216 kg ha^{-1}) according to corresponding DRIS norms for *mrig* flush presented in (Appendix XV). Hence the N requirement of the soil will be 50 per cent more than its recommended dose for Nagpur mandarin. Similarly Cu, K, P and Ca requirement can be decided. The requirement of nutrients showing higher indices should also be decided in similar pattern and the set of recommendation can be prepared.

4.6.3.2 Leaf indices

In case of leaf indices, the pattern of comparing leaf indices with DRIS norms and leaf nurient status is followed as described in case of soil indices. DRIS indices for low yielding *ambia* and *mrig* flushes are presented in Tables 11 and 12 respectively whereas, for high yielding *ambia* and *mrig* flushes are presented in Tables 15 and 16 respectively.

In case of *ambia* flush of low yielding subpopulation taking orchard 1 as an example, order of requirement of yield limiting nutrients is Cu > Fe > Mn (Table 11). Leaf Cu, Fe and Mn content of this orchard is 13.83, 50.45 and 24.38 ppm respectively (Appendix X). All these nutrients comes under low nutrient status as per DRIS norms for leaves of *ambia* flush. Therefore recommendation will indicate 25 per cent more of recommended dose in this orchard. Similarly the nutrients showing positive indices should be recommended.

For *mrig* flush site 3 of low yielding subpopulation showed order of requirement as Cu > Mn > Fe (Table 12). Leaf Cu , Mn and Fe content of this orchard were 15.60, 28.31 and 85.04 ppm respectively (Appendix XII). In this case, Cu and Mn comes under optimum or medium range and Fe in low range (Appendix XVII). Hence recommended dose should be given for Cu, Mn as recommended dose and for Fe, 25 per cent more dose should be recommended.

4.6.3.2 Soil and leaf indices together

With DRIS approach application of most limiting nurient based on leaf index could result in yield increase, assuming that the nutrient was also present in insufficient amount in the soil. Sometime situation could arise where application of most limiting nutrient does not result in yield increase. This is usually the case when other factors (like leaching, soil moisture, pH, $CaCO_3$, unfavourable climate, etc.) are limiting the uptake of the particular nutrient.

Thus in making meaningful recommendation which will have the highest chance of increasing yield profitably, both soil and plant indices together should be taken into consideration.

In present investigation what is to be recommended can be decided from the soil and leaf DRIS indices together. The critical study of the data from soil and leaf indices showed that while deciding the limiting nutreint for recommendation, four situations may be created.

1. Negative index of the nutrient in soil showed correspondingly negative index in plant.

2. Positive index of the nutrient in soil showed correspondingly positive index in plant.

3. Negative index of the nutrient in soil showed correspondingly positive index in plant.

4. Positive index of the nutrient in soil showed correspondingly negative index in plant.

As soil is a natural reservoir of nutrients in which plants grow, the emphasis is to be given on soil fertility status while using both methods i.e. soil and plant analysis together. The plant nutrient status is nothing but the reflection of fertility status of soil modified to some extent by soil atmosphere and environmental situations.

In first and second case mentioned above there is no problem for recommendation of that nutrient considering negative index as limiting and positive as sufficient or optimum. In third case, when negative soil index of particular nutrient shows positive value of index in leaf analysis it indicates that though the nutrient is in lower proportion in soil, it has been exausted in large quantity by the plant or crop and hence it is not limiting in the plants but soil may be exhausted and show deficiency subsequently. Therefore, it should be added as per soil fertility status which will improve the potential of soil without any imbalance of nutrients in soil as well as in plant.

For example, results of site 1 (Table 9) from low yielding *ambia* flush indicated negative index for N (-36) in soil fertility status, whereas in leaf nutrient status it showed positive index (+772) (Table 11). This means that though soil is deficient in N it is not the yield limiting. But for maintaining soil health and to avoid deficiency subsequently N should be diagnosed as limiting.

In fourth case if positive index of soil coincides negative index in leaf nutrient, it indicates in practical term that the nutrient was supplied but not taken up because of unvourable soil conditions or any other relative factors which need to be further studied and corrected. Otherwise, the recommendation of limiting nutrient should be made on the basis of leaf nurient standards. Iron was observed in such situation in site 1 of *ambia* flush, which showed positive value (+27) for soil and negative (-226) for leaf index besides improving soil condition.

After deciding what is to be applied it is necessary to know how much quantity of nutrient to be added. For this purpose status of limiting nutrient in orchard under diagnosis should be compared with ranges of DRIS norms presented for soil (Appendix XIV and XV) and for leaf (Appendix XVI and XVII). Amount of fertilizer reqauired will be dependent on the recommended dose for crop and new DRIS rating norms established in the present study. In above mentioned example of site 1 we have decided to apply N on soil fertility basis. Available N content of this orchard is 116.78 kg ha^{-1} (Appendix VI) which comes under very low (< 168 kg ha^{-1}) according to new DRIS norm (Appendix XIV). Therefore the nitrogen required to be applied for this orchard soil should be 50 per cent more than recommended dose of nitrogen of Nagpur mandarin for study area.

Ultimately yield is the concern of the farmers. Inspite of any one of the four situations as described earlier preveiling at his orchard site, yield is the result of efficient and balanced utilization of nutrients by the plant as indicated by the leaf nutrient status. Hence leaf analysis can be adopted over soil analysis applying DRIS norms and indices, because soil situation may not exactly reflect in yield, may be due to improper physical condition.

The study indicated that more than two nutrients are limiting the yield in 38 low yielding orchards in *ambia* and 36 low yielding orchards in *mrig* flush. In case of high yielding subpopulation, 15 orchards under ambia and 14 orchards under mrig flush showed the chances of further increase in yield. It further indicated that supplying the nutrients, which are limiting, through fertilizers will increase the yields of the orchards.

DRIS was found to be more relevent by using leaf and soil analysis together for meaningful recommendation of nutrients. DRIS indices were used to ranking of soil parameter nutrients and leaf nutrients in terms of order of their requirement by plant for getting higher yield. DRIS indices were used not only for increasing the yield of low yielding orchards but also for those high yielding orchards in which there were chances of further increase in yield economically were possible. It was possible as DRIS was expanded to include nutrient ratios with yield (Y).

DRIS norms as new rating for soil feritlity and leaf nutrient status were developed and divided into five classes *viz*. very low or deficient, low, optimum, high and excess and these norms were compared with nutrient standards established else where. New critical limits for soil mircronurients were also established from the data generated through DRIS for the study. Overall performance of DRIS approach showed successful diagnosis of nutrient requirement for getting higher yield.

SUMMARY AND CONCLUSIONS

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CHAPTER V

SUMMARY AND CONCLUSIONS

Mandarin (*Citrus reticulata* Blanco) is a popular and extensively grown tropical and subtropical fruit crop in different parts of the world. In India Maharashtra state stands first followed by Andhra Pradesh and Punjab in area and second in production of mandarin next to Andhra Pradesh. Of the four regions of Maharashtra, Vidarbha grown mandarin in more than 97 per cent mandarin area of state producing about 600 thousand tons.

Citrus plants require judicious plant nutrients supply for proper growth and yield of high quality fruits. Determination of nutritional need is an important problem of the fruit growers. To ensure high economic productivity and to sustain the available soil nutrient status at a desirable level, correct doses of manures and fertilizers must be applied by using reliable diagnostic tools. Considerations of economy, energy and environment make it imperative that fertilizers should be used efficiently. This can be achieved by the use of one or more of the diagnostic methods in consideration with a background of research results. The best diagnostic tool is one that recommends nutrient application only when a direct economic response is probable.

Diagnosis and Recommendation Integrated System (DRIS) is a holistic system of nutrient diagnosis and can be used for isolating nutrients and other factors, which determine yield level and the quality of produce. DRIS was used to develop norms of soil fertility and leaf nutrients for optimum crop production.

To study the soil fertility and leaf nutrient status as well as to develop the DRIS norms of soil fertility and leaf nutrients for Nagpur mandarin from Western Vidarbha 150 Nagpur mandarin orchards were selected 75 each for *ambia* (spring) and *mrig* (summer) flushes.

The surface (0 to 30 cm) soil samples were collected from circular band of 30-40 cm wide underneath the perimeter of tree and analyzed for different parameters using standard procedure. The leaf sampling was done at leaf age of seven months old during the month of October 1999 for *ambia* flush and eight months old during January 2000 for *mrig* flush, separately. The leaf samples were collected at height of 1.5 m from ground level from all sides of tree i.e. north, south, east and west. Only mature leaves characterized by dull green colour having rough surface were collected avoiding the immature leaves. The non-fruiting terminals were selected for collection of leaves from marked twigs. The final sample consists of minimum 100 to 125 leaves, which were used for analysis for different macro and micronutrients using standard procedures.

According to DRIS the whole population was divided in two groups based on "high" and "low" yield performance. The cut off value for dividing low and high yield was 400 fruits per tree for each orchard.

Characteristics of Nagpur mandarin soils in study area showed that most of the soils were neutral to moderately alkaline in reaction. Soils surveyed for *ambia* flush showed pH ranging from 7.28 to 8.03 in low yielding and from 7.37 to 8.06 in high yielding whereas *mrig* flush showed pH ranging from 7.37 to 7.75 in low yielding and from 7.35 to 7.96 in high yielding subpopulation. The EC of soils in low yielding orchards of *ambia* flush ranged from 0.10 to 0.48 dSm^{-1} while in high yielding subpopulation the values ranged from 0.10 to 0.38 dSm^{-1}. In case of *mrig* flush it was ranged between 0.15 to 0.37 dSm^{-1} and 0.11 to 0.36 dSm^{-1} in low and high yielding subpopulation, respectively. This range of EC values showed that all the soils were non-saline in nature. It was also observed that mean ECs of low yielding sub-population were slightly higher than high yielding sub population. Organic carbon in low yielding subpopulation orchard soils was lower in both *ambia* and *mrig* flush (mean 0.61 and 0.71% respectively) than high yielding orchards soils of both flushes (0.67 and 0.73% respectively). It was somewhat uniform at different locations of study area. Calcium carbonate content of low yielding sub-population soils from *ambia* flush was higher (mean 11.79 %) than high yielding subpopulation (mean 7.77 %) Soils from *mrig* flush orchards containing 11.7 per cent and 8.35 per cent $CaCO_3$ in low and high yielding sub populations respectively showed the similar trend. Most of the soils were slightly calcareous in nature with some exceptions.

Soil nutritional status of Nagpur mandarin orchards in Western Vidarbha under study indicate that mean available N, P_2O_5 and K_2O content in these soils were 207.77, 48.56 and 436.86 kg ha^{-1}, respectively in low yielding subpopulation and 391.92, 73.41 and 588.58 kg ha^{-1} in high yielding subpopulation of *ambia* flush. In case of *mrig* flush these mean available N, P_2O_5 and K_2O content were 204.97, 54.30 and 442.46 kg ha^{-1} respectively in low yielding and 410.59, 57.97 and 547.12 kg ha^{-1} respectively in high yielding subpopulation. Relatively high content of primary nutrients in high yielding population was observed than low yielding subpopulation in both flushes.

In case of secondary nutrients an average available (exchangeable) calcium and magnesium contents of soils of low yielding was 22.28 and 8.10 cmol (p^+) kg^{-1} respectively in *ambia* flush and 25.51 and 8.18 cmol (p^+) kg^{-1} in *mrig* flush, respectively. It was much less compared to that of high yielding orchard soils, which was 44.24 and 14.34 cmol (p^+) kg^{-1} Ca and Mg, respectively in *ambia* flush and 42.87 and 9.58 cmol (p^+) kg^{-1} Ca and Mg, respectively in *mrig* flush soils. Higher concentration of available sulphur in high yielding orchards (19.35 and 18.44 kg ha^{-1} S in *ambia* and *mrig* flush respectively) was observed than low yielding orchards (15.03 and 17.58 kg ha^{-1} S in *ambia* and *mrig* flush respectively).

Regarding soil available micronutrients, available Fe, Mn, Cu and Zn contents of soils bearing high yielding subpopulation were higher than that of soils bearing low yielding subpopulation in *ambia* flush with exception of zinc in *mrig* flush. With regards to *ambia* flush in low yielding subpopulation average available Fe, Mn, Cu and Zn content was 6.49, 13.20, 3.05 and 0.65 ppm respectively, whereas in high yielding subpopulation it was 7.29, 13.75, 5.44 and 0.70 ppm respectively. Low yielding subpopulation of Nagpur mandarin orchard soils from *mrig* flush showed the distribution of available Fe, Mn, Cu and Zn content as 6.89, 10.20, 2.18 and 0.71 ppm respectively and it was 7.78, 11.47, 4.36 and 0.70 ppm respectively in high yielding subpopulation.

In general higher nutrient status and higher organic matter content and low calcium carbonates in soils were favourable conditions for higher yields. The yields as well as available nutrient content of *ambia* were comparatively more than *mrig*. Soils with higher available nutrient status supported higher yields.

The analytical data regarding nuritional status based on leaf analysis showed that among the major nutrients nitrogen concentration was higher whereas, phosphorus and potassium concentrations were lower in high yielding than low yielding subpopulation. Leaf N was 2.21 and 2.54 per cent in low and high yielding subpopulation respectively of *ambia* flush whereas, it was 2.29 and 2.39 per cent respectively in *mrig* flush. In low yielding subpopulation the P and K concentration was 0.18 and 1.50 per cent respectively under *ambia* flush while 0.18 and 1.57 per cent, respectively in *mrig* flush. The P and K concentration in leaves of high yielding subpopulation was 0.14 and 1.45 per cent and 0.13 and 1.22 per cent in *ambia* and *mrig* flush respectively.

Regarding secondary nutrients sampling of leaves at *ambia* and *mrig* flush indicated a higher Ca, Mg and S concentration in high yielding subpopulation than low yielding. The mean Ca, Mg and S concentration in leaves sampled at *ambia* flush were 3.30, 0.61 and 0.21 per cent respectively in low yielding subpopulation and 3.90, 0.65 and 0.27 per cent respectively in high yielding subpopulation. The sampling at *mrig* flush showed 3.24, 0.64 and 0.20 per cent concentration of Ca, Mg and S respectively in low yielding where as 3.68, 0.66 and 0.23 per cent concentration of Ca, Mg and S respectively in high yielding sub-population.

The leaf micronutrients status indicates that leaf Fe, Mn, Cu and Zn concentrations in low yielding trees were lower than the high yielding trees in both *ambia* and *mrig* flushes. The contents of Fe, Mn, Cu and Zn in leaves of low yielding subpopulation was 102.90, 30.67, 15.41 and 27.94 ppm respectively from *ambia* flush whereas 88.52, 26.97, 18.96 and 28.19 ppm respectively from *mrig* flush. The leaves from high yielding subpopulation showed 121.50, 39.82, 24.74 and 30.91 ppm in *ambia* flush and 124.69, 35.78, 25.25 and 30.54 ppm in *mrig* flush Fe, Mn, Cu and Zn concentration respectively. In general excepting Mg, Cu, Zn, were having higher concentration in *ambia* flush leaves than *mrig* flush as observed in soil fertility status.

The soil fertility and leaf nutrient norms were developed using DRIS for Nagpur mandarin in Western Vidarbha region. The new DRIS norms developed for soil characteristics showed that the optimum range of pH was 7.35 to 7.71, EC 0.12 to 0.29 dSm^{-1}, organic carbon 0.37 to 0.98 per cent and calcium carbonate 4.26 to 11.29 per cent under *ambia* flush, while these ranges were for pH 7.41 to 7.65, for EC 0.14 to 0.28 dSm^{-1}, for organic carbon 0.49 to 0.98 per cent and for calcium carbonate 4.73 to 11.98 per cent under *mrig* flush. The evaluation and classification of the total orchards showed that optimum observed in pH, EC, organic carbon and calcium carbonate was observed in 89, 81, 79 and 64 per cent orchards respectively for *ambia* flush and in 88, 73, 75 and 72 per cent orchards, respectively for *mrig* flush.

The norms from *ambia* flush for major available nutrients showed that optimum ranges were as for N from 281 to 504 kg ha-1 for, P_2O_5 43 to 105 kg ha^{-1} for K_2O 366 to 812 kg ha^{-1} for Ca 38 to 51 cmol (p^+) kg^{-1} for Mg 8.51 to 20.24 cmol (p^+) $kg^{-1}$and for S 13 to 26 kg ha^{-1}. These optimum ranges of DRIS norms for mrig flush were as for N from 314 to 508 kg ha^{-1}, for P_2O_5 38 to 78 kg ha^{-1} for K_2O 348 to 747 kg ha^{-1} for Ca 36 to 51 cmol (p^+) kg^{-1} for Mg 6.01 to 13.20 cmol (p^+) kg^{-1} and for S 12 to 26 kg ha^{-1}.

The optimum ranges for available soil micronutrients for *ambia* flush were: Fe 6.03 to 8.56 ppm, Mn 9.16 to 18.34 ppm, Cu 3.10 to 7.90 ppm and Zn 0.53 to 0.87 ppm, whereas for *mrig* flush were: Fe 6.32 to 9.24 ppm, Mn 7.51 to 15.40 ppm, Cu 2.41 to 6.30 ppm and Zn 0.52 to 0.89 ppm.

The evaluation of the individual orchards indicated that more than 50 per cent orchards were in optimum range of most of the soil nutrients except N and Ca for both *ambia* and *mrig* flushes.

The optimum ranges for *ambia* flush in leaf nutrients were as N 2.06 to 3.02 per cent, P 0.09 to 0.22 per cent, K 1.05 to 1.87 per cent, Ca 3.18 to 4.66 per cent, Mg 0.58 to 0.73 per cent, S 0.20 to 0.36 per cent, Fe 74 to 170 ppm, Mn 26 to 54 ppm, Cu 15.25 to 34.25 ppm and Zn 22 to 41 ppm.

These optimum ranges for *mrig* flush in leaf nutrients were as N 2.10 to 2.68 per cent, P 0.08 to 0.19 per cent, K 0.66 to 1.79 per cent, Ca 2.97 to 4.40 per cent, Mg 0.47 to 0.87 per cent, S 0.18 to 0.30 per cent, Fe 92 to 158 ppm, Mn 23 to 50 ppm, Cu 13.82 to 36.70 ppm and Zn 23 to 39 ppm. Most of the orchards were found in optimum range of all leaf nutrients in both *ambia* and *mrig* flushes.

DRIS indices were derived for soil fertility and leaf nutrient status of low as well as high yielding Nagpur mandarin orchards, which have negative, positive and zero values. The more negative an index, the more lacking is the nutrient relative to other nutrients used in the diagnosis which have relatively more requirement. Alternatively a large positive nutrient index indicates that the corresponding nutrient is present in relatively excessive quantity and has relatively less requirement. Therefore most negative index i.e. most limiting parameter is to be that which comes first in order of requirement. Zero index is with optimal balance.

In low yielding subpopulation of *ambia* flush soil fertility DRIS indices inferred that among major nutrients nitrogen, phosphorus, calcium, magnesium and sulphur showed insufficiency in majority of orchards. Among micronutrients copper was found to be deficient in most soils, orchards with very low yield level. Zinc was limiting in two sites only i.e. site No. 14 and 37. Fe was deficient in five orchards and Mn was limiting in three sites.

Though negative indices showing nutrients affect yield, the excess of some soil parameters may also result in low yield. Free calcium carbonate is such important factors for citrus. In some of the sites $CaCO_3$ showing most positive index might have resulted in low yield rather than some limiting nutrients in that particular case. Site numbers 7, 18, 19, 23, 25, 26, 28, 29, 30, 31 and 33 showed most positive index of $CaCO_3$.

Soil fertility DRIS indices for low yielding subpopulation from *mrig* flush inferred that most of the orchards indicated the requirement of N excepting site 5, 8, 22, 32 and 35. Indices also showed insufficiency of Ca, Mg and S in majority of soils under *mrig* flush. Regarding micronutrients Cu indicated negative index in most of the orchards.

The nutrient diagnosis made by DRIS indices indicated that more than two nutrients were limiting for yield in low yielding orchards. The orchards suffering from inadequacy of nutrients can be easily diagnosed from indices and order of limitation can be fixed. The fertilizer recommendation is then made on the basis of order of requirement of particular nutrient.

Leaf nutrient indices for low yielding orchards of *ambia* flush revealed that the yield is affected due to imbalanced condition of leaf nutrient status in Nagpur mandarin. Site 17 showed all the nutrients in optimum to excess where as some orchards showed only single nutrient yield limiting. In other orchards more than two nutrients were found to be yield limiting which also carried the nutrient imbalance in plant.

Leaf nutrient indices for low yielding orchards from *mrig* flush revealed that in all orchards two or more elements were to be needed for increasing yield excepting site 11.

Fertilizer recommendation for getting optimum yield is made on the basis of either soil fertility index or leaf nutrient index or combining both soil and leaf indices of individual orchard. Thus in making meaningful recommendation which will have the highest chance of increasing yield profitably, DRIS indices based on leaf analysis can be adopted for convenience and for correct reflection.

In case of high yielding subpopulation though the yield is higher, however where yield indices are negative or nearer to optimum, there is some scope of increasing yields further even under high yielding situations. This can be achieved by providing the limiting nutrients so that better utilization of nutrients in higher amount can be effected resulting in still higher yield.

Number of orchards showing negative index values or values nearer to zero, where there are chances of further increase in yield are 15 in *ambia* and 14 in *mrig* flush.

Conclusions

From the present investigation following conclusions are drawn.

1. Characteristics of Nagpur mandarin growing soils in Western Vidarbha region showed that these soils are neutral to moderately alkaline in reaction and non-saline in nature with pH and EC within the safe limit. Soil organic carbon was somewhat uniform at different locations and it was medium to high in most (88 %) surface soils in both flushes. Although organic carbon content of most surface soils in both flushes was found medium to high, the available nitrogen was found to be in low range in some cases, which might be due to the stage of humification of organic matter. The organic carbon in low yielding subpopulation orchard soils was lower in both *ambia* and *mrig* flushes than high yielding one. All the orchard soils were slightly calcareous to calcareous in nature in both low and high yielding subpopulation of both flushes excepting two sites of low yielding subpopulation of *ambia* flush, which were strongly calcareous. Calcium carbonate content of low yielding subpopulation of soils surveyed during both flushes was higher than that of high yielding subpopulation.
2. The available nutrient status showed relatively higher content of available nutrients in high yielding than low yielding subpopulation (excepting Zn in *mrig* flush) of mandarin orchards of this region for both flushes which may be attributed to the intermittent application of organic manure with applied dose of fertilizers which helps in build up of high level of available nutrients. In general higher nutrient status and higher organic matter content and low

calcium carbonates in soils were favourable conditions for higher yields. In high yielding subpopulation perticularly, the yields as well as available nutrient content of *ambia* flush was comparatively more than *mrig* flush.

3. Leaf nutrient content of both flushes showed in general, mean leaf N, Ca, Mg, S, Fe, Mn, Cu, and Zn concentrations were higher and mean leaf P and K concentrations were lower in high yielding than low yielding trees of Nagpur mandarin. Maximum leaf nutrients excepting Mg, Cu, Zn, were having higher concentration in *ambia* flush leaves than *mrig* flush as observed in soil fertility status.

4. A new five-tier system of fertilizer recommendation has been established with specific advantages using DRIS approach for achieving enhancement in yield of Nagpur mandarin. DRIS norms as new ratings for soils fertility and leaf nutrient status were developed and divided into five classes viz., very low or deficient, low, optimum, high and excess. DRIS indices for soil and leaf have been found to be useful in diagnosing and ranking the most limiting and excessive parameter or nutrient.

5. DRIS indices provide the advantage of nutrient balance and ranking nutrients in order of most insufficient or most limiting to most relatively excessive or least limiting nutrient. The nutrient with most negative index is considered relatively the most limiting. DRIS offers the ability to evaluate nutrient balance and to identify the order in which nutrients might limit yield, which can serve to refine mandarin orchard fertility management. The set of recommendation based on DRIS indices *vis- a- vis*. DRIS norms for the particular individual orchard if applied, will result in increase of yield of subsequent mandarin crop.

6. In making meaningful recommendation, which will have the highest chance of increasing yield profitably, DRIS indices, based on leaf analysis can be adopted for convenience and for correct reflection.

7. In traditional systems of fertilizer recommendation the nutrients were supplied to the soil on the basis of nutrient status of soil irrespective of yield. In DRIS

the recommendation is made only for yield limiting nutrient / factor in proper quantum for achieving optimum yield irrespective of nutrient status in corresponding soil.

8. DRIS indices are used not only for increasing the yield of low yielding orchards but also for those high yielding orchards in which there are chances of further increase in yield economically. In present research DRIS has been expanded to include nutrient ratios with yield (Y) which is precisely used for sorting the high yielding orchards in which yield level can further increased economically.

9. On the basis of yield levels recorded at different locations of Western Vidarbha new cut off value for dividing high and low yielding orchards has been investigated using DRIS for Nagpur mandarin for this area, which is 800 fruits per tree.

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* Original not seen

APPENDICES

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Appendix - I A

Location and general information of Nagpur Mandarin orchards in low yielding subpopulation of *ambia* flush

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruits/tree)	No. of trees in orchard
AKOLA DISTRICT					
1.	Jairuddin Sujoruddin	Akot Tq. Akot	11	213	400
2.	Purushottam Motiram Korde	Kurum, Tq. Murtizapur	13	187	300
3.	C.S. Vyawahare	Kurum, Tq. Murtizapur	12	278	350
4.	Murlidhar Radhakisan Laddha	Madhapuri Tq. Murtizapur	12	297	300
5.	Pukhraj Premraj Dugad	Malsur Tq. Patur	10	252	300
AMRAVATI DISTRICT					
6.	Jiwalal Mahadev Ghatare	Bhandaraj Tq. Anjangaon Surji	12	204	350
7.	Anis Ahamad Jalil	Bhandaraj Tq. Anjangaon Surji	13	264	400
8.	Smt. Deokabai Ramchandra Borde	Anjangaon (S) Tq. Anjangaon	11	286	350
9.	Ramchandra Prithamji Borde	Anjangaon (S) Tq. Anjangaon	13	297	450
10.	D.R. Dangre	Civil Line Paratwada, Tq. Achalpur.	13	254	300
11.	Rajesh Babu	Achalpur Tq. Achalpur.	13	314	300
12.	Dr. V.N. Kavitkar	Pathrot,Tq. Achalpur	13	367	330
13.	Pravinbhai Sharadchandra Malpani	At. Po. Dabha, Tq. Amravati	13	192	450
14.	Sahadevrao Krishnarao Tarekar	At. Po. Borgaon (Dh) Tq. Amravati	13	246	500
15.	Dr. V.N. Gujar	At. Po. Borgaon (Dh) Tq. Amravati	13	238	250
16.	R.N. Dharmale	At. Po. Borgaon (Dh) Tq. Amravati	13	288	300
17.	Jairamsingh Rajput	At. Po. Borgaon (Dh) Tq. Amravati	13	190	350
18.	Shri Dalal	Morshi, Tq. Morshi	12	237	500

...continued...

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruits/tree)	No. of trees in orchard
19.	Sarangi Master	Morshi, Tq. Morshi	13	253	450
20.	Babarao Baliram Madane	Brahmanwadi, Tq. Chandur Bazar	11	286	1150
21.	Baliram Madhuji Madane	Brahmanwadi, Tq. Chandur Bazar	13	328	1000
22.	Prabhakarrao Talokar	Manjarkhed, Tq. Chandur Rly.	13	348	400
23.	Ranjeet Arunkumar Jaiswal	Anjanwati, Tq. Dhamangaon	12	261	600
24.	Pramod Ramdas Walke	Anjanwati, Tq. Dhamangaon	11	247	300
25.	Subhashchandra Pagaria	Waghuli, Tq. Dhamangaon	11	186	200
26.	Smt. Hirabai Jawaharlal Pagaria	Waghuli, Tq. Dhamangaon	10	157	210
27.	Rikhabchand Jawaharlal Pagaria	Waghuli, Tq. Dhamangaon	11	149	200
28.	Pravin Motilal Jangda	Waghuli, Tq. Dhamangaon	13	196	400
29.	Kishore Satyanarayan Mundada	Waghuli, Tq. Dhamangaon	12	162	300
30.	Pannalal Kankaria	Waghuli, Tq. Dhamangaon	12	187	300
31.	Ranchhoddas Mundada	Masadi, Tq. Dhamangaon	11	271	400
32.	Ramrao Ramkrishan Funse	Masadi, Tq. Dhamangaon	12	286	400
33	Arvind Champat Dongre	Masadi, Tq. Dhamangaon	12	187	350
BULDANA DISTRICT					
34.	Ganeshlal Darshanlal Jaiswal	Tunki, Tq. Sangrampur	10	308	250
35.	Shri. Agrawal	Sonala, Tq. Sangrampur	12	216	1000
WASHIM DISTRICT					
36.	Shafiulla Khan	Poghat, Tq. Mangrulpir	10	234	375
37.	Dattatray Sakharam Bandurge	Mungala, Tq. Malegaon.	10	183	300
YAVATMAL DISTRICT					
38.	Sudhakar Lahanuji Dhawane	Sarur, Tq. Babhulgaon.	13	312	500

Appendix - I B

Location and general information of Nagpur Mandarin orchards in high yielding subpopulation of *ambia* flush

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruits/tree)	No. of trees in orchard
AKOLA DISTRICT					
1.	Balwant Mahadev Patil	Mana,s Tq . Murtizapur	12	1158	450
2.	Ramesh Balwant Patil	Mana Tq. Murtizapur	12	1053	450
AMRAVATI DISTRICT					
3.	Arun Mahadev Jumde	Bhandarj Tq. Anjangaon Surji	13	1058	500
4.	Sukhdev Ramchandra Borde	Anjangaon Surji Tq. Anjangaon Surji	12	836	400
5.	Ramchandra Pohne	Kural (Purna) Tq. Achalpur	13	1215	400
6.	Prafulla Pohne	Kural (Purna) Tq. Achalpur	12	1585	250
7.	District fruit Nursery, Govt. of Maharashtra	Paratwada Tq. Achalpur	12	1178	400
8.	District fruit Nursery, Govt. of Maharashtra	Paratwada Tq. Achalpur	13	1226	450
9.	Eknath Verma	Achalpur	13	968	400
10.	Smt. Sitabai Nanakram Malani	Belora Tq. Amravati	11	635	300
11.	Chandrakant Mahadev Wardhekar	Belora Tq. Amravati	12	1045	300
12.	Shethbabu Ansori	At. Po. Borgaon (Dharmale) Tq. Amravati	13	948	450
13.	Hirasingh Rajput	At. Po. Borgaon (Dharmale) Tq. Amravati	13	1265	300
14.	Bhagwant Purushottam Kale	Morshi Tq. Morshi	12	1183	450
15.	Panjabrao Purushottam Kale	Morshi Tq. Morshi	11	1228	450
16.	Baliram Madhuji Madane	Brahmanwadi Tq. Chandur Bazar	13	1217	1200
17.	Pramod Narayanrao Bijawe	Manjarkhed Tq. Chandur Rly.	13	1325	400

...continued...

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruits/tree)	No. of trees in orchard
18.	Jadhav Saheb	Manjarkhed Tq. Chandur Rly.	12	1274	400
19.	Prabhakarrao Talokar	Manjarkhed Tq. Chandur Rly.	13	1483	500
20.	Natthu Wanbaji Sapate	Anjanwati Tq. Dhamangaon	13	1297	400
21.	Rangarao Suryabhan Thote	Anjanwati Tq. Dhamangaon	13	1536	350
22.	Babudas Mahadev Lavankar	Anjanwati Tq. Dhamangaon	11	1452	300
23.	Marotrao Shelokar	Anjanwati Tq. Dhamangaon	11	1416	300
24.	Kisanrao Ganthale	Anjanwati Tq. Dhamangaon	12	1061	350
25.	Subhash Zamaji Bhorse	Anjanwati Tq. Dhamangaon	11	1117	300
26.	Pundlik Shridhar Shirbhate	Anjanwati Tq. Dhamangaon	13	1284	400
27.	Premraj Motiram Matre	Wagholi Tq. Dhmangaon	13	1305	400
28.	Shri Kole	Anjanwati Tq. Dhamangaon	10	1938	350
29.	Ramkrishan Devrao Chavan	Masadi Tq. Dhamangaon	11	568	150
30	Vijay Sumarsingh Nahate	Masadi Tq. Dhamangaon	10	2254	350
31.	Babanrao Jadhav	Masadi Tq. Dhamangaon	11	2127	400
32.	Ashik Kunjalal Mundada	Kurha, Tq. Tiwasa	12	672	400
33.	Rajendra Shamrao Ambadkar	Kurha Tq. Tiwasa	12	1319	350
		BULDANA DISTRICT			
34.	Sitaram Mahadev Agrawal	Sonala Tq. Sangrampur	12	1239	500
		WASHIM DISTRICT			
35.	Suresh Chhappalwar	Sakalwadi Tq. Washim	10	1052	800
36.	Chandrakant Gaikwad	Malegaon Tq. Malegaon	12	927	400
		YAVATMAL DISTRICT			
37.	Gulabrao Tajane	Sarur Tq. Babhulgaon	12	1312	700

Appendix - I C

Location and general information of Nagpur Mandarin orchards in low yielding subpopulation of *mrig* flush.

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruits/tree)	No. of trees in orchard
AKOLA DISTRICT					
1.	Pandurang Narsaji Dharme	Akot Tq. Akot	12	305	350
2.	Lakshmanrao Dabhade	Akot Tq. Akot	11	289	400
3.	Traymbak Namdeo Randhe	Wai Tq. Akot	11	396	400
4.	Sahdeo Lakshman Shende	Divthana Tq. Akot	10	325	350
5.	Nemichand Parasmal Dugad	Malsur Tq. Patur	10	265	300
6.	Keshavrao Motiram Deshmukh	Khanapur Tq. Patur	11	248	300
7.	Chakradhar Mahadeo Band	Khanapur Tq. Patur	12	264	450
8.	Ganesh Sitaram Khandare	Khanapur Tq. Patur	11	284	300
9.	Chandrasingh Bais	Patur Tq Patur	10	321	300
AMRAVATI DISTRICT					
10.	Shri Shivaji College of Agriculture Amravati	Amravati	12	186	100
11.	Shivrajsingh Rathod	Nandgaon Peth Tq. Amravati	13	181	800
12.	B.J. Kalamkar	Nandgaon Peth Tq. Amravati	13	364	500
13.	Anupam Zanwar	Nandgaon Peth Tq. Amravati	12	288	250
14.	Gajanan Jaware	Mawali Tq. Amravati	12	354	400
15.	Shriram Daulatrao Lahane	Sategaon Tq. Anjangaon Surji	12	291	350
16.	Anis Ptail	Adgaon Tq. Anjangaon Surji.	12	324	400
17.	Bandu Dudhe	Anjangaon(S) Tq. Anjangaon Surji	12	167	300

...continued...

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruits/tree)	No. of trees in orchard
18.	Pravin Sharadchandra Malpani	Dabha Tq. Amravati	11	205	300
19.	Chandrakant Mahadev Wardhekar	Belora Tq. Amravati	11	238	450
20.	Vinayak Uttamrao Gadhave	Anjanwati Tq. Dhamangaon	10	314	600
21.	Ranchoddas Munde	Anjanwati Tq. Dhmangaon	11	328	300
22.	Sanjay Arun Rathi	Erala Tq. Morshi	13	295	750
23.	R.B. Agrawal	Erala Tq. Morshi	10	187	700
24.	Pundalik Aghade	Nimbhi Tq. Morshi	11	357	400
25.	Ratanlal Rathi	Nimbhi Tq. Morshi	12	268	300
26.	Sahebrao Ramchandra Tatte	Shirkhed Tq. Morshi	12	316	300
27.	Arvind Tatte	Shirkhed Tq. Morshi	11	256	200
28.	Narayanrao Dhole	Morshi, Tq. Morshi	13	299	500
29.	Mahaveer Daduji Shingade	Kurha Tq. Tiwasa	13	268	350
30	Prakash Mulchand Sharma	Kurha Tq. Tiwasa	10	183	400
31.	Vasanta Pohane	Kurha Tq. Tiwasa	13	291	500
BULDANA DISTRICT					
32.	Barlekar Guruji	Jalgaon Jamod Tq. Jalgain (J)	13	256	400
WASHIM DISTRICT					
33.	Kashinath Lakshman Mohole	Jambhrun (Parande), Po. Kata Tq. Washim	12	168	500
YAVATMAL DISTRICT					
34.	Ramdas Bapurao Digambar	Weni Kotha Tq. Kalamb	12	284	350
35.	Shankarrao Dudhe	Manikwada Tq. Ner Parsopant	13	306	250
36.	Dr. Prakash Khadse	Digras Tq. Digras	13	273	1000

Appendix – I D

Location and general information of Nagpur Mandarin orchards in high yielding subpopulation of *mrig* flush

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruitss/tree)	No. of trees in orchard
AKOLA DISTRICT					
1.	Pukhraj Premraj Dugad	Malsur, Tq. Patur	10	718	300
2.	Manohar Kashiram Pachpor	Babhulgaon (Dadulgaon) Tq. Patur	12	512	350
3.	Vasanta Bapu Diware	Babhulgaon (Dadulgaon) Tq. Patur	11	1158	400
4.	Ananda Motiram Barde	Deulgaon (Br.) Tq. Patur	11	1183	400
5.	Shyamrao Sakharam Raut	Khanapur Tq. Patur	12	1347	300
6.	Tryambak Govinda Khandare	Khanapur Tq. Patur	11	1015	350
7.	Jankiram Govinda Alambe	Khanapur Tq. Patur	12	1312	400
8.	Ramesh Baliram Walokar	Khanapur Tq. Patur	13	1366	500
9.	Kashiram Motiram Kawale	Khanapur Tq. Patur	12	1219	200
10.	Rambhau Govinda Tappe	Khanapur Tq. Patur	12	1011	400
11.	Parashram Deulgonkar	Patur Tq Patur	11	632	600
AMRAVATI DISTRICT					
12.	Shankar Panjabrao Jichkar	Rahatgaon Tq. Amravati	11	558	300
13.	Sundarlal Srivastav	Nandgaon Peth Tq. Amravati	13	1317	800
14.	Mohansingh Thakur	Nandgaon Peth Tq. Amravati	13	1192	200
15.	Kirankumar Shah	Nandgaon Peth Tq. Amravati	13	1073	350
16.	Vasantrao Akotkar	Nandgaon Peth Tq. Amravati	12	1248	300
17.	Jaju Seth	Nandgaon Peth Tq. Amravati	13	1135	300

...continued...

Site No.	Name of orchard Grower	Address	Age of orchard (Years)	Yield (Fruitss/tree)	No. of trees in orchard
18.	Ramesh Jaware	Nandgaon Peth Tq. Amravati	13	1298	300
19.	Hirasingh Rajput	Borgaon (Dh) Tq. Amravati	13	1218	350
20.	Abdul Hasan	Bhandaraj Tq. Anjagaon (S)	12	969	350
21.	D.J. Deshpande	Anjagaon (S)	12	1253	350
22.	Vijaykumar Ladole	Anjagaon (S)	13	1131	200
23.	Mahadevrao Dudhe	Anjagaon (S)	11	1325	350
24.	Chandu Madanlal Mundada	Anjanwati Tq. Dhamangaon	10	1113	600
25.	Maroti Govind Parate	Erala Tq. Morshi	11	893	200
26.	Sudhakar Chirde	Kurha Tq. Tiwasa	12	1024	300
27.	Jagansingh Dhumale	Kurha Tq. Tiwasa	12	1316	300
28.	Ramesh Nerkar	Kurha Tq. Tiwasa	12	1192	400
BULDANA DISTRICT					
29.	Omkar Khandelwal	Sonala Tq. Sangrampur	11	988	275
30	Ganesh Kisan Dhule	Eklara Tq. Sangrampur	10	932	500
31.	Anantrao Bhode	Eklara Tq. Sangrampur	13	1563	325
32.	Shankar Lakshman Hage	Eklara Tq. Sangrampur	12	1449	400
WASHIM DISTRICT					
33.	Chandalal Mane	Zodga (Kh) Tq. Malegaon	12	1328	400
34.	Dhanjay Jaidev Mane	Zodga (Kh) Tq. Malegaon	11	1104	800
35.	Daulatrao Ananda Paramde	Jambhrun (Parande) Tq. Washim	12	1130	200
36.	Motiram Ananda Parande	Jambhrun (Parande) Tq. Washim	11	1224	200
37.	Radheshyam Govinda Mantri	Jambhrun (Parande) Tq. Washim	12	1347	600
YAVATMAL DISTRICT					
38.	Ravindra Marotrao Chirde	Digras Tq. Digras	12	865	300
39.	Renudeo Dnyanoba Dubewar	Limbi Tq. Pusad	13	913	300

Appendix - II

Stastitical parameters for different forms of expressing soil parameters for low and high yielding population of Nagpur mandarin orchards in *ambia* flush

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
pH/EC	37.38	15.30	40.92	233.94	41.91	13.59	32.42	184.61	1.27
EC/pH	0.03	0.01	42.67	0.00	0.03	0.01	35.32	0.00	2.06
pH x EC	1.79	0.73	40.60	0.53	1.50	0.52	34.28	0.27	1.99
pH/CC	0.80	0.39	49.06	0.15	1.09	0.38	34.65	0.14	1.09
CC/pH	1.56	0.72	46.17	0.52	1.03	0.36	34.45	0.13	4.10
pH x CC	89.02	40.90	45.95	1672.83	58.41	19.54	33.45	381.77	4.38
pH/OC	15.35	9.41	61.26	88.46	13.64	10.11	74.11	102.19	0.87
OC/pH	0.08	0.03	42.75	0.00	0.09	0.03	35.27	0.00	1.21
pH x OC	4.59	1.89	41.10	3.56	5.05	1.73	34.27	2.99	1.19
pH/N	0.04	0.01	36.44	0.00	0.02	0.01	25.04	0.00	8.02
N/pH	27.58	6.76	24.51	45.70	52.09	11.32	21.73	128.18	0.36
pH x N	1565.44	366.24	23.40	134133.04	2949.31	624.66	21.18	390195.26	0.34
pH/P	0.37	0.62	169.33	0.39	0.11	0.04	35.70	0.00	234.72
P/pH	6.45	4.18	64.76	17.44	9.74	3.04	31.23	9.25	1.89
pH x P	365.71	235.64	64.43	55527.25	553.60	180.38	32.58	32535.20	1.71
pH/K	0.02	0.02	73.21	0.00	0.01	0.00	32.54	0.00	14.91
K/pH	58.00	28.65	49.40	820.72	78.32	22.62	28.88	511.73	1.60
pH x K	3291.46	1594.07	48.43	2541065.30	4424.49	1248.40	28.22	1558508.84	1.63
pH/Ca	0.38	0.14	37.49	0.02	0.17	0.02	12.93	0.00	40.16
Ca/pH	2.96	0.90	30.32	0.80	5.88	0.74	12.65	0.55	1.45
pH x Ca	168.03	50.40	30.00	2540.56	332.90	40.19	12.07	1615.41	1.57
pH/Mg	1.57	1.16	74.19	1.35	0.57	0.19	32.89	0.04	38.02
Mg/pH	1.07	0.77	72.01	0.60	1.91	0.58	30.31	0.33	1.78
pH x Mg	61.25	44.71	72.98	1998.55	108.29	33.73	31.14	1137.50	1.76
pH/S	0.88	0.86	98.69	0.75	0.42	0.13	29.76	0.02	47.62
S/pH	1.99	1.54	77.39	2.38	2.57	0.69	26.70	0.47	5.05
pH x S	113.43	87.00	76.70	7568.85	145.71	39.52	27.12	1561.94	4.85
pH/Fe	1.30	0.76	58.29	0.58	1.05	0.14	13.71	0.02	27.85
Fe/pH	0.86	0.20	23.21	0.04	0.97	0.13	13.57	0.02	2.31
pH x Fe	48.94	11.42	23.34	130.44	54.85	6.97	12.70	48.52	2.69
pH/Mn	0.61	0.15	24.93	0.02	0.58	0.12	21.57	0.02	1.52
Mn/pH	1.75	0.55	31.39	0.30	1.83	0.46	24.98	0.21	1.45
pH x Mn	99.63	31.53	31.65	994.08	103.52	26.20	25.31	686.69	1.45
pH/Cu	2.78	0.92	33.18	0.85	1.57	0.67	42.56	0.45	1.91
Cu/pH	0.40	0.15	37.57	0.02	0.72	0.24	33.54	0.06	0.39
pH x Cu	22.98	8.62	37.50	74.27	40.98	13.86	33.82	192.09	0.39
pH/Zn	12.10	2.78	22.94	7.71	11.17	2.11	18.89	4.45	1.73
Zn/pH	0.09	0.02	20.62	0.00	0.09	0.02	19.27	0.00	0.99
pH x Zn	4.93	1.06	21.50	1.12	5.25	0.96	18.34	0.93	1.21
pH/Y	0.03	0.01	24.01	0.00	0.01	0.00	30.86	0.00	14.48

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio ($S_A \div S_B$)
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	
Y/pH	32.67	7.38	22.58	54.41	164.26	47.16	28.71	2223.68	0.02
pH x Y	1858.11	419.18	22.56	175708.87	9303.29	2627.24	28.24	6902399.86	0.03
EC/CC	0.03	0.02	66.10	0.00	0.03	0.01	35.99	0.00	2.84
CC/EC	58.68	36.84	62.78	1357.03	42.18	19.69	46.68	387.59	3.50
EC x CC	2.80	1.82	64.91	3.30	1.61	0.89	55.54	0.80	4.14
EC/OC	0.45	0.30	65.69	0.09	0.34	0.22	64.49	0.05	1.83
OC/EC	2.87	1.55	54.06	2.41	3.64	1.67	46.00	2.80	0.86
EC x OC	0.15	0.11	70.39	0.01	0.14	0.07	53.37	0.01	2.14
EC/N	0.00	0.00	48.68	0.00	0.00	0.00	36.99	0.00	9.16
N/EC	1013.67	455.59	44.94	207562.02	2153.72	780.99	36.26	609944.42	0.34
EC x N	50.43	27.09	53.71	733.63	79.37	34.40	43.34	1183.33	0.62
EC/P	0.01	0.01	127.13	0.00	0.00	0.00	60.20	0.00	43.48
P/EC	241.18	205.04	85.01	42039.74	416.62	199.94	47.99	39977.02	1.05
EC x P	11.57	8.06	69.70	65.01	14.32	6.15	42.96	37.84	1.72
EC/K	0.00	0.00	100.14	0.00	0.00	0.00	33.32	0.00	39.37
K/EC	2031.61	1055.35	51.95	1113761.54	3152.20	1085.85	34.45	1179078.29	0.94
EC x K	109.79	85.23	77.63	7263.86	122.26	64.32	52.61	4137.09	1.76
EC/Ca	0.01	0.01	74.51	0.00	0.00	0.00	37.50	0.00	30.14
Ca/EC	113.43	61.95	54.62	3838.14	245.27	81.05	33.04	6568.35	0.58
EC x Ca	5.10	2.34	45.87	5.47	8.85	3.13	35.43	9.82	0.56
EC/Mg	0.05	0.05	98.73	0.00	0.02	0.01	41.61	0.00	64.41
Mg/EC	38.06	26.20	68.85	686.60	79.48	34.83	43.83	1213.36	0.57
EC x Mg	1.99	1.86	93.30	3.45	2.90	1.42	48.84	2.01	1.72
EC/S	0.03	0.04	123.82	0.00	0.01	0.01	47.47	0.00	47.85
S/EC	76.44	63.41	82.96	4021.28	108.87	48.70	44.74	2371.81	1.70
EC x S	3.55	3.88	109.07	15.02	3.85	1.78	46.26	3.16	4.75
EC/Fe	0.04	0.03	75.94	0.00	0.03	0.01	35.78	0.00	10.47
Fe/EC	32.75	16.25	49.62	264.02	40.31	13.20	32.74	174.15	1.52
EC x Fe	1.51	0.66	43.43	0.43	1.47	0.58	39.53	0.34	1.28
EC/Mn	0.02	0.01	49.05	0.00	0.02	0.01	41.90	0.00	2.19
Mn/EC	65.10	32.66	50.18	1066.94	76.65	32.55	42.46	1059.34	1.01
EC x Mn	3.14	1.64	52.32	2.70	2.74	1.11	40.68	1.24	2.17
EC/Cu	0.09	0.04	42.11	0.00	0.04	0.02	48.80	0.00	3.27
Cu/EC	15.44	11.62	75.30	135.09	29.75	12.59	42.31	158.42	0.85
EC x Cu	0.74	0.49	65.97	0.24	1.12	0.63	56.77	0.40	0.59
EC/Zn	0.39	0.22	54.90	0.05	0.30	0.11	38.42	0.01	3.65
Zn/EC	3.32	1.69	50.98	2.86	3.86	1.37	35.55	1.88	1.52
EC x Zn	0.15	0.05	36.54	0.00	0.14	0.06	39.79	0.00	0.97
EC/Y	0.00	0.00	47.30	0.00	0.00	0.00	51.03	0.00	27.55
Y/EC	1193.63	500.42	41.92	250417.08	6977.69	3442.40	49.33	11850126.65	0.02
EC x Y	59.12	26.87	45.45	722.00	242.84	92.21	37.97	8501.86	0.08
CC/OC	25.77	30.81	119.55	949.36	13.49	10.30	76.34	106.10	8.95
OC/CC	0.06	0.04	61.33	0.00	0.09	0.03	37.19	0.00	1.32
CC x OC	7.17	4.99	69.61	24.93	5.44	3.09	56.80	9.57	2.61
CC/N	0.06	0.05	82.81	0.00	0.02	0.01	40.34	0.00	40.14

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
N/CC	22.05	11.75	53.29	138.01	56.02	21.58	38.53	465.77	0.30
CC x N	2424.22	1238.10	51.07	1532880.18	3077.84	1369.57	44.50	1875716.07	0.82
CC/P	0.47	0.70	148.31	0.48	0.12	0.06	49.56	0.00	138.80
P/CC	4.77	3.51	73.69	12.34	10.78	5.75	53.32	33.03	0.37
CC x P	606.92	494.33	81.45	244363.49	562.19	248.23	44.15	61617.79	3.97
CC/K	0.04	0.04	116.00	0.00	0.01	0.01	42.81	0.00	51.18
K/CC	44.18	30.16	68.27	909.85	83.06	33.68	40.55	1134.15	0.80
CC x K	5354.98	4060.84	75.83	16490416.47	4637.40	2122.19	45.76	4503671.82	3.66
CC/Ca	0.62	0.42	68.32	0.18	0.18	0.06	31.35	0.00	58.94
Ca/CC	2.46	1.53	62.08	2.33	6.32	2.23	35.31	4.98	0.47
CC x Ca	252.84	131.16	51.88	17203.94	347.61	138.80	39.93	19266.34	0.89
CC/Mg	2.33	1.91	82.15	3.65	0.60	0.31	52.58	0.10	37.33
Mg/CC	0.81	0.65	80.28	0.43	2.07	1.00	48.31	1.00	0.43
CC x Mg	98.90	88.73	89.73	7873.89	111.15	47.74	42.95	2279.08	3.45
CC/S	1.13	0.97	85.66	0.93	0.45	0.23	52.06	0.05	17.08
S/CC	1.31	0.74	56.38	0.55	2.87	1.45	50.61	2.12	0.26
CC x S	212.72	251.25	118.11	63125.83	145.77	53.88	36.96	2903.32	21.74
CC/Fe	2.22	2.63	118.17	6.90	1.09	0.43	39.70	0.19	36.71
Fe/CC	0.71	0.42	59.33	0.18	1.05	0.39	37.08	0.15	1.17
CC x Fe	73.80	34.10	46.20	1162.61	56.31	19.09	33.90	364.32	3.19
CC/Mn	0.97	0.57	58.97	0.33	0.59	0.22	36.43	0.05	7.12
Mn/CC	1.39	0.77	55.22	0.59	1.98	0.88	44.42	0.77	0.77
CC x Mn	153.82	78.40	50.97	6147.01	107.38	47.17	43.93	2225.38	2.76
CC/Cu	4.50	3.22	71.54	10.37	1.58	0.74	46.94	0.55	18.74
Cu/CC	0.33	0.22	67.27	0.05	0.78	0.38	48.58	0.14	0.35
CC x Cu	35.11	19.49	55.50	379.74	43.03	22.14	51.46	490.34	0.77
CC/Fe	2.22	2.63	118.17	6.90	1.09	0.43	39.70	0.19	36.71
Fe/CC	0.71	0.42	59.33	0.18	1.05	0.39	37.08	0.15	1.17
CC x Fe	73.80	34.10	46.20	1162.61	56.31	19.09	33.90	364.32	3.19
CC/Y	0.05	0.03	53.96	0.00	0.01	0.00	62.92	0.00	39.01
Y/CC	27.36	18.19	66.48	330.94	181.66	86.22	47.46	7434.29	0.04
CC x Y	2811.27	1293.74	46.02	1673753.21	9328.14	3415.14	36.61	11663159.44	0.14
OC/N	0.00	0.00	34.78	0.00	0.00	0.00	34.82	0.00	2.81
N/OC	382.14	127.71	33.42	16310.46	683.53	490.48	71.76	240575.39	0.07
OC x N	135.01	79.48	58.87	6317.74	272.38	132.77	48.75	17628.54	0.36
OC/P	0.03	0.05	172.71	0.00	0.01	0.00	44.59	0.00	124.42
P/OC	95.92	85.47	89.11	7305.33	124.68	64.47	51.71	4156.74	1.76
OC x P	31.55	31.49	99.81	991.65	50.52	27.28	54.01	744.32	1.33
OC/K	0.00	0.00	68.57	0.00	0.00	0.00	36.56	0.00	7.29
K/OC	762.98	331.91	43.50	110164.18	978.88	500.01	51.08	250011.24	0.44
OC x K	295.22	235.13	79.65	55286.32	412.23	197.93	48.01	39174.94	1.41
OC/Ca	0.03	0.02	58.64	0.00	0.02	0.01	37.07	0.00	9.60
Ca/OC	43.86	25.37	57.84	643.64	80.76	66.21	81.99	4384.17	0.15
OC x Ca	13.95	8.35	59.82	69.66	29.72	11.08	37.28	122.76	0.57
OC/Mg	0.12	0.11	86.67	0.01	0.05	0.02	46.08	0.00	21.21

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
Mg/OC	15.28	11.42	74.73	130.32	25.54	19.22	75.28	369.54	0.35
OC x Mg	5.18	4.86	93.85	23.61	9.71	4.28	44.07	18.29	1.29
OC/S	0.07	0.08	105.02	0.01	0.04	0.02	54.66	0.00	12.95
S/OC	35.65	54.44	152.68	2963.50	35.51	26.15	73.63	683.77	4.33
OC x S	8.48	6.32	74.56	39.99	12.68	5.02	39.61	25.21	1.59
OC/Fe	0.11	0.10	92.14	0.01	0.09	0.04	39.33	0.00	7.48
Fe/OC	13.29	8.63	64.93	74.45	13.12	9.12	69.50	83.14	0.90
OC x Fe	3.92	1.91	48.78	3.66	4.88	1.74	35.73	3.04	1.21
OC/Mn	0.05	0.02	48.50	0.00	0.05	0.02	39.79	0.00	1.35
Mn/OC	25.68	14.05	54.71	197.34	24.30	15.49	63.75	239.98	0.82
OC x Mn	8.31	5.05	60.77	25.51	9.28	4.10	44.16	16.80	1.52
OC/Cu	0.22	0.11	51.14	0.01	0.14	0.08	53.70	0.01	2.25
Cu/OC	5.98	3.66	61.10	13.36	9.71	6.73	69.29	45.28	0.30
OC x Cu	1.88	1.11	58.76	1.22	3.64	1.73	47.59	3.01	0.41
OC/Zn	1.01	0.56	56.08	0.32	0.98	0.33	34.07	0.11	2.85
Zn/OC	1.34	0.83	61.74	0.68	1.23	0.81	65.92	0.66	1.03
OC x ZN	0.39	0.17	43.80	0.03	0.47	0.20	42.06	0.04	0.74
OC/Y	0.00	0.00	45.55	0.00	0.00	0.00	48.89	0.00	16.55
Y/OC	495.57	318.75	64.32	101604.37	2274.57	2081.41	91.51	4332252.06	0.02
OC x Y	151.53	73.58	48.56	5413.64	833.15	410.99	49.33	168913.10	0.03
N/P	10.00	16.91	169.12	286.04	5.83	2.19	37.59	4.81	59.52
P/N	0.25	0.16	66.29	0.03	0.19	0.06	33.09	0.00	6.52
N x P	10466.03	8574.88	81.93	73528628.87	29418.55	13245.58	45.02	175445484.34	0.42
N/K	0.60	0.36	59.47	0.13	0.72	0.25	34.22	0.06	2.14
K/N	2.11	0.94	44.61	0.88	1.57	0.57	36.71	0.33	2.67
N x K	96098.98	60655.12	63.12	3679043621.25	233024.13	88345.22	37.91	7804878494.60	0.47
N/Ca	10.29	4.68	45.43	21.87	8.96	2.11	23.58	4.46	4.90
Ca/N	0.11	0.04	39.21	0.00	0.12	0.03	25.81	0.00	2.13
N x Ca	4708.55	2063.90	43.83	4259671.86	17412.83	4618.34	26.52	21329020.31	0.20
N/Mg	43.12	32.79	76.06	1075.39	29.34	9.22	31.43	85.05	12.64
Mg/N	0.04	0.04	88.26	0.00	0.04	0.02	40.05	0.00	5.97
N x Mg	1678.25	1232.50	73.44	1519048.22	5689.67	2276.30	40.01	5181556.90	0.29
N/S	25.69	28.80	112.09	829.16	22.16	9.20	41.50	84.57	9.80
S/N	0.09	0.10	111.95	0.01	0.05	0.02	37.82	0.00	23.51
N x S	2958.09	2383.42	80.57	5680698.12	7505.06	2370.71	31.59	5620249.61	1.01
N/Fe	35.40	17.87	50.48	319.26	54.84	14.21	25.90	201.81	1.58
Fe/N	0.03	0.02	44.98	0.00	0.02	0.01	31.25	0.00	6.16
N x Fe	1344.13	422.28	31.42	178320.84	2847.16	688.08	24.17	473456.29	0.38
N/Mn	16.68	5.25	31.50	27.60	29.89	8.37	27.99	70.00	0.39
Mn/N	0.07	0.03	39.49	0.00	0.04	0.01	36.84	0.00	3.81
N x Mn	2804.18	1336.19	47.65	1785397.71	5399.03	1807.77	33.48	3268026.09	0.55
N/Cu	74.28	25.42	34.22	646.14	79.74	31.44	39.43	988.53	0.65
Cu/N	0.02	0.01	39.01	0.00	0.01	0.01	37.93	0.00	1.19
N x Cu	646.72	293.19	45.33	85958.52	2165.06	898.33	41.49	806998.20	0.11
N/Zn	339.39	135.38	39.89	18328.98	575.95	139.29	24.19	19403.01	0.94

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio ($S_A \div S_B$)
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	
Zn/N	0.00	0.00	42.65	0.00	0.00	0.00	31.98	0.00	6.05
N x Zn	133.85	38.83	29.01	1507.80	274.95	81.99	29.82	6722.57	0.22
N/Y	0.89	0.30	34.13	0.09	0.34	0.11	31.36	0.01	8.30
Y/N	1.28	0.53	41.28	0.28	3.24	0.94	29.09	0.89	0.32
N x Y	51206.26	17114.11	33.42	292892838.41	494754.01	204151.18	41.26	41677703491.74	0.01
P/K	0.15	0.14	95.51	0.02	0.14	0.08	54.81	0.01	3.32
K/P	18.77	30.03	160.01	901.96	9.07	4.59	50.68	21.11	42.73
P x K	22611.99	20859.80	92.25	435131351.13	42398.43	16121.33	38.02	259897288.52	1.67
P/Ca	2.37	1.55	65.33	2.40	1.68	0.57	33.78	0.32	7.43
Ca/P	1.05	1.65	156.39	2.71	0.67	0.26	38.47	0.07	40.60
P x Ca	1122.93	997.52	88.83	995046.74	3256.05	1161.41	35.67	1348880.67	0.74
P/Mg	9.77	8.74	89.46	76.44	5.67	2.70	47.59	7.27	10.52
Mg/P	0.36	0.59	164.07	0.35	0.22	0.12	53.83	0.01	24.36
P x Mg	401.96	401.86	99.97	161488.77	1037.23	421.56	40.64	177716.45	0.91
P/S	5.14	5.63	109.49	31.71	4.09	1.98	48.42	3.93	8.07
S/P	0.74	1.61	217.43	2.60	0.29	0.11	39.58	0.01	198.10
P x S	737.61	768.56	104.20	590684.56	1425.30	576.84	40.47	332747.31	1.78
P/Fe	8.67	7.12	82.13	50.70	10.25	3.52	34.37	12.40	4.09
Fe/P	0.36	0.73	199.84	0.53	0.11	0.05	42.90	0.00	232.65
P x Fe	301.59	198.37	65.78	39351.58	533.94	180.95	33.89	32741.94	1.20
P/Mn	4.15	3.26	78.65	10.65	5.61	2.07	36.88	4.29	2.48
Mn/P	0.70	1.24	177.10	1.53	0.21	0.10	47.59	0.01	153.71
P x Mn	606.12	387.88	63.99	150451.73	1006.19	398.87	39.64	159097.74	0.95
P/Cu	17.54	13.68	78.04	187.28	14.81	6.18	41.75	38.24	4.90
Cu/P	0.13	0.20	152.35	0.04	0.08	0.04	51.44	0.00	22.84
P x Cu	151.06	103.09	68.25	10627.50	407.21	203.65	50.01	41471.71	0.26
P/Zn	80.70	67.02	83.05	4491.86	108.41	38.56	35.57	1486.90	3.02
Zn/P	0.04	0.07	198.74	0.00	0.01	0.00	38.92	0.00	288.18
P x Zn	30.62	18.16	59.32	329.81	51.29	18.80	36.65	353.26	0.93
P/Y	0.20	0.12	59.82	0.01	0.06	0.03	43.48	0.00	18.31
Y/P	10.70	15.28	142.76	233.54	18.58	7.97	42.88	63.47	3.68
P x Y	12403.87	9349.42	75.38	87411677.72	91321.00	39847.33	43.63	1587810048.37	0.06
K/Ca	22.83	17.14	75.09	293.90	13.47	4.13	30.65	17.04	17.25
Ca/K	0.07	0.06	81.57	0.00	0.08	0.03	32.09	0.00	5.06
K x Ca	9511.71	5324.18	55.98	28346942.82	26113.29	8411.02	32.21	70745292.53	0.40
K/Mg	85.69	78.42	91.52	6150.18	43.72	16.01	36.62	256.22	24.00
Mg/K	0.02	0.02	80.84	0.00	0.03	0.01	39.98	0.00	3.12
K x Mg	3852.76	3816.21	99.05	14563485.24	8622.98	3887.46	45.08	15112353.01	0.96
K/S	54.19	60.18	111.06	3622.02	33.78	16.04	47.49	257.37	14.07
S/K	0.05	0.08	146.03	0.01	0.04	0.02	45.88	0.00	22.45
K x S	6114.54	5467.54	89.42	29894028.57	11072.34	3435.97	31.03	11805887.12	2.53
K/Fe	79.98	82.69	103.39	6837.21	81.44	23.06	28.31	531.73	12.86
Fe/K	0.02	0.02	77.18	0.00	0.01	0.00	32.23	0.00	13.98
K x Fe	2784.20	1490.18	53.52	2220629.84	4325.57	1505.39	34.80	2266190.19	0.98
K/Mn	34.56	18.17	52.56	330.04	45.84	18.25	39.81	333.08	0.99

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
Mn/K	0.04	0.03	65.49	0.00	0.03	0.01	45.26	0.00	4.89
K x Mn	5977.34	3916.50	65.52	15338957.28	7932.77	2467.84	31.11	6090221.97	2.52
K/Cu	163.65	95.82	58.55	9180.58	125.65	74.75	59.49	5587.11	1.64
Cu/K	0.01	0.01	111.01	0.00	0.01	0.01	48.75	0.00	5.48
K x Cu	1273.26	713.91	56.07	509663.89	3144.37	1254.91	39.91	1574808.94	0.32
K/Zn	709.45	402.01	56.67	161612.07	867.70	288.69	33.27	83344.34	1.94
Zn/K	0.00	0.00	71.44	0.00	0.00	0.00	34.13	0.00	11.41
K x Zn	282.33	146.92	52.04	21584.27	413.11	149.88	36.28	22465.44	0.96
K/Y	1.84	0.97	52.58	0.94	0.52	0.21	39.97	0.04	21.98
Y/K	0.77	0.57	73.74	0.32	2.32	1.11	47.77	1.23	0.26
K x Y	109483.96	64490.99	58.90	4159088135.81	718435.38	251231.28	34.97	63117158439.35	0.07
Ca/Mg	5.03	4.34	86.28	18.83	3.40	1.27	37.44	1.62	11.59
Mg/Ca	0.46	0.51	111.75	0.26	0.33	0.13	38.14	0.02	16.13
Ca x Mg	162.28	100.43	61.88	10085.82	627.57	169.65	27.03	28780.84	0.35
Ca/S	2.68	2.98	111.41	8.90	2.50	0.87	35.03	0.76	11.64
S/Ca	0.84	1.03	122.03	1.05	0.45	0.15	32.75	0.02	48.75
Ca x S	308.87	194.98	63.13	38018.05	847.55	222.82	26.29	49648.71	0.77
Ca/Fe	3.85	2.38	61.90	5.68	6.16	1.03	16.76	1.07	5.33
Fe/Ca	0.33	0.15	46.43	0.02	0.17	0.03	17.02	0.00	28.49
Ca x Fe	143.99	53.27	36.99	2837.36	323.10	61.40	19.00	3770.05	0.75
Ca/Mn	1.82	0.73	40.16	0.53	3.40	0.85	24.90	0.72	0.74
Mn/Ca	0.66	0.30	45.56	0.09	0.32	0.10	30.55	0.01	9.54
Ca x Mn	295.42	137.70	46.61	18960.41	605.34	151.56	25.04	22971.48	0.83
Ca/Cu	8.23	3.77	45.80	14.19	9.25	4.06	43.93	16.50	0.86
Cu/Ca	0.15	0.08	52.58	0.01	0.13	0.05	37.37	0.00	2.93
Ca x Cu	68.35	37.67	55.11	1419.04	239.98	84.30	35.13	7105.66	0.20
Ca/Zn	36.40	16.45	45.21	270.71	65.21	12.36	18.96	152.80	1.77
Zn/Ca	0.03	0.01	44.39	0.00	0.02	0.00	20.60	0.00	19.89
Ca x Zn	14.33	4.57	31.90	20.90	31.01	7.62	24.56	58.02	0.36
Ca/Y	0.10	0.04	39.08	0.00	0.04	0.01	35.46	0.00	7.22
Y/Ca	12.33	5.50	44.56	30.21	28.67	10.43	36.39	108.85	0.28
Ca x Y	5482.76	2031.52	37.05	4127054.36	54150.18	14304.67	26.42	204623483.94	0.02
Mg/S	0.98	1.27	129.73	1.60	0.72	0.68	94.09	0.46	3.47
S/Mg	2.98	2.78	93.25	7.73	3.21	3.45	107.43	11.90	0.65
Mg x S	133.78	215.04	160.74	46243.03	255.41	272.74	106.78	74387.27	0.62
Mg/Fe	1.44	1.46	101.20	2.13	2.04	0.83	40.48	0.68	3.12
Fe/Mg	1.39	1.14	82.09	1.30	0.56	0.23	40.65	0.05	24.63
Mg x Fe	52.19	44.76	85.75	2003.18	103.02	27.85	27.03	775.41	2.58
Mg/Mn	0.65	0.50	77.79	0.25	0.84	0.53	63.36	0.28	0.90
Mn/Mg	2.64	1.93	73.20	3.72	2.01	1.68	83.70	2.84	1.31
Mg x Mn	110.96	93.65	84.40	8771.12	163.07	142.13	87.16	20199.89	0.43
Mg/Cu	2.98	2.35	78.84	5.50	2.35	1.82	77.42	3.32	1.66
Cu/Mg	0.66	0.64	96.99	0.41	0.85	0.84	98.72	0.70	0.59
Mg x Cu	24.15	18.32	75.85	335.69	62.59	57.15	91.31	3265.66	0.10
Mg/Zn	12.81	9.04	70.59	81.80	21.57	9.10	42.18	82.81	0.99

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio ($S_A \div S_B$)
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	
Zn/Mg	0.13	0.10	75.71	0.01	0.05	0.02	37.35	0.00	25.82
Mg x Zn	5.40	4.59	84.97	21.08	9.90	3.00	30.26	8.98	2.35
Mg/Y	0.03	0.02	70.35	0.00	0.01	0.01	71.54	0.00	11.59
Y/Mg	49.68	38.43	77.36	1477.24	181.56	155.42	85.60	24155.29	0.06
Mg x Y	2077.37	1764.08	84.92	3111983.68	14388.66	11054.30	76.83	122197510.83	0.03
S/Fe	2.68	2.93	109.11	8.57	2.70	0.83	30.53	0.68	12.58
Fe/S	0.76	0.79	103.03	0.62	0.41	0.14	33.71	0.02	32.56
S x Fe	96.82	76.99	79.52	5927.92	140.70	40.92	29.08	1674.26	3.54
S/Mn	1.27	1.07	84.10	1.14	1.59	0.89	56.08	0.80	1.42
Mn/S	1.70	2.43	142.56	5.91	0.87	0.56	65.15	0.32	18.56
S x Mn	186.73	132.84	71.14	17646.14	309.69	237.03	76.54	56184.45	0.31
S/Cu	5.63	5.12	90.98	26.23	4.14	2.26	54.68	5.13	5.11
Cu/S	0.35	0.35	101.87	0.12	0.33	0.21	62.31	0.04	2.93
S x Cu	46.86	47.43	101.22	2249.87	125.76	102.35	81.39	10476.54	0.21
S/Zn	23.61	19.79	83.80	391.46	29.13	10.95	37.59	119.86	3.27
Zn/S	0.07	0.06	78.87	0.00	0.04	0.02	38.02	0.00	13.43
S x Zn	9.92	7.50	75.60	56.28	13.30	3.75	28.23	14.10	3.99
S/Y	0.07	0.06	82.95	0.00	0.02	0.01	67.63	0.00	20.34
Y/S	30.12	32.25	107.07	1040.16	76.15	46.89	61.57	2198.29	0.47
S x Y	3548.47	2739.68	77.21	7505869.54	28048.36	21727.09	77.46	472066417.44	0.02
Fe/Mn	0.52	0.16	31.60	0.03	0.56	0.15	26.29	0.02	1.25
Mn/Fe	2.20	1.02	46.35	1.04	1.94	0.66	34.03	0.43	2.39
Fe x Mn	86.65	35.07	40.47	1229.63	99.35	24.23	24.38	586.87	2.10
Fe/Cu	2.40	1.04	43.45	1.09	1.52	0.66	43.23	0.43	2.51
Cu/Fe	0.51	0.26	50.40	0.07	0.77	0.30	39.68	0.09	0.73
Fe x Cu	19.67	8.21	41.73	67.40	39.40	13.05	33.12	170.31	0.40
Fe/Zn	10.29	2.99	29.09	8.96	10.75	2.18	20.23	4.73	1.89
Zn/Fe	0.11	0.06	55.88	0.00	0.10	0.02	20.27	0.00	9.97
Fe x Zn	4.29	1.56	36.27	2.42	5.11	1.27	24.86	1.61	1.50
Fe/Y	0.03	0.01	33.84	0.00	0.01	0.00	33.15	0.00	19.76
Y/Fe	42.90	28.42	66.24	807.58	173.03	59.54	34.41	3545.21	0.23
Fe x Y	1596.23	533.45	33.42	284568.25	8969.55	2493.25	27.80	6216282.47	0.05
Mn/Cu	4.83	2.04	42.21	4.15	2.80	1.12	39.97	1.25	3.31
Cu/Mn	0.25	0.12	46.97	0.01	0.41	0.16	38.48	0.03	0.54
Mn x Cu	40.29	19.56	48.55	382.64	76.32	39.14	51.28	1531.58	0.25
Mn/Zn	21.44	11.35	52.93	128.77	20.40	6.81	33.38	46.36	2.78
Zn/Mn	0.05	0.02	31.06	0.00	0.05	0.01	26.41	0.00	1.37
Mn x Zn	8.60	3.15	36.62	9.91	9.57	2.73	28.49	7.43	1.33
Mn/Y	0.06	0.03	45.32	0.00	0.01	0.01	45.63	0.00	22.03
Y/Mn	20.36	7.67	37.67	58.83	94.39	30.44	32.25	926.47	0.06
Mn x Y	3203.18	1075.18	33.57	1156017.25	17112.56	7930.64	46.34	62895007.26	0.02
Cu/Zn	4.89	2.19	44.68	4.78	8.20	3.69	44.98	13.60	0.35
Zn/Cu	0.24	0.09	37.98	0.01	0.15	0.06	43.81	0.00	2.03
Cu x Zn	1.99	0.84	42.11	0.70	3.73	1.13	30.31	1.28	0.55
Cu/Y	0.01	0.01	46.86	0.00	0.00	0.00	43.35	0.00	8.86

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio ($S_A \div S_B$)
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	
Y/Cu	90.21	34.28	38.01	1175.30	253.79	113.37	44.67	12852.91	0.09
Cu x Y	750.61	312.43	41.62	97610.25	6780.87	3018.06	44.51	9108660.70	0.01
Zn/Y	0.00	0.00	33.60	0.00	0.00	0.00	38.39	0.00	15.69
Y/Zn	392.92	114.21	29.07	13044.10	1842.95	664.03	36.03	440931.08	0.03
Zn x Y	161.68	54.58	33.76	2979.17	856.55	269.50	31.46	72632.25	0.04

Appendix –III

Stastitical parameters for different forms of expressing soil parameters for low and high yielding population of Nagpur mandarin orchards in *mrig* flush

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
pH/EC	31.90	8.86	27.76	78.45	40.39	12.11	29.97	146.57	0.54
EC/pH	0.03	0.01	24.41	0.00	0.03	0.01	28.98	0.00	1.10
pH x EC	1.92	0.47	24.45	0.22	1.52	0.42	27.74	0.18	1.23
pH/CC	0.78	0.43	55.30	0.19	1.02	0.39	37.89	0.15	1.25
CC/pH	1.55	0.58	37.38	0.34	1.11	0.36	32.59	0.13	2.58
pH x CC	89.05	33.67	37.80	1133.34	62.84	20.50	32.62	420.19	2.70
pH/OC	12.24	5.28	43.16	27.91	11.04	3.17	28.67	10.03	2.78
OC/pH	0.09	0.03	36.17	0.00	0.10	0.03	25.77	0.00	1.86
pH x OC	5.40	1.95	36.04	3.79	5.50	1.37	24.84	1.86	2.03
pH/N	0.04	0.02	51.50	0.00	0.02	0.00	17.93	0.00	43.37
N/pH	27.10	9.50	35.06	90.32	54.57	9.86	18.06	97.15	0.93
pH x N	1550.12	542.63	35.01	294451.27	3089.67	540.34	17.49	291967.85	1.01
pH/P	0.35	0.54	156.69	0.29	0.14	0.04	25.60	0.00	232.34
P/pH	7.17	4.65	64.88	21.62	7.71	2.08	26.95	4.31	5.01
pH x P	411.38	267.78	65.09	71708.38	435.98	114.35	26.23	13075.18	5.48
pH/K	0.02	0.01	40.93	0.00	0.01	0.00	27.05	0.00	4.11
K/pH	58.45	21.60	36.96	466.72	72.74	20.20	27.77	408.07	1.14
pH x K	3349.62	1254.63	37.46	1574099.47	4115.51	1111.56	27.01	1235557.63	1.27
pH/Ca	0.31	0.10	31.72	0.01	0.18	0.03	15.29	0.00	12.94
Ca/pH	3.50	1.00	28.53	1.00	5.69	0.82	14.36	0.67	1.50
pH x Ca	200.63	57.64	28.73	3322.75	322.90	48.24	14.94	2327.06	1.43
pH/Mg	1.26	0.84	66.79	0.71	0.85	0.26	30.88	0.07	10.25
Mg/pH	1.08	0.54	49.59	0.29	1.27	0.36	28.18	0.13	2.24
pH x Mg	61.79	30.57	49.48	934.73	72.19	20.50	28.40	420.22	2.22
pH/S	0.55	0.29	53.35	0.08	0.44	0.13	30.17	0.02	4.71
S/pH	2.32	1.08	46.34	1.16	2.45	0.71	29.07	0.51	2.29
pH x S	132.97	61.88	46.54	3829.54	138.90	41.28	29.72	1703.73	2.25
pH/Fe	1.12	0.14	12.62	0.02	0.99	0.14	14.48	0.02	0.97
Fe/pH	0.91	0.11	12.36	0.01	1.03	0.15	14.46	0.02	0.57
pH x Fe	52.09	6.25	12.01	39.11	58.51	8.09	13.82	65.39	0.60
pH/Mn	0.77	0.12	16.03	0.02	0.69	0.14	20.96	0.02	0.72
Mn/pH	1.35	0.31	22.71	0.09	1.52	0.40	26.00	0.16	0.60
pH x Mn	77.23	18.09	23.42	327.25	86.35	22.23	25.74	494.20	0.66
pH/Cu	4.04	1.54	38.08	2.36	1.91	0.60	31.18	0.35	6.67
Cu/pH	0.29	0.12	41.13	0.01	0.58	0.20	33.81	0.04	0.36
pH x Cu	16.48	6.91	41.92	47.70	32.81	10.96	33.41	120.12	0.40
pH/Zn	10.98	2.17	19.75	4.70	11.21	2.38	21.24	5.68	0.83
Zn/pH	0.09	0.02	17.89	0.00	0.09	0.02	19.70	0.00	0.85
pH x Zn	5.40	0.96	17.79	0.92	5.27	1.07	20.40	1.15	0.80
pH/Y	0.03	0.01	24.40	0.00	0.01	0.00	30.03	0.00	10.71
Y/pH	36.44	7.66	21.02	58.70	148.45	31.68	21.34	1003.44	0.06

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio ($S_A \div S_B$)
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	
pH x Y	2085.44	435.24	20.87	189435.44	8409.69	1779.37	21.16	3166164.74	0.06
EC/CC	0.03	0.02	69.83	0.00	0.03	0.01	48.45	0.00	1.86
CC/EC	48.48	19.94	41.14	397.67	44.87	19.89	44.32	395.60	1.01
EC x CC	3.01	1.36	45.23	1.86	1.68	0.71	42.48	0.51	3.66
EC/OC	0.39	0.15	39.42	0.02	0.29	0.11	36.34	0.01	2.13
OC/EC	2.88	0.94	32.51	0.88	3.86	1.35	34.93	1.81	0.48
EC x OC	0.19	0.10	52.66	0.01	0.15	0.07	44.19	0.00	2.22
EC/N	0.00	0.00	59.41	0.00	0.00	0.00	30.47	0.00	30.70
N/EC	844.71	319.13	37.78	101843.63	2192.45	773.63	35.29	598505.03	0.17
EC x N	52.96	25.57	48.29	654.04	83.80	32.66	38.97	1066.52	0.61
EC/P	0.01	0.02	180.35	0.00	0.00	0.00	36.66	0.00	278.99
P/EC	234.03	184.19	78.70	33926.33	308.00	117.16	38.04	13726.42	2.47
EC x P	13.51	9.46	70.05	89.58	11.82	4.95	41.82	24.45	3.66
EC/K	0.00	0.00	44.76	0.00	0.00	0.00	35.81	0.00	4.37
K/EC	1875.96	971.01	51.76	942866.47	2921.35	1203.40	41.19	1448167.07	0.65
EC x K	111.74	50.85	45.51	2585.92	111.81	53.64	47.97	2876.93	0.90
EC/Ca	0.01	0.00	46.88	0.00	0.00	0.00	32.10	0.00	10.29
Ca/EC	112.81	46.78	41.47	2188.83	230.02	79.30	34.48	6289.07	0.35
EC x Ca	6.62	2.22	33.51	4.92	8.67	2.77	31.99	7.69	0.64
EC/Mg	0.04	0.03	64.10	0.00	0.02	0.01	42.04	0.00	7.49
Mg/EC	34.19	19.92	58.26	396.81	51.28	20.33	39.66	413.51	0.96
EC x Mg	2.10	1.24	59.01	1.53	1.95	0.85	43.49	0.72	2.14
EC/S	0.02	0.01	65.00	0.00	0.01	0.01	43.72	0.00	5.34
S/EC	75.08	41.79	55.66	1746.20	99.32	43.57	43.87	1898.68	0.92
EC x S	4.39	2.27	51.68	5.14	3.68	1.26	34.26	1.59	3.23
EC/Fe	0.04	0.01	24.12	0.00	0.03	0.01	32.09	0.00	1.10
Fe/EC	28.74	7.46	25.94	55.58	41.55	12.85	30.92	165.09	0.34
EC x Fe	1.76	0.52	29.78	0.27	1.57	0.49	31.14	0.24	1.14
EC/Mn	0.03	0.01	29.56	0.00	0.02	0.01	30.84	0.00	1.83
Mn/EC	43.79	21.01	47.99	441.59	60.62	21.29	35.12	453.25	0.97
EC x Mn	2.56	0.75	29.17	0.56	2.35	0.98	41.64	0.96	0.58
EC/Cu	0.14	0.06	46.57	0.00	0.05	0.02	37.13	0.00	11.63
Cu/EC	9.34	5.44	58.22	29.57	22.85	9.02	39.50	81.45	0.36
EC x Cu	0.55	0.26	48.18	0.07	0.90	0.45	50.09	0.20	0.34
EC/Zn	0.37	0.13	35.20	0.02	0.30	0.09	30.32	0.01	2.11
Zn/EC	3.05	1.14	37.53	1.31	3.70	1.22	32.84	1.48	0.88
EC x Zn	0.18	0.05	27.29	0.00	0.14	0.05	36.78	0.00	0.86
EC/Y	0.00	0.00	35.44	0.00	0.00	0.00	47.16	0.00	14.03
Y/EC	1170.47	430.22	36.76	185091.57	6015.53	2213.85	36.80	4901135.79	0.04
EC x Y	69.35	21.19	30.55	448.81	224.64	79.30	35.30	6288.70	0.07
CC/OC	18.25	8.70	47.69	75.76	12.02	4.73	39.39	22.41	3.38
OC/CC	0.07	0.04	57.08	0.00	0.10	0.04	43.26	0.00	0.91
CC x OC	8.65	4.85	56.05	23.51	6.19	2.73	44.20	7.48	3.14
CC/N	0.07	0.05	69.28	0.00	0.02	0.01	37.33	0.00	37.75
N/CC	21.86	16.32	74.69	266.44	55.47	24.39	43.97	594.75	0.45

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
CC x N	2361.99	1197.15	50.68	1433157.06	3432.53	1315.51	38.32	1730569.43	0.83
CC/P	0.52	0.86	164.77	0.74	0.16	0.07	44.22	0.00	153.06
P/CC	5.57	4.85	87.21	23.57	8.16	4.76	58.30	22.63	1.04
CC x P	637.63	455.42	71.42	207402.97	468.06	159.52	34.08	25447.99	8.15
CC/K	0.03	0.02	55.99	0.00	0.02	0.01	36.52	0.00	8.62
K/CC	46.54	36.72	78.90	1348.39	73.53	36.72	49.93	1348.17	1.00
CC x K	5150.69	2740.86	53.21	7512292.49	4581.62	1900.44	41.48	3611672.99	2.08
CC/Ca	0.48	0.23	48.67	0.06	0.20	0.07	36.06	0.01	10.70
Ca/CC	2.71	1.63	60.06	2.65	5.80	2.45	42.19	5.98	0.44
CC x Ca	314.14	160.28	51.02	25690.17	357.91	129.14	36.08	16678.09	1.54
CC/Mg	2.07	1.71	82.57	2.92	0.95	0.43	45.49	0.19	15.71
Mg/CC	0.89	0.73	81.53	0.53	1.30	0.62	48.17	0.39	1.35
CC x Mg	91.81	55.62	60.58	3093.73	79.84	34.88	43.69	1216.72	2.54
CC/S	0.86	0.55	64.48	0.31	0.51	0.26	51.17	0.07	4.60
S/CC	1.87	1.48	79.12	2.19	2.53	1.25	49.42	1.56	1.40
CC x S	205.27	138.34	67.39	19138.12	151.71	70.36	46.38	4951.23	3.87
CC/Fe	1.74	0.73	41.64	0.53	1.09	0.38	34.95	0.14	3.65
Fe/CC	0.71	0.39	55.00	0.15	1.04	0.39	37.25	0.15	1.02
CC x Fe	80.48	29.92	37.17	894.99	65.34	24.04	36.79	578.02	1.55
CC/Mn	1.21	0.54	44.43	0.29	0.77	0.32	41.49	0.10	2.83
Mn/CC	1.07	0.69	64.42	0.48	1.56	0.70	45.13	0.49	0.97
CC x Mn	116.95	40.48	34.61	1638.62	94.92	36.75	38.71	1350.38	1.21
CC/Cu	6.41	3.66	57.02	13.37	2.13	1.02	48.09	1.05	12.73
Cu/CC	0.23	0.18	78.85	0.03	0.59	0.31	52.69	0.10	0.34
CC x Cu	24.87	13.04	52.42	169.93	36.13	16.82	46.55	282.92	0.60
CC/Zn	17.02	6.76	39.70	45.67	12.38	4.58	36.95	20.94	2.18
Zn/CC	0.07	0.04	58.00	0.00	0.09	0.04	42.81	0.00	1.12
CC x Zn	8.39	3.59	42.80	12.89	5.87	2.48	42.23	6.15	2.10
CC/Y	0.05	0.02	52.97	0.00	0.01	0.00	37.71	0.00	67.19
Y/CC	28.32	15.87	56.04	251.96	149.73	66.14	44.17	4374.35	0.06
CC x Y	3230.54	1443.45	44.68	2083543.05	9405.98	3849.74	40.93	14820477.07	0.14
OC/N	0.00	0.00	50.81	0.00	0.00	0.00	18.83	0.00	35.72
N/OC	321.64	155.20	48.25	24085.75	581.38	109.31	18.80	11949.37	2.02
OC x N	149.61	80.92	54.09	6548.23	309.74	123.13	39.75	15162.15	0.43
OC/P	0.03	0.07	195.02	0.00	0.01	0.00	35.35	0.00	206.44
P/OC	94.09	92.66	98.48	8586.17	84.69	32.69	38.60	1068.71	8.03
OC x P	35.84	22.13	61.76	489.91	42.47	16.14	38.00	260.44	1.88
OC/K	0.00	0.00	46.07	0.00	0.00	0.00	25.68	0.00	5.64
K/OC	723.26	481.41	66.56	231758.17	769.39	185.78	24.15	34513.41	6.72
OC x K	317.38	176.90	55.74	31291.96	415.24	196.83	47.40	38741.78	0.81
OC/Ca	0.03	0.02	65.01	0.00	0.02	0.01	30.54	0.00	14.34
Ca/OC	44.66	27.42	61.40	751.70	62.51	18.60	29.76	345.99	2.17
OC x Ca	18.18	6.83	37.59	46.69	31.45	9.59	30.51	92.05	0.51
OC/Mg	0.11	0.08	69.76	0.01	0.08	0.04	43.49	0.00	4.62
Mg/OC	12.51	6.82	54.50	46.49	14.44	7.15	49.49	51.08	0.91

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
OC x Mg	6.09	4.05	66.47	16.38	6.86	2.32	33.88	5.40	3.03
OC/S	0.05	0.04	73.70	0.00	0.04	0.02	41.77	0.00	4.48
S/OC	28.17	16.43	58.33	269.95	27.30	11.83	43.34	140.02	1.93
OC x S	12.55	7.81	62.27	61.05	13.31	4.66	35.03	21.73	2.81
OC/Fe	0.10	0.04	36.32	0.00	0.10	0.03	27.81	0.00	2.05
Fe/OC	11.14	5.24	47.05	27.49	11.35	3.54	31.16	12.52	2.20
OC x Fe	4.93	1.94	39.38	3.78	5.71	1.78	31.13	3.16	1.20
OC/Mn	0.07	0.03	40.55	0.00	0.07	0.02	28.94	0.00	2.34
Mn/OC	16.43	7.58	46.15	57.51	16.66	6.02	36.13	36.22	1.59
OC x Mn	7.27	2.90	39.89	8.40	8.49	3.63	42.74	13.18	0.64
OC/Cu	0.39	0.25	62.81	0.06	0.18	0.07	40.05	0.01	11.14
Cu/OC	3.56	2.05	57.52	4.19	6.40	2.95	46.12	8.72	0.48
OC x Cu	1.52	0.80	52.55	0.64	3.18	1.29	40.69	1.67	0.38
OC/Zn	1.05	0.50	47.65	0.25	1.09	0.36	33.07	0.13	1.92
Zn/OC	1.16	0.55	47.04	0.30	1.03	0.38	36.72	0.14	2.09
OC x ZN	0.50	0.18	36.19	0.03	0.51	0.16	30.62	0.02	1.36
OC/Y	0.00	0.00	49.13	0.00	0.00	0.00	37.63	0.00	27.30
Y/OC	448.37	211.51	47.17	44735.17	1624.05	536.52	33.04	287858.07	0.16
OC x Y	194.85	77.11	39.57	5946.04	821.56	285.64	34.77	81589.82	0.07
N/P	9.15	15.60	170.51	243.21	7.62	2.49	32.74	6.22	39.12
P/N	0.31	0.30	96.68	0.09	0.15	0.05	35.20	0.00	34.48
N x P	11312.66	9075.60	80.23	82366435.50	23606.54	6859.27	29.06	47049524.59	1.75
N/K	0.53	0.29	55.32	0.09	0.79	0.20	25.81	0.04	2.09
K/N	2.49	1.43	57.60	2.06	1.35	0.35	25.77	0.12	17.04
N x K	91246.74	47895.43	52.49	2293971887.09	229278.75	92785.67	40.47	8609180121.94	0.27
N/Ca	8.66	4.45	51.36	19.80	9.77	2.19	22.39	4.78	4.14
Ca/N	0.16	0.11	67.98	0.01	0.11	0.02	22.62	0.00	19.49
N x Ca	5285.75	2186.39	41.36	4780290.65	17647.38	4322.50	24.49	18683981.88	0.26
N/Mg	34.16	27.36	80.08	748.55	46.97	17.89	38.08	320.00	2.34
Mg/N	0.05	0.03	66.15	0.00	0.02	0.01	35.76	0.00	12.07
N x Mg	1677.37	1030.31	61.42	1061529.98	3910.56	1272.05	32.53	1618116.63	0.66
N/S	14.61	9.21	63.03	84.83	24.22	8.59	35.48	73.83	1.15
S/N	0.10	0.07	66.80	0.00	0.05	0.01	31.46	0.00	20.80
N x S	3604.22	2237.01	62.07	5004205.72	7589.18	2652.47	34.95	7035621.21	0.71
N/Fe	30.04	10.28	34.23	105.71	53.95	12.68	23.50	160.79	0.66
Fe/N	0.04	0.02	52 99	0.00	0.02	0.00	24.06	0.00	19.63
N x Fe	1418.59	564.58	39.80	318746.06	3182.46	663.18	20.84	439811.46	0.72
N/Mn	20.78	8.28	39.88	68.64	37.64	9.80	26.05	96.14	0.71
Mn/N	0.06	0.03	53.75	0.00	0.03	0.01	34.20	0.00	9.95
N x Mn	2097.09	874.83	41.72	765319.42	4702.01	1423.55	30.28	2026488.42	0.38
N/Cu	107.19	52.20	48.70	2725.08	105.54	40.84	38.70	1667.98	1.63
Cu/N	0.01	0.01	59.26	0.00	0.01	0.01	44.95	0.00	2.04
N x Cu	457.06	271.05	59.30	73466.57	1758.68	569.57	32.39	324412.94	0.23
N/Zn	303.66	138.78	45.70	19260.90	611.41	164.20	26.86	26960.88	0.71
Zn/N	0.00	0.00	62.91	0.00	0.00	0.00	28.35	0.00	27.90

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
N x Zn	143.35	49.78	34.73	2478.45	286.79	74.58	26.01	5562.81	0.45
N/Y	0.77	0.31	39.73	0.09	0.39	0.12	30.37	0.01	6.80
Y/N	1.54	0.71	45.84	0.50	2.78	0.68	24.40	0.46	1.09
N x Y	57153.53	24010.83	42.01	576519949.77	462698.58	137058.91	29.62	18785144512.08	0.03
P/K	0.14	0.12	83.27	0.01	0.11	0.05	43.46	0.00	5.53
K/P	21.28	42.79	201.08	1830.87	9.97	3.11	31.19	9.67	189.41
P x K	23935.57	17853.60	74.59	318750987.90	31937.29	13231.53	41.43	175073272.41	1.82
P/Ca	2.11	1.49	70.47	2.22	1.40	0.50	35.53	0.25	8.98
Ca/P	1.16	2.13	184.29	4.56	0.80	0.25	31.39	0.06	72.92
P x Ca	1488.37	1073.23	72.11	1151826.92	2462.80	691.16	28.06	477701.49	2.41
P/Mg	10.85	12.74	117.46	162.31	6.54	2.55	39.06	6.53	24.87
Mg/P	0.38	0.55	142.62	0.30	0.18	0.07	37.13	0.00	70.55
P x Mg	383.32	264.42	68.98	69917.63	557.81	225.75	40.47	50964.84	1.37
P/S	4.31	3.88	90.00	15.05	3.46	1.41	40.61	1.97	7.62
S/P	0.85	1.32	156.49	1.75	0.35	0.15	44.60	0.02	73.59
P x S	827.24	482.00	58.27	232328.51	1051.94	366.43	34.83	134271.54	1.73
P/Fe	8.03	5.21	64.83	27.10	7.63	2.46	32.23	6.05	4.48
Fe/P	0.33	0.57	170.20	0.32	0.14	0.04	30.01	0.00	173.65
P x Fe	372.42	255.49	68.60	65273.57	450.24	143.25	31.82	20520.74	3.18
P/Mn	5.56	3.71	66.66	13.74	5.24	1.58	30.12	2.49	5.51
Mn/P	0.48	0.74	155.11	0.55	0.21	0.06	28.36	0.00	159.59
P x Mn	544.71	377.75	69.35	142694.90	678.91	309.05	45.52	95511.78	1.49
P/Cu	28.46	21.38	75.11	456.90	14.07	3.77	26.80	14.21	32.15
Cu/P	0.10	0.18	176.04	0.03	0.08	0.02	32.20	0.00	51.91
P x Cu	120.02	103.30	86.06	10670.30	264.11	141.97	53.76	20156.19	0.53
P/Zn	77.58	52.41	67.55	2746.52	86.34	28.97	33.56	839.48	3.27
Zn/P	0.03	0.04	137.98	0.00	0.01	0.00	32.15	0.00	99.73
P x Zn	38.98	26.33	67.56	693.37	40.50	13.26	32.75	175.89	3.94
P/Y	0.21	0.15	71.93	0.02	0.06	0.03	46.04	0.00	34.56
Y/P	12.51	20.17	161.24	406.90	20.51	6.40	31.18	40.91	9.95
P x Y	14828.74	9757.46	65.80	95208095.08	64804.03	22279.24	34.38	496364478.07	0.19
K/Ca	18.35	10.28	56.02	105.63	13.02	4.21	32.30	17.69	5.97
Ca/K	0.07	0.04	52.86	0.00	0.08	0.02	27.56	0.00	2.54
K x Ca	11613.46	4875.87	41.98	23774085.53	23525.13	7439.48	31.62	55345906.91	0.43
K/Mg	74.13	56.53	76.26	3195.27	61.09	21.76	35.62	473.49	6.75
Mg/K	0.02	0.02	69.38	0.00	0.02	0.01	36.27	0.00	5.03
K x Mg	3525.83	1996.64	56.63	3986569.21	5320.31	2347.52	44.12	5510833.35	0.72
K/S	33.46	25.88	77.36	670.01	33.14	16.25	49.04	264.12	2.54
S/K	0.05	0.03	68.65	0.00	0.04	0.02	42.31	0.00	4.43
K x S	7496.17	4114.18	54.88	16926495.22	9890.95	3518.11	35.57	12377085.46	1.37
K/Fe	65.40	27.13	41.49	736.15	72.27	25.03	34.63	626.53	1.17
Fe/K	0.02	0.01	42.17	0.00	0.02	0.00	29.86	0.00	2.76
K x Fe	3038.08	1149.49	37.84	1321322.36	4224.59	1159.41	27.44	1344234.86	0.98
K/Mn	45.20	18.04	39.90	325.35	49.62	15.36	30.96	235.96	1.38
Mn/K	0.03	0.02	66.86	0.00	0.02	0.01	32.64	0.00	6.49

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio ($S_A \div S_B$)
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	
K x Mn	4437.43	1718.86	38.74	2954481.72	6405.71	3144.07	49.08	9885161.55	0.30
K/Cu	241.40	134.87	55.87	18191.17	137.34	50.24	36.58	2524.28	7.21
Cu/K	0.01	0.00	71.30	0.00	0.01	0.00	45.23	0.00	1.18
K x Cu	935.22	472.84	50.56	223582.39	2407.51	1184.04	49.18	1401947.22	0.16
K/Zn	647.05	279.79	43.24	78284.11	807.16	248.15	30.74	61578.09	1.27
Zn/K	0.00	0.00	49.50	0.00	0.00	0.00	31.00	0.00	4.93
K x Zn	312.17	120.92	38.73	14620.74	386.07	142.12	36.81	20198.45	0.72
K/Y	1.66	0.62	37.44	0.39	0.51	0.17	32.55	0.03	14.00
Y/K	0.72	0.33	46.26	0.11	2.16	0.71	33.07	0.51	0.21
K x Y	123218.23	56280.21	45.68	3167461873.17	620070.42	240765.40	38.83	57967977540.83	0.05
Ca/Mg	4.65	4.00	86.06	15.99	4.91	1.82	36.96	3.30	4.85
Mg/Ca	0.34	0.20	58.98	0.04	0.23	0.08	35.34	0.01	6.15
Ca x Mg	209.39	107.28	51.23	11508.92	406.93	116.47	28.62	13564.40	0.85
Ca/S	1.89	1.15	60.81	1.33	2.55	0.93	36.51	0.87	1.53
S/Ca	0.71	0.39	54.41	0.15	0.44	0.15	34.45	0.02	6.52
Ca x S	471.18	278.09	59.02	77334.47	785.39	239.16	30.45	57197.02	1.35
Ca/Fe	3.88	1.08	27.89	1.17	5.63	1.21	21.41	1.46	0.80
Fe/Ca	0.28	0.09	33.08	0.01	0.19	0.04	23.54	0.00	4.52
Ca x Fe	183.75	60.81	33.09	3697.76	332.60	66.18	19.90	4379.68	0.84
Ca/Mn	2.71	0.92	33.90	0.84	3.93	1.00	25.39	1.00	0.84
Mn/Ca	0.43	0.20	46.64	0.04	0.27	0.09	31.22	0.01	5.40
Ca x Mn	267.41	84.24	31.50	7095.86	491.63	143.55	29.20	20606.60	0.34
Ca/Cu	13.87	5.83	41.99	33.93	10.86	3.72	34.24	13.83	2.45
Cu/Ca	0.09	0.05	55.45	0.00	0.10	0.04	36.03	0.00	1.73
Ca x Cu	57.90	27.93	48.23	779.99	187.35	72.32	38.60	5230.26	0.15
Ca/Zn	38.85	14.95	38.48	223.50	63.71	16.46	25.84	271.04	0.82
Zn/Ca	0.03	0.01	38.19	0.00	0.02	0.00	22.29	0.00	9.32
Ca x Zn	18.67	5.22	27.95	27.23	30.09	7.98	26.53	63.73	0.43
Ca/Y	0.10	0.04	36.51	0.00	0.04	0.01	34.98	0.00	6.57
Y/Ca	11.30	4.22	37.39	17.84	26.76	7.39	27.61	54.59	0.33
Ca x Y	7345.85	2817.53	38.36	7938493.30	47683.31	11563.40	24.25	133712320.55	0.06
Mg/S	0.53	0.33	61.51	0.11	0.55	0.29	53.13	0.09	1.25
S/Mg	2.60	1.55	59.69	2.42	2.36	1.20	50.93	1.45	1.67
Mg x S	155.57	120.25	77.30	14460.68	219.94	172.91	78.62	29898.72	0.48
Mg/Fe	1.19	0.58	48.67	0.33	1.27	0.44	34.84	0.19	1.72
Fe/Mg	1.13	0.72	63.81	0.52	0.89	0.33	36.58	0.11	4.91
Mg x Fe	57.10	30.96	54.22	958.43	74.00	21.81	29.47	475.68	2.01
Mg/Mn	0.82	0.42	50.56	0.17	0.90	0.36	39.72	0.13	1.34
Mn/Mg	1.70	1.24	73.19	1.54	1.32	0.62	47.06	0.39	3.97
Mg x Mn	85.04	52.88	62.18	2796.00	116.52	59.33	50.91	3519.53	0.79
Mg/Cu	4.22	2.43	57.50	5.89	2.58	1.46	56.52	2.13	2.77
Cu/Mg	0.35	0.23	66.82	0.05	0.51	0.27	51.87	0.07	0.75
Mg x Cu	18.24	12.76	69.92	162.73	43.30	23.52	54.31	553.11	0.29
Mg/Zn	11.41	5.31	46.57	28.23	14.19	4.67	32.90	21.79	1.30
Zn/Mg	0.11	0.07	58.61	0.00	0.08	0.03	36.69	0.00	5.27

Form of expression	Population A (Low yield) Parameter mean	SD	CV	Variance (S_A)	Population B (High yield) Parameter mean	SD	CV	Variance (S_B)	Variance ratio ($S_A \div S_B$)
Mg x Zn	6.04	3.45	57.20	11.92	6.73	2.41	35.85	5.82	2.05
Mg/Y	0.03	0.02	53.05	0.00	0.01	0.00	44.31	0.00	15.55
Y/Mg	46.34	34.76	75.00	1207.97	130.25	62.32	47.85	3884.09	0.31
Mg x Y	2269.25	1290.35	56.86	1664995.06	11285.46	5367.28	47.56	28807692.39	0.06
S/Fe	2.55	1.15	44.94	1.32	2.43	0.85	34.83	0.72	1.84
Fe/S	0.49	0.25	50.40	0.06	0.46	0.16	34.09	0.02	2.45
S x Fe	122.80	63.29	51.54	4006.00	142.53	42.97	30.15	1846.62	2.17
S/Mn	1.78	0.88	49.33	0.77	1.92	1.00	52.34	1.01	0.76
Mn/S	0.73	0.41	55.52	0.16	0.64	0.29	44.80	0.08	1.98
S x Mn	180.97	103.11	56.97	10630.88	239.86	119.56	49.85	14295.55	0.74
S/Cu	9.15	5.61	61.32	31.48	5.74	4.34	75.54	18.81	1.67
Cu/S	0.15	0.08	56.34	0.01	0.26	0.14	55.01	0.02	0.35
S x Cu	39.25	26.21	66.78	687.04	85.13	31.75	37.30	1008.20	0.68
S/Zn	25.29	12.78	50.53	163.27	27.72	10.86	39.16	117.86	1.39
Zn/S	0.05	0.03	55.03	0.00	0.04	0.02	39.87	0.00	2.82
S x Zn	12.65	6.46	51.04	41.68	12.78	4.37	34.15	19.06	2.19
S/Y	0.07	0.04	56.64	0.00	0.02	0.01	52.43	0.00	13.46
Y/S	19.84	11.41	57.50	130.13	62.92	27.37	43.50	749.06	0.17
S x Y	4860.29	2593.85	53.37	6728056.74	23659.46	13572.50	57.37	184212761.12	0.04
Fe/Mn	0.70	0.14	19.58	0.02	0.72	0.19	26.05	0.03	0.54
Mn/Fe	1.51	0.46	30.37	0.21	1.52	0.55	36.13	0.30	0.70
Fe x Mn	70.03	15.98	22.82	255.47	88.49	22.73	25.68	516.53	0.49
Fe/Cu	3.63	1.28	35.21	1.63	1.97	0.65	32.92	0.42	3.89
Cu/Fe	0.32	0.14	44.44	0.02	0.57	0.24	41.84	0.06	0.35
Fe x Cu	15.09	6.58	43.60	43.29	33.88	12.26	36.18	150.22	0.29
Fe/Zn	10.03	2.47	24.61	6.10	11.72	3.46	29.50	11.95	0.51
Zn/Fe	0.11	0.03	24.62	0.00	0.09	0.03	29.66	0.00	0.89
Fe x Zn	4.89	0.95	19.37	0.90	5.37	1.00	18.67	1.01	0.89
Fe/Y	0.03	0.01	26.65	0.00	0.01	0.00	34.26	0.00	7.53
Y/Fe	40.69	10.56	25.95	111.49	147.39	41.17	27.93	1695.22	0.07
Fe x Y	1897.32	457.86	24.13	209634.47	8631.42	1966.40	22.78	3866741.16	0.05
Mn/Cu	5.34	2.09	39.09	4.36	2.81	0.82	29.31	0.68	6.43
Cu/Mn	0.22	0.08	39.24	0.01	0.39	0.12	30.45	0.01	0.52
Mn x Cu	23.04	15.29	66.34	233.71	52.43	31.49	60.06	991.66	0.24
Mn/Zn	14.78	4.20	28.38	17.60	16.93	4.64	27.42	21.55	0.82
Zn/Mn	0.07	0.02	24.69	0.00	0.06	0.02	30.15	0.00	0.86
Mn x Zn	7.31	2.53	34.60	6.39	8.10	3.11	38.47	9.70	0.66
Mn/Y	0.04	0.01	33.47	0.00	0.01	0.00	34.49	0.00	12.16
Y/Mn	27.92	7.25	25.97	52.58	102.15	30.65	30.01	939.57	0.06
Mn x Y	2809.15	799.34	28.45	638941.09	12933.16	4976.23	38.48	24762818.31	0.03
Cu/Zn	3.09	1.22	39.52	1.49	6.39	2.09	32.63	4.35	0.34
Zn/Cu	0.37	0.14	36.97	0.02	0.18	0.06	35.94	0.00	4.80
Cu x Zn	1.58	0.80	50.80	0.64	3.10	1.44	46.58	2.09	0.31
Cu/Y	0.01	0.00	49.10	0.00	0.00	0.00	47.34	0.00	4.26
Y/Cu	145.91	59.44	40.74	3533.36	282.54	105.58	37.37	11147.06	0.32

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Parameter mean	SD	CV	Variance (S_A)	Parameter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
Cu x Y	598.26	253.44	42.36	64233.87	4879.37	2017.52	41.35	4070369.91	0.02
Zn/Y	0.00	0.00	31.31	0.00	0.00	0.00	33.87	0.00	14.54
Y/Zn	398.74	105.38	26.43	11104.95	1648.10	426.20	25.86	181643.78	0.06
Zn x Y	196.89	56.11	28.50	3148.11	790.10	269.03	34.05	72375.95	0.04

Appendix – IV

Stastitical parameters for different forms of expressing leaf nutrient for low and high yielding population of Nagpur mandarin orchards in *ambia* flush

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio SA÷SB
	Parameter mean	SD	CV	Variance SA	Parameter mean	SD	CV	Variance SB	
N/P	12.60	2.58	0.20	6.64	17.40	6.78	0.39	45.93	0.14
P/N	0.08	0.39	4.89	0.15	0.06	0.15	2.57	0.02	6.92
N x P	0.39	0.01	360.38	0.00	0.37	0.02	520.50	0.00	0.53
N/K	1.48	0.28	0.19	0.08	1.74	1.16	0.66	1.34	0.06
K/N	0.68	3.56	5.25	12.64	0.57	0.86	1.51	0.75	16.90
N x K	3.31	0.13	386.77	0.02	3.69	0.11	305.97	0.01	1.28
N/Ca	0.67	0.45	0.68	0.21	0.65	0.63	0.97	0.40	0.52
Ca/N	1.49	2.20	1.47	4.83	1.54	1.58	1.03	2.49	1.94
N x Ca	7.28	0.08	108.60	0.01	9.88	0.21	208.29	0.04	0.15
N/Mg	3.63	1.85	0.51	3.41	3.90	6.03	1.55	36.37	0.09
Mg/N	0.28	0.54	1.97	0.29	0.26	0.17	0.65	0.03	10.66
N x Mg	1.34	0.02	144.98	0.00	1.65	0.02	131.07	0.00	0.81
N/S	10.61	4.22	0.40	17.84	9.22	5.73	0.62	32.82	0.54
S/N	0.09	0.24	2.51	0.06	0.11	0.17	1.61	0.03	1.84
N x S	0.46	0.01	185.27	0.00	0.70	0.02	326.49	0.00	0.14
N/Fe	0.02	0.01	0.24	0.00	0.02	0.01	0.48	0.00	0.27
Fe/N	46.57	194.62	4.18	37878.77	47.91	100.44	2.10	10088.14	3.75
N x Fe	227.19	7.00	308.10	48.99	308.15	13.10	425.09	171.59	0.29
N/Mn	0.07	0.02	0.29	0.00	0.06	0.03	0.52	0.00	0.38
Mn/N	13.89	48.55	3.50	2356.62	15.70	29.93	1.91	895.82	2.63
N x Mn	67.75	1.75	257.71	3.05	101.00	3.90	386.49	15.24	0.20
N/Cu	0.14	0.03	0.24	0.00	0.10	0.05	0.49	0.00	0.45
Cu/N	6.98	29.41	4.22	864.74	9.76	19.75	2.02	389.87	2.22
N x Cu	34.04	1.06	310.73	1.12	62.75	2.58	410.36	6.63	0.17
N/Zn	0.08	0.02	0.28	0.00	0.08	0.05	0.57	0.00	0.23
Zn/N	12.65	44.68	3.53	1996.18	12.19	21.24	1.74	450.93	4.43
Y/N	111.53	292.30	2.62	85440.21	487.34	973.09	2.00	946898.91	0.09
N x Y	544.12	10.51	193.20	110.51	3134.74	126.91	404.85	16106.29	0.01
P/K	0.12	0.11	0.93	0.01	0.10	0.17	1.70	0.03	0.41
K/P	8.54	9.16	1.07	83.97	9.97	5.86	0.59	34.37	2.44
P x K	0.26	0.05	1890.80	0.00	0.21	0.02	785.46	0.00	8.89
P/Ca	0.05	0.18	3.32	0.03	0.04	0.09	2.50	0.01	3.56
Ca/P	18.80	5.66	0.30	32.09	26.73	10.70	0.40	114.39	0.28
P x Ca	0.58	0.03	530.90	0.00	0.57	0.03	534.70	0.00	1.02
P/Mg	0.29	0.72	2.49	0.51	0.22	0.89	3.97	0.79	0.65
Mg/P	3.47	1.40	0.40	1.95	4.46	1.12	0.25	1.26	1.54
P x Mg	0.11	0.01	708.77	0.00	0.09	0.00	336.46	0.00	5.61

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio SA÷SB
	Parameter mean	SD	CV	Variance SA	Parameter mean	SD	CV	Variance SB	
P/S	0.84	1.64	1.95	2.69	0.53	0.85	1.59	0.71	3.76
S/P	1.19	0.61	0.51	0.37	1.89	1.18	0.63	1.40	0.27
P x S	0.04	0.00	905.74	0.00	0.04	0.00	838.12	0.00	0.97
P/Fe	0.00	0.00	1.17	0.00	0.00	0.00	1.22	0.00	1.84
Fe/P	586.71	501.60	0.85	251600.45	833.52	680.73	0.82	463396.05	0.54
P x Fe	18.03	2.72	1506.21	7.38	17.71	1.93	1091.25	3.74	1.97
P/Mn	0.01	0.01	1.40	0.00	0.00	0.00	1.35	0.00	2.63
Mn/P	174.95	125.11	0.72	15653.26	273.19	202.85	0.74	41149.19	0.38
P x Mn	5.38	0.68	1259.90	0.46	5.81	0.58	992.14	0.33	1.38
P/Cu	0.01	0.01	1.16	0.00	0.01	0.01	1.27	0.00	3.12
Cu/P	87.90	75.79	0.86	5743.84	169.74	133.82	0.79	17908.69	0.32
P x Cu	2.70	0.41	1519.09	0.17	3.61	0.38	1053.44	0.14	1.17
P/Zn	0.01	0.01	1.38	0.00	0.00	0.01	1.47	0.00	1.56
Zn/P	159.36	115.15	0.72	13259.10	212.05	143.92	0.68	20713.44	0.64
P x Zn	4.90	0.62	1272.98	0.39	4.51	0.41	906.87	0.17	2.33
P/Y	0.00	0.00	1.87	0.00	0.00	0.00	1.29	0.00	76.64
Y/P	1405.19	753.34	0.54	567515.68	8479.05	6595.12	0.78	43495554.58	0.01
P x Y	43.19	4.08	944.51	16.64	180.17	18.73	1039.29	350.63	0.05
K/Ca	0.45	1.62	3.56	2.62	0.37	0.55	1.47	0.30	8.71
Ca/K	2.20	0.62	0.28	0.38	2.68	1.82	0.68	3.33	0.11
K x Ca	4.93	0.28	569.77	0.08	5.66	0.18	314.32	0.03	2.49
K/Mg	2.46	6.57	2.67	43.13	2.23	5.22	2.33	27.21	1.58
Mg/K	0.41	0.15	0.37	0.02	0.45	0.19	0.43	0.04	0.63
K x Mg	0.91	0.07	760.67	0.00	0.95	0.02	197.78	0.00	13.70
K/S	7.19	15.02	2.09	225.47	5.29	4.96	0.94	24.56	9.18
S/K	0.14	0.07	0.48	0.00	0.19	0.20	1.07	0.04	0.11
K x S	0.31	0.03	972.07	0.00	0.40	0.02	492.68	0.00	2.36
K/Fe	0.01	0.02	1.26	0.00	0.01	0.01	0.72	0.00	4.50
Fe/K	68.72	54.74	0.80	2996.40	83.58	116.12	1.39	13483.07	0.22
K x Fe	153.96	24.89	1616.51	619.36	176.64	11.33	641.48	128.39	4.82
K/Mn	0.05	0.07	1.50	0.01	0.04	0.03	0.79	0.00	6.42
Mn/K	20.49	13.65	0.67	186.42	27.39	34.60	1.26	1197.29	0.16
K x Mn	45.91	6.21	1352.17	38.53	57.89	3.38	583.22	11.40	3.38
K/Cu	0.10	0.12	1.24	0.01	0.06	0.04	0.75	0.00	7.62
Cu/K	10.29	8.27	0.80	68.41	17.02	22.83	1.34	521.08	0.13
K x Cu	23.06	3.76	1630.33	14.14	35.97	2.23	619.26	4.96	2.85
K/Zn	0.05	0.08	1.49	0.01	0.05	0.04	0.87	0.00	3.82
Zn/K	18.66	12.57	0.67	157.91	21.26	24.55	1.15	602.68	0.26
K x Zn	41.82	5.71	1366.20	32.64	44.94	2.40	533.10	5.74	5.69
K/Y	0.01	0.01	2.00	0.00	0.00	0.00	0.76	0.00	187.25
Y/K	164.58	82.21	0.50	6758.74	850.21	1124.97	1.32	1265556.09	0.01
K x Y	368.73	37.38	1013.68	1397.04	1796.85	109.78	610.94	12050.85	0.12
Ca/Mg	5.42	4.06	0.75	16.49	5.99	9.52	1.59	90.58	0.18
Mg/Ca	0.18	0.25	1.34	0.06	0.17	0.11	0.63	0.01	5.49

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio SA÷SB
	Parameter mean	SD	CV	Variance SA	Parameter mean	SD	CV	Variance SB	
Ca x Mg	2.00	0.04	213.58	0.00	2.53	0.03	134.64	0.00	1.57
Ca/S	15.84	9.28	0.59	86.17	14.17	9.04	0.64	81.73	1.05
S/Ca	0.06	0.11	1.71	0.01	0.07	0.11	1.57	0.01	0.95
Ca x S	0.69	0.02	272.94	0.00	1.07	0.04	335.39	0.00	0.27
Ca/Fe	0.03	0.01	0.35	0.00	0.03	0.02	0.49	0.00	0.52
Fe/Ca	31.21	88.54	2.84	7840.12	31.19	63.65	2.04	4051.12	1.94
Ca x Fe	338.98	15.39	453.88	236.71	473.37	20.67	436.69	427.31	0.55
Ca/Mn	0.11	0.05	0.42	0.00	0.10	0.05	0.54	0.00	0.74
Mn/Ca	9.31	22.09	2.37	487.77	10.22	18.97	1.86	359.74	1.36
Ca x Mn	101.08	3.84	379.66	14.73	155.15	6.16	397.03	37.94	0.39
Ca/Cu	0.21	0.07	0.35	0.01	0.16	0.08	0.51	0.01	0.87
Cu/Ca	4.68	13.38	2.86	178.98	6.35	12.51	1.97	156.56	1.14
Ca x Cu	50.78	2.32	457.76	5.40	96.40	4.06	421.56	16.51	0.33
Ca/Zn	0.12	0.05	0.42	0.00	0.13	0.07	0.59	0.01	0.44
Zn/Ca	8.48	20.33	2.40	413.17	7.93	13.46	1.70	181.08	2.28
Ca x Zn	92.07	3.53	383.60	12.47	120.43	4.37	362.90	19.10	0.65
Ca/Y	0.01	0.01	0.56	0.00	0.00	0.00	0.51	0.00	21.50
Y/Ca	74.75	132.98	1.78	17684.34	317.25	616.64	1.94	380248.30	0.05
Ca x Y	811.86	23.11	284.62	533.93	4815.39	200.27	415.90	40108.08	0.01
Mg/S	2.92	2.29	0.78	5.23	2.37	0.95	0.40	0.90	5.79
S/Mg	0.34	0.44	1.28	0.19	0.42	1.05	2.49	1.11	0.17
Mg x S	0.13	0.00	364.38	0.00	0.18	0.00	211.04	0.00	1.49
Mg/Fe	0.01	0.00	0.47	0.00	0.01	0.00	0.31	0.00	2.84
Fe/Mg	169.17	359.51	2.13	129244.95	186.77	605.75	3.24	366931.48	0.35
Mg x Fe	62.54	3.79	605.95	14.36	79.04	2.17	274.78	4.72	3.04
Mg/Mn	0.02	0.01	0.56	0.00	0.02	0.01	0.34	0.00	4.05
Mn/Mg	50.45	89.67	1.78	8040.94	61.21	180.51	2.95	32583.21	0.25
Mg x Mn	18.65	0.95	506.86	0.89	25.91	0.65	249.83	0.42	2.13
Mg/Cu	0.04	0.02	0.47	0.00	0.03	0.01	0.32	0.00	4.81
Cu/Mg	25.34	54.32	2.14	2950.56	38.03	119.08	3.13	14180.66	0.21
Mg x Cu	9.37	0.57	611.13	0.33	16.10	0.43	265.26	0.18	1.80
Mg/Zn	0.02	0.01	0.56	0.00	0.02	0.01	0.37	0.00	2.41
Zn/Mg	45.95	82.53	1.80	6811.09	47.51	128.07	2.70	16401.55	0.42
Mg x Zn	16.99	0.87	512.12	0.76	20.11	0.46	228.36	0.21	3.59
Mg/Y	0.00	0.00	0.75	0.00	0.00	0.00	0.32	0.00	118.14
Y/Mg	405.17	539.93	1.33	291527.84	1899.90	5868.66	3.09	34441139.94	0.01
Mg x Y	149.78	5.69	379.98	32.39	804.09	21.04	261.70	442.81	0.07
S/Fe	0.00	0.00	0.60	0.00	0.00	0.00	0.77	0.00	0.49
Fe/S	494.27	821.94	1.66	675591.63	441.94	575.41	1.30	331098.87	2.04
S x Fe	21.40	1.66	774.35	2.75	33.41	2.29	684.49	5.23	0.53
S/Mn	0.01	0.00	0.72	0.00	0.01	0.01	0.84	0.00	0.70
Mn/S	147.39	205.02	1.39	42031.77	144.85	171.47	1.18	29401.31	1.43
S x Mn	6.38	0.41	647.72	0.17	10.95	0.68	622.32	0.46	0.37
S/Cu	0.01	0.01	0.60	0.00	0.01	0.01	0.80	0.00	0.83

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio SA÷SB
	Parameter mean	SD	CV	Variance SA	Parameter mean	SD	CV	Variance SB	
Cu/S	74.05	124.19	1.68	15423.23	90.00	113.12	1.26	12795.85	1.21
S x Cu	3.21	0.25	780.97	0.06	6.80	0.45	660.77	0.20	0.31
S/Zn	0.01	0.01	0.71	0.00	0.01	0.01	0.92	0.00	0.42
Zn/S	134.25	188.69	1.41	35603.04	112.43	121.65	1.08	14799.86	2.41
S x Zn	5.81	0.38	654.44	0.14	8.50	0.48	568.84	0.23	0.62
S/Y	0.00	0.00	0.96	0.00	0.00	0.00	0.81	0.00	20.39
Y/S	1183.78	1234.46	1.04	1523879.79	4495.65	5574.75	1.24	31077798.58	0.05
S x Y	51.26	2.49	485.58	6.20	339.82	22.15	651.90	490.74	0.01
Fe/Mn	3.35	4.01	1.20	16.07	3.05	3.36	1.10	11.26	1.43
Mn/Fe	0.30	0.25	0.84	0.06	0.33	0.30	0.91	0.09	0.70
Fe x Mn	3154.64	339.80	1077.13	115461.29	4838.67	392.07	810.28	153717.39	0.75
Fe/Cu	6.68	6.62	0.99	43.80	4.91	5.09	1.04	25.88	1.69
Cu/Fe	0.15	0.15	1.01	0.02	0.20	0.20	0.97	0.04	0.59
Fe x Cu	1584.90	205.83	1298.72	42367.61	3006.37	258.65	860.34	66899.93	0.63
Fe/Zn	3.68	4.36	1.18	18.98	3.93	4.73	1.20	22.37	0.85
Zn/Fe	0.27	0.23	0.85	0.05	0.25	0.21	0.83	0.04	1.18
Fe x Zn	2873.55	312.73	1088.31	97801.55	3755.78	278.17	740.64	77377.36	1.26
Fe/Y	0.42	0.67	1.59	0.44	0.10	0.10	1.05	0.01	41.61
Y/Fe	2.40	1.50	0.63	2.26	10.17	9.69	0.95	93.86	0.02
Fe x Y	25337.65	2046.00	807.49	4186098.23	150177.44	12746.86	848.79	162482499.22	0.03
Mn/Cu	1.99	1.65	0.83	2.73	1.61	1.52	0.94	2.30	1.19
Cu/Mn	0.50	0.61	1.21	0.37	0.62	0.66	1.06	0.44	0.84
Mn x Cu	472.60	51.34	1086.34	2635.89	985.36	77.08	782.20	5940.66	0.44
Mn/Zn	1.10	1.09	0.99	1.18	1.29	1.41	1.09	1.99	0.59
Zn/Mn	0.91	0.92	1.01	0.85	0.78	0.71	0.91	0.50	1.68
Mn x Zn	856.87	78.00	910.34	6084.70	1230.99	82.89	673.38	6871.05	0.89
Mn/Y	0.12	0.17	1.33	0.03	0.03	0.03	0.95	0.00	29.15
Y/Mn	8.03	6.02	0.75	36.26	31.04	32.51	1.05	1057.02	0.03
Mn x Y	7555.45	510.33	675.45	260437.09	49221.93	3798.46	771.70	14428312.78	0.02
Cu/Zn	0.55	0.66	1.19	0.43	0.80	0.93	1.16	0.86	0.50
Zn/Cu	1.81	1.52	0.84	2.31	1.25	1.08	0.86	1.16	2.00
Cu x Zn	430.49	47.25	1097.62	2232.73	764.84	54.68	714.98	2990.37	0.75
Cu/Y	0.06	0.10	1.61	0.01	0.02	0.02	1.01	0.00	24.58
Y/Cu	15.99	9.94	0.62	98.80	49.95	49.28	0.99	2428.74	0.04
Cu x Y	3795.89	309.14	814.40	95565.34	30582.65	2505.87	819.38	6279400.47	0.02
Zn/Y	0.11	0.15	1.35	0.02	0.03	0.02	0.87	0.00	49.06
Y/Zn	8.82	6.54	0.74	42.80	39.99	45.82	1.15	2099.87	0.02
Zn x Y	6882.25	469.68	682.46	220603.40	38206.10	2694.97	705.38	7262839.95	0.03

Appendix –V

Stastitical parameters for different forms of expressing leaf nutrient for low and high yielding population of Nagpur mandarin orchards in *mrig* flush

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Paramter mean	SD	CV	Variance (S_A)	Paramter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
N/P	12.44	2.08	0.17	4.32	18.01	5.08	0.28	25.80	0.17
P/N	0.08	0.48	5.99	0.23	0.06	0.20	3.54	0.04	5.97
N x P	0.42	0.02	559.38	0.00	0.32	0.01	308.94	0.00	5.80
N/K	1.46	0.35	0.24	0.12	1.96	0.53	0.27	0.28	0.44
K/N	0.68	2.88	4.21	8.30	0.51	1.90	3.72	3.62	2.29
N x K	3.58	0.14	393.23	0.02	2.91	0.09	324.50	0.01	2.22
N/Ca	0.71	0.39	0.55	0.15	0.65	0.41	0.63	0.17	0.87
Ca/N	1.42	2.60	1.83	6.74	1.54	2.43	1.58	5.89	1.14
N x Ca	7.42	0.13	171.06	0.02	8.78	0.12	137.28	0.01	1.11
N/Mg	3.55	0.73	0.21	0.53	3.60	1.43	0.40	2.06	0.26
Mg/N	0.28	1.37	4.87	1.88	0.28	0.70	2.51	0.49	3.87
N x Mg	1.47	0.07	455.37	0.00	1.58	0.03	218.75	0.00	3.75
N/S	11.69	6.34	0.54	40.14	10.23	4.79	0.47	22.91	1.75
S/N	0.09	0.16	1.85	0.02	0.10	0.21	2.14	0.04	0.57
N x S	0.45	0.01	172.45	0.00	0.56	0.01	186.28	0.00	0.55
N/Fe	0.03	0.01	0.33	0.00	0.02	0.01	0.46	0.00	0.93
Fe/N	38.69	117.13	3.03	13719.24	52.24	112.76	2.16	12714.29	1.08
N x Fe	202.51	5.73	282.88	32.82	297.60	5.60	188.11	31.34	1.05
N/Mn	0.08	0.03	0.37	0.00	0.07	0.02	0.32	0.00	2.27
Mn/N	11.79	31.50	2.67	992.50	15.00	47.48	3.17	2254.44	0.44
N x Mn	61.70	1.54	249.73	2.37	85.45	2.36	275.86	5.56	0.43
N/Cu	0.12	0.04	0.32	0.00	0.09	0.03	0.27	0.00	2.25
Cu/N	8.29	25.69	3.10	660.08	10.58	38.53	3.64	1484.62	0.44
N x Cu	43.37	1.26	289.75	1.58	60.27	1.91	317.38	3.66	0.43
N/Zn	0.08	0.05	0.55	0.00	0.08	0.04	0.46	0.00	1.55
Zn/N	12.32	22.21	1.80	493.48	12.80	27.63	2.16	763.43	0.65
N x Zn	64.50	1.09	168.44	1.18	72.90	1.37	188.18	1.88	0.63
N/Y	0.01	0.00	0.46	0.00	0.00	0.00	0.44	0.00	16.64
Y/N	120.50	260.79	2.16	68009.87	468.09	1063.68	2.27	1131411.03	0.06
N x Y	630.65	12.75	202.24	162.67	2666.60	52.81	198.04	2788.90	0.06
P/K	0.12	0.17	1.42	0.03	0.11	0.10	0.95	0.01	2.61
K/P	8.52	5.99	0.70	35.86	9.21	9.67	1.05	93.53	0.38
P x K	0.29	0.07	2353.93	0.00	0.16	0.02	1150.31	0.00	13.27
P/Ca	0.06	0.19	3.27	0.03	0.04	0.08	2.25	0.01	5.22
Ca/P	17.64	5.40	0.31	29.11	27.74	12.33	0.44	151.98	0.19
P x Ca	0.60	0.06	1024.00	0.00	0.49	0.02	486.65	0.00	6.63
P/Mg	0.29	0.35	1.23	0.12	0.20	0.28	1.41	0.08	1.54
Mg/P	3.50	2.85	0.81	8.12	5.00	3.54	0.71	12.54	0.65
P x Mg	0.12	0.03	2725.88	0.00	0.09	0.01	775.42	0.00	22.41
P/S	0.94	3.05	3.24	9.29	0.57	0.94	1.66	0.89	10.47

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Paramter mean	SD	CV	Variance (S_A)	Paramter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
S/P	1.06	0.33	0.31	0.11	1.76	1.06	0.60	1.13	0.10
P x S	0.04	0.00	1032.31	0.00	0.03	0.00	660.34	0.00	3.31
P/Fe	0.00	0.00	1.98	0.00	0.00	0.00	1.64	0.00	5.54
Fe/P	481.38	243.43	0.51	59259.70	940.67	572.77	0.61	328060.04	0.18
P x Fe	16.28	2.76	1693.33	7.60	16.53	1.10	666.83	1.21	6.25
P/Mn	0.01	0.02	2.24	0.00	0.00	0.00	1.12	0.00	13.57
Mn/P	146.66	65.48	0.45	4287.06	270.11	241.18	0.89	58170.13	0.07
P x Mn	4.96	0.74	1494.90	0.55	4.75	0.46	977.88	0.22	2.55
P/Cu	0.01	0.02	1.93	0.00	0.01	0.01	0.97	0.00	13.44
Cu/P	103.08	53.40	0.52	2851.19	190.52	195.72	1.03	38306.82	0.07
P x Cu	3.49	0.60	1734.50	0.37	3.35	0.38	1125.07	0.14	2.58
P/Zn	0.01	0.02	3.32	0.00	0.00	0.01	1.64	0.00	9.24
Zn/P	153.32	46.17	0.30	2131.57	230.42	140.35	0.61	19698.34	0.11
P x Zn	5.18	0.52	1008.31	0.27	4.05	0.27	667.05	0.07	3.75
P/Y	0.00	0.00	2.77	0.00	0.00	0.00	1.56	0.00	99.38
Y/P	1499.13	542.00	0.36	293765.79	8428.64	5403.07	0.64	29193191.34	0.01
P x Y	50.69	6.14	1210.64	37.66	148.09	10.40	702.03	108.09	0.35
K/Ca	0.48	1.11	2.30	1.23	0.33	0.78	2.36	0.62	2.00
Ca/K	2.07	0.90	0.44	0.81	3.01	1.27	0.42	1.62	0.50
K x Ca	5.08	0.37	719.85	0.13	4.49	0.23	511.16	0.05	2.54
K/Mg	2.43	2.10	0.86	4.42	1.84	2.73	1.48	7.46	0.59
Mg/K	0.41	0.48	1.16	0.23	0.54	0.37	0.67	0.13	1.69
K x Mg	1.01	0.19	1916.24	0.04	0.81	0.07	814.47	0.00	8.59
K/S	8.01	18.25	2.28	333.24	5.23	9.11	1.74	83.04	4.01
S/K	0.12	0.05	0.44	0.00	0.19	0.11	0.57	0.01	0.25
K x S	0.31	0.02	725.69	0.00	0.28	0.02	693.60	0.00	1.27
K/Fe	0.02	0.02	1.39	0.00	0.01	0.02	1.73	0.00	2.12
Fe/K	56.51	40.65	0.72	1652.64	102.16	59.22	0.58	3507.42	0.47
K x Fe	138.65	16.50	1190.38	272.41	152.18	10.66	700.41	113.61	2.40
K/Mn	0.06	0.09	1.57	0.01	0.03	0.04	1.18	0.00	5.20
Mn/K	17.22	10.93	0.64	119.56	29.34	24.94	0.85	621.92	0.19
K x Mn	42.24	4.44	1050.88	19.71	43.70	4.49	1027.13	20.14	0.98
K/Cu	0.08	0.11	1.36	0.01	0.05	0.05	1.02	0.00	5.15
Cu/K	12.10	8.92	0.74	79.51	20.69	20.24	0.98	409.55	0.19
K x Cu	29.69	3.62	1219.32	13.11	30.82	3.64	1181.73	13.27	0.99
K/Zn	0.06	0.13	2.33	0.02	0.04	0.07	1.72	0.00	3.54
Zn/K	18.00	7.71	0.43	59.45	25.03	14.51	0.58	210.60	0.28
K x Zn	44.16	3.13	708.82	9.80	37.28	2.61	700.65	6.82	1.44
K/Y	0.01	0.01	1.94	0.00	0.00	0.00	1.64	0.00	38.10
Y/K	175.99	90.51	0.51	8192.57	915.41	558.67	0.61	312115.94	0.03
K x Y	431.80	36.75	851.05	1350.42	1363.55	100.55	737.39	10109.68	0.13
Ca/Mg	5.04	1.89	0.38	3.59	5.55	3.48	0.63	12.12	0.30
Mg/Ca	0.20	0.53	2.66	0.28	0.18	0.29	1.59	0.08	3.38
Ca x Mg	2.09	0.17	833.60	0.03	2.44	0.08	344.57	0.01	4.29
Ca/S	16.58	16.45	0.99	270.51	15.76	11.62	0.74	134.93	2.00

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio
	Paramter mean	SD	CV	Variance (S_A)	Paramter mean	SD	CV	Variance (S_B)	($S_A \div S_B$)
S/Ca	0.06	0.06	1.01	0.00	0.06	0.09	1.36	0.01	0.50
Ca x S	0.63	0.02	315.69	0.00	0.86	0.03	293.44	0.00	0.63
Ca/Fe	0.04	0.02	0.60	0.00	0.03	0.02	0.73	0.00	1.06
Fe/Ca	27.29	45.12	1.65	2035.86	33.91	46.46	1.37	2158.58	0.94
Ca x Fe	287.17	14.87	517.84	221.13	458.52	13.59	296.32	184.60	1.20
Ca/Mn	0.12	0.08	0.69	0.01	0.10	0.05	0.50	0.00	2.60
Mn/Ca	8.31	12.14	1.46	147.28	9.74	19.56	2.01	382.75	0.38
Ca x Mn	87.49	4.00	457.15	16.00	131.66	5.72	434.54	32.73	0.49
Ca/Cu	0.17	0.10	0.59	0.01	0.15	0.06	0.43	0.00	2.57
Cu/Ca	5.84	9.90	1.69	97.95	6.87	15.88	2.31	252.05	0.39
Ca x Cu	61.49	3.26	530.43	10.64	92.86	4.64	499.95	21.56	0.49
Ca/Zn	0.12	0.12	1.02	0.01	0.12	0.09	0.73	0.01	1.77
Zn/Ca	8.69	8.56	0.98	73.23	8.31	11.38	1.37	129.61	0.56
Ca x Zn	91.46	2.82	308.35	7.95	112.32	3.33	296.42	11.08	0.72
Ca/Y	0.01	0.01	0.85	0.00	0.00	0.00	0.69	0.00	19.03
Y/Ca	84.97	100.46	1.18	10092.31	303.82	438.28	1.44	192085.96	0.05
Ca x Y	894.30	33.11	370.22	1096.22	4108.43	128.17	311.96	16426.97	0.07
Mg/S	3.29	8.69	2.64	75.45	2.84	3.34	1.17	11.14	6.78
S/Mg	0.30	0.12	0.38	0.01	0.35	0.30	0.85	0.09	0.15
Mg x S	0.13	0.01	840.36	0.00	0.15	0.01	467.55	0.00	2.14
Mg/Fe	0.01	0.01	1.61	0.00	0.01	0.01	1.16	0.00	3.58
Fe/Mg	137.53	85.43	0.62	7299.07	188.06	161.72	0.86	26154.14	0.28
Mg x Fe	56.97	7.85	1378.47	61.68	82.67	3.90	472.14	15.24	4.05
Mg/Mn	0.02	0.04	1.82	0.00	0.02	0.01	0.79	0.00	8.78
Mn/Mg	41.90	22.98	0.55	528.04	54.00	68.10	1.26	4637.53	0.11
Mg x Mn	17.36	2.11	1216.93	4.46	23.74	1.64	692.39	2.70	1.65
Mg/Cu	0.03	0.05	1.57	0.00	0.03	0.02	0.69	0.00	8.70
Cu/Mg	29.45	18.74	0.64	351.18	38.09	55.26	1.45	3053.96	0.11
Mg x Cu	12.20	1.72	1411.98	2.97	16.74	1.33	796.60	1.78	1.67
Mg/Zn	0.02	0.06	2.70	0.00	0.02	0.03	1.16	0.00	5.98
Zn/Mg	43.80	16.20	0.37	262.55	46.07	39.63	0.86	1570.42	0.17
Mg x Zn	18.15	1.49	820.82	2.22	20.25	0.96	472.31	0.91	2.43
Mg/Y	0.00	0.01	2.25	0.00	0.00	0.00	1.10	0.00	64.32
Y/Mg	428.30	190.22	0.44	36183.42	1685.05	1525.58	0.91	2327387.22	0.02
Mg x Y	177.43	17.49	985.53	305.76	740.75	36.82	497.07	1355.77	0.23
S/Fe	0.00	0.00	0.61	0.00	0.00	0.00	0.99	0.00	0.53
Fe/S	452.41	742.11	1.64	550721.26	534.44	539.68	1.01	291255.76	1.89
S x Fe	17.32	0.90	522.03	0.82	29.09	1.17	402.08	1.37	0.60
S/Mn	0.01	0.01	0.69	0.00	0.01	0.00	0.68	0.00	1.30
Mn/S	137.84	199.60	1.45	39841.13	153.46	227.25	1.48	51644.17	0.77
S x Mn	5.28	0.24	460.86	0.06	8.35	0.49	589.63	0.24	0.24
S/Cu	0.01	0.01	0.60	0.00	0.01	0.01	0.59	0.00	1.28
Cu/S	96.88	162.78	1.68	26497.12	108.24	184.42	1.70	34009.27	0.78
S x Cu	3.71	0.20	534.73	0.04	5.89	0.40	678.38	0.16	0.25
S/Zn	0.01	0.01	1.02	0.00	0.01	0.01	0.99	0.00	0.88

Form of expression	Population A (Low yield)				Population B (High yield)				Variance ratio ($S_A \div S_B$)
	Paramter mean	SD	CV	Variance (S_A)	Paramter mean	SD	CV	Variance (S_B)	
Zn/S	144.10	140.75	0.98	19809.43	130.91	132.24	1.01	17488.43	1.13
S x Zn	5.52	0.17	310.85	0.03	7.13	0.29	402.21	0.08	0.36
S/Y	0.00	0.00	0.85	0.00	0.00	0.00	0.94	0.00	9.49
Y/S	1408.91	1652.29	1.17	2730069.10	4788.66	5090.98	1.06	25918076.55	0.11
S x Y	53.94	2.01	373.23	4.05	260.66	11.03	423.30	121.74	0.03
Fe/Mn	3.28	3.72	1.13	13.82	3.48	2.37	0.68	5.64	2.45
Mn/Fe	0.30	0.27	0.88	0.07	0.29	0.42	1.47	0.18	0.41
Fe x Mn	2387.27	180.47	755.96	32569.08	4464.23	265.81	595.42	70655.08	0.46
Fe/Cu	4.67	4.56	0.98	20.78	4.94	2.93	0.59	8.56	2.43
Cu/Fe	0.21	0.22	1.02	0.05	0.20	0.34	1.69	0.12	0.41
Fe x Cu	1677.92	147.18	877.13	21660.70	3148.78	215.70	685.04	46528.54	0.47
Fe/Zn	3.14	5.27	1.68	27.80	4.08	4.08	1.00	16.65	1.67
Zn/Fe	0.32	0.19	0.60	0.04	0.24	0.25	1.00	0.06	0.60
Fe x Zn	2495.68	127.25	509.90	16193.69	3808.35	154.68	406.16	23926.16	0.68
Fe/Y	0.32	0.45	1.40	0.20	0.11	0.11	0.95	0.01	17.95
Y/Fe	3.11	2.23	0.71	4.96	8.96	9.43	1.05	88.99	0.06
Fe x Y	24401.71	1493.91	612.21	2231759.86	139305.08	5954.74	427.46	35458872.86	0.06
Mn/Cu	1.42	1.23	0.86	1.50	1.42	1.23	0.87	1.52	0.99
Cu/Mn	0.70	0.82	1.16	0.67	0.71	0.81	1.15	0.66	1.01
Mn x Cu	511.21	39.59	774.34	1567.01	904.15	90.83	1004.60	8250.23	0.19
Mn/Zn	0.96	1.42	1.48	2.01	1.17	1.72	1.47	2.95	0.68
Zn/Mn	1.05	0.71	0.67	0.50	0.85	0.58	0.68	0.34	1.47
Mn x Zn	760.36	34.23	450.15	1171.51	1093.54	65.13	595.63	4242.48	0.28
Mn/Y	0.10	0.12	1.23	0.01	0.03	0.04	1.39	0.00	7.32
Y/Mn	10.22	8.28	0.81	68.52	31.20	22.40	0.72	501.86	0.14
Mn x Y	7434.47	401.81	540.47	161453.44	40000.53	2507.47	626.86	6287408.31	0.03
Cu/Zn	0.67	1.16	1.72	1.34	0.83	1.39	1.69	1.94	0.69
Zn/Cu	1.49	0.86	0.58	0.75	1.21	0.72	0.59	0.51	1.45
Cu x Zn	534.43	27.91	522.30	779.13	771.31	52.86	685.28	2793.80	0.28
Cu/Y	0.07	0.10	1.43	0.01	0.02	0.04	1.60	0.00	7.40
Y/Cu	14.54	10.15	0.70	103.03	44.24	27.61	0.62	762.09	0.14
Cu x Y	5225.41	327.69	627.10	107377.74	28213.80	2034.81	721.21	4140451.38	0.03
Zn/Y	0.10	0.09	0.83	0.01	0.03	0.03	0.95	0.00	10.75
Y/Zn	9.78	11.74	1.20	137.82	36.58	38.50	1.05	1482.01	0.09
Zn x Y	7772.08	283.33	364.55	80276.33	34123.67	1459.15	427.61	2129125.74	0.04

Appendix – VI

Soil fertility status of low yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush .

Site No.*	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N Kg ha^{-1}	P_2O_5 Kg ha^{-1}	K_2O Kg ha^{-1}	Ca c mol(p^+) kg^{-1}	Mg c mol(p^+) kg^{-1}	S Kg ha^{-1}	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	7.59	0.14	0.36	6.70	116.78	49.88	449.92	28.75	5.85	10.50	7.16	9.64	1.80	0.70	213
2	7.44	0.32	0.78	8.11	215.13	68.74	296.48	22.70	16.30	7.70	4.27	13.09	2.86	0.59	187
3	7.47	0.18	0.62	10.58	242.79	115.90	317.76	30.95	3.73	9.10	5.08	9.37	3.02	0.57	278
4	7.40	0.24	0.64	4.58	258.16	12.15	520.48	29.85	4.85	2.10	6.58	16.11	2.63	0.58	297
5	7.49	0.29	0.76	9.17	252.01	15.30	252.80	26.55	3.35	14.70	7.66	12.18	1.93	0.71	252
6	7.58	0.16	0.74	7.05	193.62	2.72	325.60	21.05	3.65	16.10	10.36	15.90	2.35	0.80	204
7	7.55	0.26	0.90	23.62	159.81	40.45	722.08	19.95	11.55	21.70	1.39	8.56	1.77	0.60	264
8	7.65	0.27	0.57	8.46	205.91	75.03	485.76	28.20	3.90	10.50	2.78	11.86	3.25	0.69	286
9	7.58	0.27	0.34	7.05	190.54	53.02	444.32	22.15	2.00	7.70	7.08	12.40	3.00	0.86	297
10	7.36	0.20	0.47	5.29	144.44	5.86	136.32	24.35	8.05	10.50	7.97	10.79	2.55	0.71	254
11	7.61	0.29	0.76	13.04	135.22	31.02	488.00	10.05	29.50	38.50	8.55	11.18	2.38	0.84	314
12	7.41	0.28	0.70	4.94	230.50	71.89	792.64	22.15	12.45	4.90	8.11	11.57	2.03	0.72	367
13	7.28	0.48	0.79	5.64	212.06	43.59	110.56	27.10	2.41	13.30	5.73	10.15	5.47	0.50	192
14	7.34	0.36	1.18	18.69	288.89	65.60	748.96	31.50	2.65	13.30	6.08	11.73	2.61	0.47	246
15	7.47	0.47	1.04	14.10	255.08	43.59	807.20	12.25	11.90	13.30	5.51	19.88	4.16	0.57	238
16	7.45	0.40	0.47	10.93	208.98	62.46	404.00	12.25	12.51	2.10	6.53	9.19	3.77	0.45	288
17	7.36	0.40	0.82	15.16	264.30	62.46	840.80	10.05	2.84	11.90	6.90	12.62	3.44	0.61	190
18	7.51	0.24	0.12	23.97	73.76	62.46	89.28	17.75	5.32	39.90	6.57	10.75	1.50	0.57	237
19	7.68	0.24	0.39	15.51	110.64	31.02	251.68	17.75	9.22	11.90	5.67	17.86	2.58	0.80	253

...continued...

Site No.*	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N Kg ha^{-1}	P_2O_5 Kg ha^{-1}	K_2O Kg ha^{-1}	Ca c mol(p^+) kg^{-1}	Mg c mol(p^+) kg^{-1}	S Kg ha^{-1}	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
20	7.68	0.29	0.47	6.70	181.32	34.16	465.60	24.35	1.59	4.90	7.33	13.97	3.15	0.58	286
21	7.67	0.29	0.54	7.40	230.50	18.44	765.76	15.55	13.00	4.90	5.77	13.41	2.42	0.56	328
22	7.58	0.13	0.26	4.23	175.18	43.59	149.76	19.95	9.70	10.50	6.26	8.52	4.16	0.82	348
23	7.48	0.13	0.60	16.92	212.06	78.18	395.04	21.05	9.05	24.50	5.74	11.31	3.84	0.57	261
24	8.03	0.24	0.40	11.28	208.98	34.16	258.40	21.05	16.20	9.10	6.85	15.50	3.52	0.63	247
25	7.57	0.13	0.31	19.74	175.18	37.30	416.32	16.65	4.65	17.50	7.55	13.77	1.84	0.56	186
26	7.61	0.13	0.45	12.69	175.18	46.74	374.88	15.00	6.30	16.10	6.74	13.87	1.89	0.81	157
27	7.65	0.13	0.39	10.22	218.20	2.72	409.60	16.65	8.75	23.10	6.94	12.64	2.57	0.91	149
28	7.67	0.16	0.36	16.57	208.98	46.74	421.92	26.55	2.21	21.70	6.99	10.27	3.42	0.73	196
29	7.66	0.18	0.42	16.57	208.98	24.73	451.04	33.15	2.78	17.50	5.71	13.10	1.82	0.55	162
30	7.70	0.10	0.36	12.69	181.32	53.02	118.40	30.95	2.40	30.10	7.00	12.91	6.85	0.58	187
31	7.60	0.16	0.48	16.57	205.91	34.16	202.40	16.65	6.95	14.70	6.45	8.28	4.21	0.76	271
32	7.56	0.16	1.10	14.10	282.74	159.92	604.48	33.15	9.70	9.10	6.41	9.24	2.23	0.41	286
33	7.50	0.16	1.01	16.57	291.96	46.74	803.84	23.25	16.85	9.10	6.92	21.19	3.87	0.82	187
34	7.62	0.18	0.62	12.34	230.50	100.18	698.56	22.15	15.20	11.90	6.79	19.75	2.74	0.81	308
35	7.44	0.37	0.43	20.10	242.79	65.60	464.48	11.15	13.55	60.90	5.31	11.53	3.93	0.56	216
36	7.43	0.27	0.79	5.99	190.54	43.59	354.72	24.90	2.00	13.30	7.80	11.73	2.53	0.61	234
37	7.52	0.23	0.76	8.81	258.16	9.01	428.64	28.75	9.70	2.10	6.80	29.09	2.45	0.35	183
38	7.46	0.13	1.02	5.99	258.16	53.02	332.32	30.40	5.30	10.50	7.19	16.70	5.26	0.84	312
Mean	**7.54**	**0.24**	**0.61**	**11.79**	**207.77**	**48.56**	**436.86**	**22.28**	**8.10**	**15.03**	**6.49**	**13.20**	**3.05**	**0.65**	**246**

* Refer Appendix – I A for loclation and general information of corresponding site number

Appendix – VII

Soil fertility status of high yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush .

Site No. *	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N Kg ha^{-1}	P_2O_5 Kg ha^{-1}	K_2O Kg ha^{-1}	Ca c $mol(p^+)$ kg^{-1}	Mg c $mol(p^+)$ kg^{-1}	S Kg ha^{-1}	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	7.54	0.18	1.19	8.36	382.59	96.90	753.76	36.30	8.68	19.60	7.66	12.70	4.28	0.84	1158
2	7.50	0.16	0.82	8.14	219.52	68.74	771.68	42.90	18.30	11.20	8.53	9.93	4.58	0.58	1033
3	7.75	0.17	0.67	7.46	338.69	56.02	806.40	43.45	16.65	17.22	7.36	10.23	1.82	0.51	1058
4	7.38	0.18	0.50	5.71	225.79	56.02	591.36	44.00	13.55	21.00	7.64	13.65	3.49	0.99	836
5	7.51	0.14	0.74	4.75	426.50	90.61	788.95	50.05	8.95	19.60	8.29	12.42	4.60	0.66	1215
6	7.51	0.21	0.71	4.23	413.95	81.18	614.72	47.85	10.60	26.60	7.82	11.24	4.33	0.63	1585
7	7.44	0.27	0.87	6.78	332.42	45.15	586.56	48.40	14.45	12.60	6.35	11.47	2.71	0.78	1176
8	7.48	0.20	0.74	6.10	476.67	54.58	757.12	46.20	13.90	15.40	7.17	13.49	2.96	0.85	1226
9	7.44	0.14	0.48	5.20	301.06	71.74	778.22	35.75	18.30	23.80	6.68	9.61	5.84	0.54	968
10	7.41	0.16	0.42	11.98	257.15	43.45	370.72	47.85	6.18	17.60	8.71	20.85	5.18	0.68	635
11	7.61	0.23	0.54	5.20	326.14	42.44	624.96	39.05	29.30	23.80	5.64	23.48	10.24	0.52	1045
12	7.37	0.27	0.91	10.17	413.95	62.31	630.43	46.75	13.76	15.40	6.43	17.14	5.35	0.80	948
13	7.57	0.32	0.70	7.46	457.86	81.18	623.84	39.60	18.35	21.00	8.31	15.73	6.34	0.65	1265
14	7.39	0.34	0.76	8.14	420.22	32.01	882.24	44.55	15.41	14.80	9.59	11.77	5.17	0.65	1183
15	7.48	0.26	0.73	7.68	407.68	45.15	717.28	37.95	12.80	11.20	8.30	11.54	3.92	0.86	1226
16	7.59	0.18	0.60	5.71	426.50	90.61	844.48	56.10	12.34	16.80	8.43	12.05	3.95	0.91	1217
17	7.60	0.17	0.34	4.36	382.59	93.49	362.54	50.05	11.45	21.00	7.28	10.91	6.26	0.89	1325
18	7.51	0.13	0.54	5.55	445.31	115.76	468.92	46.75	12.55	19.60	7.72	10.09	8.07	0.62	1274
19	7.44	0.16	0.11	7.35	370.05	34.02	382.56	48.40	13.45	17.50	6.62	10.43	4.34	0.57	1483

...*continued*...

Site No. *	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N Kg ha^{-1}	P_2O_5 Kg ha^{-1}	K_2O Kg ha^{-1}	Ca c $mol(p^+)$ kg^{-1}	Mg c $mol(p^+)$ kg^{-1}	S Kg ha^{-1}	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
20	7.47	0.20	0.81	11.53	482.94	81.18	757.12	45.65	16.10	15.60	6.56	12.32	5.78	0.65	1297
21	7.45	0.29	0.82	11.75	508.03	68.60	786.24	42.35	19.95	14.00	6.94	13.93	6.34	0.93	1536
22	7.44	0.12	0.43	7.91	282.24	68.60	400.96	38.50	15.33	19.40	8.37	11.86	5.30	0.84	1452
23	7.80	0.12	0.40	4.07	370.05	52.88	440.16	37.95	14.45	25.73	7.74	16.63	5.00	0.77	1416
24	8.06	0.17	0.45	4.58	413.95	128.34	300.16	39.05	19.85	12.60	5.99	16.91	6.34	0.64	1061
25	7.72	0.19	0.39	7.68	250.88	87.46	375.20	42.90	7.30	26.60	6.81	15.04	2.65	0.51	1117
26	7.76	0.10	0.50	8.14	332.42	74.89	443.52	46.20	14.45	22.40	6.74	11.57	5.72	0.58	1284
27	7.52	0.27	0.51	10.40	344.96	56.02	472.64	48.40	12.35	27.43	7.74	16.40	9.67	0.55	1305
28	7.48	0.17	0.51	5.65	382.59	81.18	343.17	34.10	11.15	24.80	7.27	11.53	7.46	0.53	1938
29	7.52	0.12	0.93	14.01	413.95	71.74	454.72	48.95	13.90	18.80	5.65	14.47	4.41	0.77	568
30	7.48	0.13	0.98	6.10	395.14	84.32	431.20	39.60	14.45	24.74	5.86	21.75	4.83	0.69	2254
31	7.46	0.14	0.79	7.01	551.94	74.89	612.64	36.85	23.80	21.54	6.40	19.45	4.82	0.60	2127
32	7.47	0.38	0.79	10.40	351.23	96.90	722.28	41.25	12.25	23.14	7.15	13.17	6.79	0.66	672
33	7.53	0.32	0.91	9.49	470.40	59.17	566.56	40.15	15.55	27.51	6.33	9.25	7.95	0.62	1319
34	7.42	0.24	0.59	11.30	432.77	81.18	680.13	53.35	13.15	15.40	7.23	13.30	6.39	0.75	1239
35	7.55	0.20	0.78	11.98	451.58	65.46	719.84	51.70	16.13	11.20	6.31	12.71	6.41	0.66	1052
36	7.45	0.19	0.67	4.97	464.13	96.90	416.64	46.75	8.95	28.00	8.53	14.29	4.61	0.80	927
37	7.44	0.17	1.22	10.36	577.02	125.19	497.68	51.15	13.66	11.20	7.58	15.29	7.54	0.73	1312
Mean	**7.53**	**0.20**	**0.67**	**7.77**	**391.92**	**73.41**	**588.58**	**44.24**	**14.37**	**19.35**	**7.29**	**13.75**	**5.44**	**0.70**	**1236**

* Refer Appendix -- I B for loclation and general information of corresponding site number

Appendix – VIII

Soil fertility status of low yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush .

Site No.*	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N $Kg\ ha^{-1}$	P_2O_5 $Kg\ ha^{-1}$	K_2O $Kg\ ha^{-1}$	Ca c mol(p^+) kg^{-1}	Mg c mol(p^+) kg^{-1}	S $Kg\ ha^{-1}$	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	7.42	0.20	0.51	5.35	211.76	34.74	320.32	28.65	13.70	16.80	6.64	8.52	1.96	0.85	305
2	7.37	0.23	0.39	9.70	155.31	6.44	620.48	27.00	10.95	22.40	7.63	9.04	1.99	0.86	289
3	7.53	0.23	0.62	16.39	211.76	37.88	278.88	22.05	10.40	21.00	5.40	9.05	1.93	0.85	396
4	7.50	0.20	0.87	10.70	199.22	37.88	538.72	24.25	15.35	15.40	8.14	11.17	1.57	0.75	325
5	7.55	0.35	0.71	8.03	224 30	125.91	329.28	19.30	9.85	16.80	8.17	13.61	4.06	0.83	265
6	7.61	0.29	0.82	16.72	155.31	50.46	322.56	23.15	4.35	12.60	5.86	8.46	4.06	0.81	248
7	7.58	0.35	0.64	3.01	268.21	50.46	644.00	26.45	6.00	18.20	6.60	8.31	1.60	0.59	264
8	7.56	0.21	0.64	9.03	343.47	34.74	487.20	26.45	4.90	33.60	7.53	9.25	2.91	0.54	284
9	7.66	0.17	0.45	16.72	192.94	47.31	868.00	19.85	3.84	19.60	5.65	10.82	1.58	0.72	321
10	7.56	0.28	0.45	14.38	54.96	81.90	398.72	30.85	4.24	7.00	6.42	10.29	2.10	0.90	186
11	7.58	0.29	0.82	17.73	161.58	56.74	388.64	24.80	12.60	21.00	7.25	8.31	1.71	0.76	181
12	7.57	0.22	0.68	19.07	142 77	41.02	264.32	29.75	10.40	26.60	7.05	10.29	2.37	0.83	364
13	7.75	0.32	0.78	11.71	86.32	15 87	506.24	25.90	14.80	30.80	8.21	10.10	1.72	0.76	268
14	7.48	0.33	0.98	5.69	305.84	34.74	283.36	19.30	14.80	33.60	8.10	10.09	1.87	0.81	354
15	7.70	0.29	0.96	10.70	130.22	66.18	614.88	31.40	4.90	5.60	5.98	9.51	1.15	0.68	291
16	7.54	0.18	0.73	10.70	142.77	31.59	568.96	16.55	8.20	7.00	5.75	9.05	1.18	0.87	324
17	7.58	0.22	1.01	19.73	142 77	25.30	383.04	34.70	8.20	35.00	6.82	9.02	1.18	0.67	167
18	7.66	0.17	0.62	4.68	205.49	44.17	508.48	29.20	13.70	23.80	6.49	12.34	4.25	0.82	205
19	7.66	0.15	0.62	6.02	205.49	12.73	180.32	17.10	12.05	26.60	5.65	21.22	4.24	0.92	238

...continued...

Site No.*	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N Kg ha^{-1}	P_2O_5 Kg ha^{-1}	K_2O Kg ha^{-1}	Ca c mol(p^+) kg^{-1}	Mg c mol(p^+) kg^{-1}	S Kg ha^{-1}	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
20	7.62	0.24	0.85	13.04	255.66	85.04	549.92	37.45	2.08	8.40	6.36	12.75	1.70	0.54	314
21	7.58	0.25	0.70	14.05	318.38	63.03	540.96	29.75	5.45	15.40	7.26	10.62	3.17	0.66	328
22	7.62	0.26	0.54	15.72	243.12	97.62	400.96	19.85	2.15	8.40	5.87	10.31	1.05	0.56	295
23	7.59	0.29	0.51	16.72	318.38	110.19	215.04	18.75	3.60	11.20	6.62	8.49	1.47	0.83	187
24	7.59	0.25	0.50	16.72	205.49	50.46	412.16	46.25	4.35	26.60	7.23	8.51	2.73	0.68	357
25	7.54	0.26	0.29	9.70	123.95	3.30	203.84	40.75	5.45	22.40	8.13	9.80	2.33	0.51	268
26	7.61	0.15	0.59	10.70	92.59	110.19	232.96	38.55	2.15	12.60	7.37	10.40	2.14	0.63	316
27	7.62	0.20	0.26	6.36	205.49	110.19	586.88	29.75	5.45	9.80	7.47	10.33	2.36	0.69	256
28	7.56	0.15	0.33	6.69	167.86	119.62	654.08	28.10	7.65	15.40	5.75	8.31	1.94	0.82	299
29	7.51	0.28	1.22	11.37	199.22	31.59	331.52	13.80	9.85	18.20	6.63	9.41	1.57	0.80	268
30	7.45	0.29	1.22	10.70	230.58	6.44	415.52	14.35	5.45	19.60	6.65	10.75	0.98	0.43	183
31	7.48	0.29	0.70	9.03	186.67	69.32	526.40	31.95	8.20	18.20	6.72	11.03	1.29	0.59	291
32	7.56	0.23	0.68	10.37	324.66	107.05	394.24	29.20	6.55	11.20	8.15	8.46	3.06	0.61	256
33	7.45	0.24	0.88	15.39	136.50	69.32	425.60	29.20	7.10	12.60	7.24	8.61	1.89	0.70	168
34	7.47	0.34	0.71	10.03	274.48	25.30	265.44	28.65	13.70	8.40	6.58	12.89	1.82	0.54	284
35	7.58	0.37	1.26	14.38	280.75	3.30	801.92	13.80	8.20	7.00	7.83	10.10	2.74	0.58	306
36	7.67	0.34	1.16	16.39	274.48	56.74	464.80	27.55	13.70	14.00	6.70	8.15	2.66	0.71	273
Mean	**7.57**	**0.25**	**0.71**	**11.76**	**204.97**	**54.30**	**442.46**	**26.51**	**8.18**	**17.58**	**6.89**	**10.20**	**2.18**	**0.70**	**276**

* Refer Appendix –I C for loclation and general information of corresponding site number

Appendix – IX

Soil fertility status of high yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush .

Site No.*	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N $Kg\ ha^{-1}$	P_2O_5 $Kg\ ha^{-1}$	K_2O $Kg\ ha^{-1}$	Ca c mol(p^+) kg^{-1}	Mg c mol(p^+) kg^{-1}	S $Kg\ ha^{-1}$	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	7.45	0.28	0.73	5.20	345.14	84.50	446.00	51.15	7.15	21.00	10.22	13.21	6.73	0.64	718
2	7.44	0.26	0.51	4.09	294.96	86.47	357.52	37.40	10.40	19.60	7.20	10.61	6.04	0.67	512
3	7.51	0.26	0.56	6.33	332.59	68.74	384.40	37.95	13.15	14.00	6.94	13.65	6.69	0.63	1158
4	7.47	0.28	0.45	6.55	363.95	82.76	434.80	38.50	13.70	19.60	7.27	13.60	4.87	0.62	1183
5	7.49	0.25	0.76	12.43	464.30	56.17	525.52	45.65	7.10	14.00	7.67	8.24	6.56	0.96	1347
6	7.52	0.28	0.68	12.88	376.50	59.31	496.40	48.95	7.89	11.20	6.58	9.30	3.97	0.87	1015
7	7.53	0.14	0.62	4.52	407.86	79.72	266.80	39.05	6.04	22.40	7.27	11.61	4.91	0.61	1312
8	7.57	0.20	0.54	5.88	363.95	65.60	458.32	42.90	5.45	19.60	7.12	8.12	3.82	0.91	1366
9	7.58	0.11	0.65	8.59	451.76	43.59	446.00	45.10	7.65	19.40	7.93	11.07	3.05	0.55	1219
10	7.56	0.13	0.76	7.68	458.03	49.88	531.12	44.55	8.20	26.60	7.60	11.41	3.67	0.41	1011
11	7.64	0.14	0.50	10.36	301.23	49.88	633.04	41.80	12.05	11.20	7.66	10.69	3.91	0.78	632
12	7.56	0.25	0.96	7.23	483.12	46.74	475.12	49.50	9.30	18.34	7.41	11.10	2.47	0.75	558
13	7.54	0.14	0.51	11.53	345.14	42.15	466.16	38.50	11.70	24.34	6.63	9.35	2.74	0.91	1317
14	7.65	0.18	0.65	12.17	401.58	42.58	477.36	39.60	12.45	27.64	8.46	11.41	2.60	0.68	1192
15	7.96	0.20	0.53	7.46	370.22	41.02	359.76	45.65	9.30	22.34	7.25	11.86	3.62	0.88	1073
16	7.47	0.18	0.68	5.17	426.67	48.44	609.52	43.45	13.15	29.37	6.94	13.43	3.40	0.68	1248
17	7.54	0.21	0.73	7.03	432.94	47.30	597.20	42.35	6.35	23.80	6.69	9.90	3.98	0.74	1135
18	7.44	0.25	0.79	4.17	501.94	59.31	652.08	38.50	7.55	16.80	7.21	10.75	3.16	0.84	1299
19	7.62	0.17	0.67	6.78	357.68	80.75	751.76	47.85	13.35	19.60	5.16	20.11	8.32	0.92	1218

...continued...

Site No.*	pH	EC dSm^{-1}	Org. C. %	$CaCO_3$ %	N Kg ha^{-1}	P_2O_5 Kg ha^{-1}	K_2O Kg ha^{-1}	Ca c $mol(p^+)$ kg^{-1}	Mg c $mol(p^+)$ kg^{-1}	S Kg ha^{-1}	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
20	7.56	0.18	0.36	4.75	345.14	41.02	395.60	43.45	13.70	22.40	8.94	8.90	2.53	0.60	969
21	7.63	0.11	0.91	3.62	527.02	77.91	802.16	53.35	9.30	14.00	6.73	9.91	3.98	0.72	1253
22	7.49	0.13	0.84	8.59	458.03	65.03	785.36	50.60	9.85	9.80	7.47	8.26	3.80	0.68	1131
23	7.60	0.16	0.82	13.33	476.85	49.88	664.40	37.95	13.80	31.57	6.83	9.93	2.80	0.75	1325
24	7.57	0.20	0.84	10.40	338.86	47.49	582.64	51.15	8.20	14.00	9.41	9.02	3.85	0.46	1113
25	7.54	0.12	0.60	8.81	382.77	41.58	420.24	34.65	8.67	11.20	8.15	7.72	4.57	0.62	893
26	7.51	0.17	0.59	7.01	370.22	65.60	456.08	30.25	10.95	22.40	7.78	9.28	2.84	0.47	1024
27	7.44	0.19	0.65	10.17	357.68	53.02	516.56	34.10	8.20	21.00	9.17	9.96	4.04	0.61	1316
28	7.49	0.21	0.91	7.68	476.85	78.55	636.40	32.45	13.40	16.80	9.56	11.88	4.46	0.59	1192
29	7.50	0.18	0.71	9.27	332.59	67.11	630.80	49.50	7.10	15.40	7.87	10.64	4.33	0.51	988
30	7.53	0.28	0.91	6.78	495.66	37.30	571.44	51.15	9.30	23.80	7.55	11.46	4.60	0.78	932
31	7.50	0.29	0.84	7.01	483.12	48.44	726.00	46.20	13.15	12.60	7.46	9.68	2.91	0.83	1563
32	7.45	0.20	1.05	6.62	370.22	78.18	841.36	34.10	7.10	16.80	7.77	21.25	6.14	0.83	1449
33	7.57	0.16	0.47	11.75	294.96	53.02	454.96	50.60	11.50	11.20	8.16	16.62	7.57	0.94	1328
34	7.35	0.36	1.05	9.94	564.66	56.17	1001.52	36.85	12.34	12.60	7.44	15.30	5.95	0.70	1104
35	7.44	0.18	0.99	11.30	426.67	84.23	507.60	31.90	8.75	12.60	10.33	9.66	4.94	0.68	1130
36	7.43	0.23	0.84	9.72	451.76	35.24	480.72	46.75	4.35	18.20	8.90	10.51	5.05	0.62	1224
37	7.47	0.23	1.05	11.98	520.75	55.74	478.48	44.55	7.10	16.80	6.39	14.78	3.65	0.61	1347
38	7.50	0.20	1.01	10.40	527.02	43.59	499.76	48.95	6.35	19.60	8.75	12.70	2.71	0.62	865
39	7.49	0.20	0.78	10.40	332.59	46.74	516.56	45.10	8.75	15.40	9.37	10.52	4.89	0.61	913
Mean	7.53	0.20	0.73	8.35	410.59	57.97	547.12	42.87	9.58	18.44	7.78	11.47	4.36	0.70	1117

* Refer Appendix – I D for loclation and general information of corresponding site number

Appendix - X

Leaf nutrient status on dry matter basis of low yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush .

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	2.12	0.13	1.37	3.33	0.61	0.25	50.45	24.38	13.83	38.06	213
2	2.65	0.13	0.97	3.78	0.46	0.19	51.85	24.59	13.45	16.79	187
3	2.27	0.14	1.10	3.33	0.94	0.19	79.37	30.59	8.70	24.57	278
4	2.13	0.11	1.40	2.61	0.52	0.14	112.85	38.66	15.85	27.08	297
5	2.41	0.38	0.52	3.78	0.67	0.21	116.83	26.59	9.61	27.97	252
6	2.20	0.24	1.15	3.06	0.67	0.30	50.00	31.18	10.30	46.27	204
7	2.18	0.16	2.47	2.75	0.70	0.24	75.52	26.02	12.46	30.06	264
8	2.30	0.10	2.08	3.47	0.61	0.20	79.89	26.29	12.24	38.03	286
9	2.18	0.13	1.69	3.02	0.46	0.17	104.63	25.33	14.17	26.04	297
10	2.10	0.12	0.76	2.93	0.67	0.19	176.13	29.27	18.81	32.23	254
11	2.15	0.14	1.93	3.42	0.58	0.26	189.60	28.67	13.19	40.64	314
12	2.43	0.29	3.33	3.42	0.58	0.17	128.77	34.99	10.30	37.26	367
13	2.27	0.14	0.98	2.70	0.36	0.18	81.59	19.41	21.32	22.57	192
14	2.02	0.12	1.87	3.06	0.61	0.19	121.40	24.08	12.27	21.46	246
15	2.07	0.16	1.92	3.20	0.58	0.20	51.65	41.57	26.49	22.31	238
16	2.16	0.11	1.57	3.74	0.64	0.19	81.99	18.45	21.17	19.27	288
17	2.20	0.19	1.88	3.69	0.52	0.19	137.84	31.18	21.39	21.90	190
18	2.18	0.08	0.52	4.01	0.52	0.32	111.26	26.05	9.20	26.07	237
19	2.02	0.12	0.94	3.65	0.64	0.19	57.38	28.96	15.31	49.28	253
20	2.23	0.08	1.82	2.97	0.73	0.15	132.62	19.89	11.89	21.59	286
21	2.43	0.16	3.27	3.11	0.64	0.17	80.67	33.37	14.48	26.32	328

...continued...

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
22	2.01	0.16	0.71	2.93	0.88	0.17	70.02	21.56	19.15	37.92	348
23	2.16	0.13	1.51	3.69	0.67	0.26	97.24	24.08	15.73	16.07	261
24	2.48	0.33	0.85	4.10	0.58	0.18	127.60	33.11	16.64	24.26	247
25	2.46	0.25	1.64	3.24	0.58	0.21	129.82	27.10	8.89	24.22	186
26	2.18	0.17	1.13	2.97	0.64	0.22	110.23	29.48	10.30	34.11	157
27	2.15	0.22	1.14	3.69	0.49	0.21	127.00	23.42	14.78	35.52	149
28	2.46	0.14	1.65	2.75	0.67	0.25	122.28	31.88	17.21	26.38	196
29	2.49	0.16	1.79	2.97	0.64	0.20	52.60	30.85	9.46	22.82	162
30	2.16	0.29	0.69	2.84	0.58	0.29	109.76	31.00	34.85	18.25	187
31	2.15	0.23	0.64	2.84	0.64	0.21	87.49	25.87	20.33	28.58	271
32	2.23	0.11	1.37	4.01	0.58	0.14	77.27	42.66	8.44	21.41	286
33	2.27	0.12	2.00	3.69	0.58	0.17	102.63	50.95	19.30	31.27	187
34	2.09	0.14	2.49	3.33	0.58	0.19	102.53	51.22	12.62	32.06	308
35	2.15	0.26	1.90	2.75	0.58	0.32	107.08	27.08	16.23	26.42	216
36	2.27	0.22	0.97	3.15	0.58	0.24	199.57	27.49	12.65	19.44	234
37	1.55	0.20	1.67	3.78	0.61	0.18	135.30	63.15	18.54	10.97	183
38	1.96	0.31	1.18	3.56	0.58	0.18	77.77	35.07	23.98	36.28	312
Mean	**2.21**	**0.18**	**1.50**	**3.30**	**0.61**	**0.21**	**102.86**	**30.67**	**15.41**	**27.94**	**246**

* Refer Appendix – I A for loclation and general information of corresponding site number

Appendix – XI

Leaf nutrient status on dry matter basis of high yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *ambia* flush .

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	2.98	0.19	1.07	3.30	0.68	0.25	100.62	27.59	21.60	21.91	1158
2	1.67	0.16	1.54	5.20	0.49	0.19	149.38	30.19	21.40	28.02	1033
3	2.46	0.10	1.02	4.00	0.68	0.22	95.06	29.86	32.45	27.04	1058
4	2.40	0.13	1.51	4.30	0.49	0.28	99.13	47.82	17.55	22.06	836
5	1.69	0.15	1.83	3.35	0.68	0.24	162.29	42.54	14.70	47.66	1215
6	2.28	0.14	1.66	3.15	0.78	0.31	170.30	39.44	15.75	47.36	1585
7	2.71	0.09	1.74	4.30	0.55	0.22	90.77	31.72	15.10	33.13	1176
8	2.64	0.14	1.03	4.20	0.65	0.23	104.35	34.00	16.95	32.61	1226
9	2.58	0.15	1.45	3.60	0.65	0.27	75.17	38.93	33.75	27.56	968
10	2.68	0.09	1.38	3.65	0.68	0.22	177.43	59.75	24.35	43.58	635
11	2.20	0.12	1.27	4.85	0.65	0.39	71.32	70.95	41.40	33.58	1045
12	2.46	0.12	1.07	3.75	0.62	0.25	76.20	42.01	23.70	16.51	948
13	2.64	0.15	1.09	4.50	0.65	0.28	174.12	46.32	24.90	41.63	1265
14	2.71	0.03	1.68	3.65	0.65	0.20	177.55	30.28	20.55	29.92	1183
15	2.84	0.08	1.86	3.85	0.65	0.23	159.01	34.12	24.75	31.10	1226
16	2.98	0.18	1.71	3.85	0.68	0.28	150.09	47.85	17.65	38.62	1217
17	2.66	0.27	1.74	2.50	0.65	0.27	112.46	26.62	24.25	29.57	1325
18	2.93	0.24	1.81	3.20	0.62	0.28	122.30	26.90	32.95	27.64	1274
19	2.37	0.07	1.49	3.65	0.62	0.22	85.95	27.96	19.90	44.67	1483
20	2.46	0.17	1.41	3.95	0.68	0.20	118.26	39.91	27.85	24.41	1297
21	2.53	0.12	1.76	4.65	0.68	0.25	116.57	40.32	26.85	23.84	1536

...continued...

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
22	2.95	0.13	1.77	3.65	0.68	0.31	177.72	30.16	22.25	39.52	1452
23	3.08	0.09	1.62	3.70	0.75	0.36	144.75	54.64	22.65	34.47	1416
24	1.73	0.27	1.65	4.30	0.65	0.22	125.29	45.99	26.55	33.29	1061
25	2.37	0.15	1.83	3.30	0.68	0.31	76.12	28.60	11.35	24.74	1117
26	2.78	0.13	1.25	3.25	0.68	0.27	79.82	31.69	29.30	22.96	1284
27	2.38	0.09	0.96	3.45	0.65	0.38	143.10	42.37	26.55	33.37	1305
28	2.53	0.15	1.58	3.20	0.65	0.34	119.00	34.91	32.90	33.93	1938
29	2.28	0.15	1.05	4.20	0.68	0.23	76.02	50.65	17.25	29.71	568
30	2.53	0.18	1.59	3.95	0.65	0.32	76.83	59.09	19.90	34.96	2254
31	2.88	0.14	1.05	4.75	0.62	0.38	85.95	57.48	24.55	31.89	2127
32	2.58	0.20	2.11	3.45	0.68	0.43	109.32	35.85	33.55	27.29	672
33	1.93	0.13	1.12	4.45	0.62	0.38	88.22	34.55	37.60	19.46	1319
34	2.38	0.15	1.07	4.20	0.68	0.25	129.97	32.07	32.20	21.54	1239
35	2.58	0.11	1.46	4.35	0.52	0.20	139.43	32.31	31.60	24.46	1052
36	3.02	0.24	1.05	4.55	0.65	0.32	190.73	39.54	16.70	27.03	927
37	2.97	0.21	1.55	3.95	0.72	0.20	145.02	48.54	32.25	32.78	1312
Mean	**2.54**	**0.15**	**1.45**	**3.90**	**0.65**	**0.27**	**121.50**	**39.82**	**24.74**	**30.91**	**1236**

* Refer Appendix –1 B for loclation and general information of corresponding site number

Appendix – XII

Leaf nutrient status on dry matter basis of low yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush .

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	2.32	0.10	1.11	2.60	0.55	0.22	105.71	26.27	19.35	34.11	305
2	2.41	0.11	0.99	2.76	0.49	0.20	105.28	25.84	19.05	35.58	289
3	2.43	0.14	1.05	3.01	0.54	0.19	85.04	28.31	15.60	34.38	396
4	2.46	0.17	2.48	3.43	0.52	0.18	138.55	25.07	13.15	31.23	325
5	2.32	0.36	1.79	3.01	0.50	0.20	134.38	16.07	34.40	30.96	265
6	2.17	0.11	1.41	2.64	0.77	0.18	55.33	22.52	32.40	32.73	248
7	2.43	0.18	0.77	3.35	0.55	0.14	58.44	22.25	16.40	21.26	264
8	1.92	0.06	2.23	3.39	0.45	0.27	95.74	22.37	24.05	20.91	284
9	2.58	0.09	2.67	3.52	0.25	0.19	95.40	29.97	15.60	27.11	321
10	2.20	0.32	0.97	3.43	0.65	0.24	81.97	29.54	19.35	34.52	186
11	2.47	0.18	0.99	3.43	0.52	0.20	118.55	30.97	19.55	27.21	181
12	2.52	0.12	1.53	2.72	1.02	0.18	102.21	32.03	20.55	31.13	364
13	2.32	0.08	0.91	2.60	0.97	0.26	121.25	23.84	17.70	37.27	268
14	2.41	0.14	1.41	3.93	0.42	0.26	120.53	31.44	25.20	36.31	354
15	2.47	0.19	2.00	3.52	0.20	0.16	45.16	23.50	13.90	27.58	291
16	2.04	0.17	2.53	2.64	1.10	0.18	63.05	23.35	13.15	30.16	324
17	2.27	0.11	1.38	3.60	0.20	0.21	81.01	33.54	12.85	27.21	167
18	2.44	0.15	1.17	3.73	0.60	0.23	58.89	22.76	34.40	32.51	205
19	1.95	0.08	1.71	4.14	1.22	0.24	41.16	58.28	26.60	30.64	238
20	1.62	0.28	1.83	3.64	0.37	0.17	91.43	29.95	17.35	20.96	314
21	2.17	0.19	1.99	3.31	1.02	0.20	104.54	33.23	21.85	22.62	328

...continued...

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
22	2.52	0.29	0.89	3.47	0.60	0.14	50.71	30.70	14.75	21.19	295
23	2.55	0.44	1.23	2.34	0.72	0.15	85.49	24.39	14.95	31.62	187
24	2.38	0.17	1.02	2.26	1.20	0.24	84.40	15.69	14.80	26.81	357
25	2.03	0.05	0.82	3.10	0.47	0.23	103.12	23.63	20.30	21.56	268
26	2.21	0.32	1.34	3.47	0.70	0.18	122.62	29.77	20.70	26.93	316
27	2.14	0.28	0.54	3.31	0.92	0.16	103.16	29.95	19.55	29.70	256
28	2.37	0.25	0.70	3.47	0.75	0.19	58.42	22.23	15.25	30.79	299
29	1.86	0.09	2.38	3.52	0.60	0.21	76.98	22.27	14.05	30.86	268
30	2.55	0.08	2.66	2.34	1.20	0.22	58.20	29.14	14.20	20.82	183
31	2.21	0.45	1.99	2.72	0.22	0.19	89.21	23.21	12.40	23.79	291
32	2.32	0.31	1.97	2.89	1.12	0.18	118.84	30.30	17.35	22.08	256
33	2.41	0.16	1.32	2.89	0.17	0.18	97.94	23.30	17.40	25.87	168
34	2.46	0.09	1.65	3.85	0.52	0.16	60.74	29.80	17.80	24.30	284
35	2.06	0.08	2.09	5.07	0.67	0.14	96.42	23.01	20.05	27.14	306
36	2.38	0.23	2.86	3.68	0.37	0.19	76.81	22.42	16.40	25.20	273
Mean	**2.29**	**0.18**	**1.57**	**3.24**	**0.64**	**0.20**	**88.52**	**26.97**	**18.96**	**28.19**	**276**

* Refer Appendix – I C for loclation and general information of corresponding site number

Appendix – XIII

Leaf nutrient status on dry matter basis of high yielding subpopulation of Nagpur mandarin orchards of Western Vidarbha from *mrig* flush .

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
1	2.25	0.25	0.89	4.64	0.64	0.24	153.65	30.83	41.67	34.12	718
2	2.29	0.14	0.72	3.19	0.46	0.22	113.41	39.64	37.96	28.02	512
3	2.42	0.19	0.61	3.28	0.68	0.20	112.91	36.54	45.24	27.17	1158
4	2.33	0.17	1.14	3.46	0.57	0.23	87.95	33.87	26.52	24.86	1183
5	2.40	0.09	1.21	3.87	0.60	0.21	87.17	26.26	34.06	38.21	1347
6	2.47	0.11	1.12	4.14	0.71	0.19	78.76	27.06	19.76	36.18	1015
7	2.55	0.15	0.76	3.37	0.57	0.24	90.45	27.69	28.86	23.22	1312
8	2.33	0.13	1.09	3.55	0.71	0.23	93.36	28.93	19.57	37.18	1366
9	2.61	0.12	1.04	3.91	0.68	0.29	129.27	30.74	24.18	17.61	1219
10	2.67	0.11	1.18	3.78	0.68	0.26	129.46	34.82	24.70	27.66	1011
11	2.12	0.09	1.59	3.55	0.64	0.22	110.84	35.86	23.92	32.42	632
12	2.01	0.07	1.05	4.23	0.78	0.30	110.80	32.51	13.20	28.00	558
13	2.44	0.13	0.70	3.32	0.89	0.32	99.67	29.62	15.21	36.84	1317
14	2.55	0.15	0.97	3.46	0.50	0.35	140.30	37.82	13.46	22.24	1192
15	2.12	0.09	0.66	3.91	0.75	0.26	138.05	27.85	25.03	37.60	1073
16	2.58	0.08	1.41	3.59	0.60	0.30	118.31	46.68	15.67	27.31	1248
17	2.64	0.15	1.39	3.41	0.82	0.19	116.36	30.46	22.56	33.27	1135
18	1.95	0.12	1.56	3.32	0.78	0.23	142.80	38.02	16.77	32.62	1299
19	2.26	0.11	1.80	4.78	0.53	0.24	133.23	70.57	42.38	39.61	1218
20	2.44	0.12	0.79	3.59	0.60	0.24	163.82	28.13	13.78	23.11	969
21	2.61	0.22	1.91	4.50	0.71	0.21	98.11	31.94	21.84	29.11	1253

...continued...

Site No.*	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Yield Fruit/tree
22	1.88	0.13	1.64	4.28	0.71	0.17	100.10	29.73	28.93	28.24	1131
23	2.10	0.14	1.45	3.14	0.78	0.37	95.00	30.06	18.27	29.36	1325
24	2.47	0.15	1.21	4.32	0.53	0.23	148.73	30.82	21.52	28.54	1113
25	2.45	0.10	0.83	3.00	0.57	0.18	161.56	20.50	25.55	21.68	893
26	2.44	0.11	0.97	2.68	0.46	0.21	130.07	30.69	16.51	22.57	1024
27	2.45	0.17	1.11	2.91	0.53	0.20	165.27	31.37	26.39	28.66	1316
28	2.44	0.26	1.62	2.73	0.92	0.18	157.48	34.57	23.92	23.82	1192
29	2.23	0.21	1.56	4.10	0.92	0.22	126.77	38.98	21.97	33.06	988
30	2.58	0.09	1.18	4.05	0.89	0.26	119.25	37.14	23.08	27.01	932
31	2.64	0.10	1.46	3.96	0.43	0.18	120.56	30.90	14.69	31.19	1563
32	2.48	0.09	2.05	3.14	1.00	0.22	91.96	68.76	33.02	39.21	1449
33	2.29	0.10	0.93	4.28	0.60	0.22	126.94	61.86	43.16	48.08	1328
34	2.66	0.14	2.67	3.19	0.96	0.19	117.36	41.67	29.51	29.38	1104
35	2.47	0.16	1.06	2.73	0.57	0.19	174.70	26.86	30.16	36.59	1130
36	2.56	0.12	1.04	4.05	0.68	0.23	139.73	39.37	30.49	30.52	1224
37	1.82	0.11	1.01	4.10	0.39	0.22	136.00	41.86	24.12	34.65	1347
38	2.66	0.09	1.04	4.00	0.53	0.24	149.77	36.29	17.36	27.67	865
39	2.44	0.10	1.16	3.91	0.46	0.22	152.91	39.07	29.97	34.66	913
Mean	**2.39**	**0.13**	**1.22**	**3.68**	**0.66**	**0.23**	**124.69**	**35.80**	**25.25**	**30.54**	**1117**

* Refer Appendix – I D for loclation and general information of corresponding site number

Appendix - XIV

Soil fertility norms for *ambia* flush with evaluation and classification of the total orchards

Soil parameters	Unit	Observed range	Very low (Less than)	Low	Optimum	High	Excess (More than)
pH	-	7.28-8.06	7.16 (-)	7.17-7.34 (3)	7.35-7.71 (89)	7.72-7.89 (5)	7.89 (3)
EC	dSm^{-1}	0.10-0.48	0.01 (-)	0.02-0.11 (3)	0.12-0.29 (81)	0.30-0.39 (11)	0.39 (5)
Organic carbon	%	0.11-1.22	0.05 (-)	0.06-0.36 (12)	0.37-0.98 (79)	0.99-1.29 (9)	1.29 (-)
$CaCO_3$	%	4.06-23.97	0.74 (-)	0.75-4.25 (4)	4.26-11.29 (64)	11.30-14.81 (16)	14.81 (16)
N	$Kg\ ha^{-1}$	74-577	168 (8)	169-280 (44)	281-504 (44)	505-615 (4)	615 (-)
P_2O_5	$Kg\ ha^{-1}$	3-128	11 (5)	12-42 (19)	43-105 (69)	106-136 (5)	136 (1)
K_2O	$Kg\ ha^{-1}$	89-882	141 (5)	142-365 (17)	366-812 (73)	813-1036 (4)	1036 (-)
Ca	$c\ mol(p+)\ kg^{-1}$	10-56	30 (44)	31-37 (12)	38-51 (40)	52-58 (4)	58 (-)
Mg	$c\ mol(p+)\ kg^{-1}$	1.59-29.30	2.62 (8)	2.63-8.50 (23)	8.51-20.24 (67)	20.25-26.12 (-)	26.12 (3)
S	$Kg\ ha^{-1}$	2.10-60.90	5 (8)	6-12 (24)	13-26 (57)	27-33 (7)	33 (4)
Fe	ppm	1.39-10.36	4.80 (3)	4.81-6.02 (17)	6.03-8.56 (76)	8.57-9.82 (3)	9.82 (1)
Mn	ppm	8.27-29.09	4.56 (-)	4.57-9.15 (3)	9.16-18.34 (88)	18.35-22.93 (7)	22.93 (3)
Cu	ppm	1.50-10.24	0.56 (-)	0.57-3.00 (36)	3.01-7.88 (60)	7.89-10.33 (4)	10.33 (-)
Zn	ppm	0.51-0.93	0.35 (-)	0.36-0.52 (11)	0.53-0.87 (83)	0.88-1.05 (7)	1.05 (-)
Yield	Fruits/plant	162-2254	299 (43)	300-767 (12)	768-1705 (41)	1706-2173 (3)	2173 (1)

Values in parentheses indicate the percentage of total (low and high yielding together) orchards.

Appendix - XV

Soil fertility norms for *mrig* flush with evaluation and classification of the total orchards

Soil parameters	Unit	Observed range	Very low (Less than)	Low	Optimum	High	Excess (More than)
pH	-	7.35-7.96	7.27 (-)	7.28-7.40 (3)	7.41-7.65 (88)	7.66-7.78 (9)	7.78 (-)
EC	dSm^{-1}	0.11-0.37	0.05 (-)	0.06-0.13 (4)	0.14 –0.28 (73)	0.29-0.36 (20)	0.36 (3)
Organic carbon	%	0.26-1.25	0.24 (-)	0.25-0.48 (12)	0.49-0.98 (75)	0.99-1.22 (13)	1.22 (-)
$CaCO_3$	%	3.01-19.73	1.09 (-)	1.10-4.72 (7)	4.73-11.98 (72)	11.99-15.60 (8)	15.60 (13)
N	Kg ha^{-1}	55-343	216 (31)	217-313 (16)	314 –508 (48)	509-605 (5)	605 (-)
P_2O_5	Kg ha^{-1}	3-126	17 (8)	18-37 (12)	38- 78 (60)	79-99 (12)	99 (8)
K_2O	Kg ha^{-1}	180-1002	148 (-)	149- 347 (17)	348-747 (73)	748-946 (8)	946 (1)
Ca	c mol(p+) kg^{-1}	14-53	26 (20)	27-35 (31)	36-51 (48)	52-60 (1)	60 (-)
Mg	c mol(p+) kg^{-1}	2-15	2.40 (4)	2.41-6.00 (17)	6.01-13.20 (63)	13.21-16.80 (16)	16.80 (-)
S	Kg ha^{-1}	6-35	4 (-)	5-11 (15)	12-26 (71)	27-33 (11)	33 (4)
Fe	ppm	5.16-10.33	4.80 (-)	4.81-6.31 (15)	6.32-9.24 (79)	9.25-10.70 (7)	10.70 (-)
Mn	ppm	7.70-21.20	3.60 (-)	3.61-7.50 (-)	7.51-15.40 (95)	15.41-19.40 (1)	19.40 (4)
Cu	ppm	0.97-8.32	0.45 (-)	0.46-2.40 (35)	2.41-6.30 (59)	6.31-8.30 (7)	8.30 (-)
Zn	ppm	0.41-0.96	0.33 (-)	0.34-0.51 (8)	0.52-0.89 (84)	0.90-1.07 (8)	1.07 (-)
Yield	Fruits/plant	167-1347	485 (48)	486-801 (5)	802-1433 (47)	1434-1749 (-)	1749 (-)

Values in parentheses indicate the percentage of total (low and high yielding together) orchards.

Appendix - XVI

Leaf nutrient norms for *ambia* flush with evaluation and classification of the total orchards

Leaf nutrients	Unit	Observed range	Deficient (Less than)	Low	Optimum	High	Excess (More than)
N	%	1.55-3.08	1.57 (1)	1.58-2.05 (11)	2.06-3.02 (87)	3.03-3.50 (1)	3.50 (-)
P	%	0.03-0.38	0.01 (-)	0.01-0.08 (3)	0.09-0.22 (80)	0.23-0.29 (13)	0.29 (4)
K	%	0.52-3.33	0.62 (3)	0.63-1.04 (16)	1.05-1.87 (67)	1.88-2.29 (9)	2.29 (5)
Ca	%	2.50-5.20	2.38 (-)	2.39-3.17 (20)	3.18-4.66 (76)	4.67-5.42 (4)	5.42 (-)
Mg	%	0.37-0.88	0.49 (8)	0.50-0.57 (7)	0.58-0.73 (79)	0.74-0.81 (4)	0.81 (3)
S	%	0.14-0.43	0.11 (-)	0.12-0.19 (28)	0.20-0.36 (65)	0.37-0.44 (7)	0.44 (-)
Fe	ppm	50.00-199.60	25 (-)	26-73 (11)	74-170 (77)	171-218 (12)	218 (-)
Mn	ppm	18.45-70.94	11 (-)	12-25 (12)	26-54 (80)	55-69 (7)	69 (1)
Cu	ppm	8.43-41.40	5.73 (-)	5.74-15.24 (31)	15.25-34.25 (65)	34.26-43.76 (4)	43.76 (-)
Zn	ppm	10.97-49.28	10 (-)	11-21 (13)	22-41 (77)	42-51 (9)	51 (-)
Yield	Fruits/plant	162-2254	299 (43)	300-767 (12)	768-1705 (41)	1706-2173 (3)	2173 (1)

Values in parentheses indicate the percentage of total (low and high yielding together) orchards

Appendix - XVII

Leaf nutrient norms for *mrig* flush with evaluation and classification of the total orchards

Leaf nutrients	Unit	Observed Range	Deficient (Less than)	Low	Optimum	High	Excess (More than)
N	%	1.62-2.67	1.79 (1)	1.80-2.09 (13)	2.10-2.68 (85)	2.69-2.98 (-)	2.98 (-)
P	%	0.05-0.45	0.02 (-)	0.02-0.07 (4)	0.08-0.19 (75)	0.20-0.25 (9)	0.25 (12)
K	%	0.61-2.86	0.09 (-)	0.10-0.65 (1)	0.66-1.79 (75)	1.80-2.35 (15)	2.35 (9)
Ca	%	2.26-5.07	2.24 (-)	2.25-2.96 (21)	2.97-4.40 (73)	4.41-5.12 (5)	5.12 (-)
Mg	%	0.17-1.22	0.25 (4)	0.26-0.46 (12)	0.47-0.87 (67)	0.88-1.08 (11)	1.08 (7)
S	%	0.14-0.37	0.11 (-)	0.12-0.17 (11)	0.18-0.30 (83)	0.31-0.36 (5)	0.36 (1)
Fe	ppm	41.16-174.70	58 (9)	59-91 (21)	92-158 (64)	159-192 (5)	192 (-)
Mn	ppm	15.69-70.57	8 (-)	9-22 (9)	23-50 (85)	51-64 (3)	64 (3)
Cu	ppm	12.40-45.24	2.36 (-)	2.37-13.81 (5)	13.82-36.70 (88)	36.71-48.15 (7)	48.15 (-)
Zn	ppm	17.61-48.08	14 (-)	15-22 (13)	23-39 (83)	40-47 (3)	47 (1)
Yield	fruits/plant	167-1347	485 (48)	486-801 (5)	802-1433 (47)	167-1347	485 (48)

Values in parentheses indicate the percentage of total (low and high yielding together) orchards

Appendix – XVIII

Rating limits of available nutrient elements for assessing the soil fertility status

Nutrient (Unit)	Low / Critical (Less than)	Medium	High (More than)	Reference
Organic carbon (%)	0.50	0.50 – 0.75	0.75	Muhr *et al.* (1965)
N (kg ha^{-1})	280	280 – 560	560	
P_2O_5 (kg ha^{-1})	22.90	22.90 – 56.33	56.33	
K_2O (kg ha^{-1})	108	108 – 280	280	
Fe (ppm)	4.5	-	-	Lindsay and Norvell (1978)
Mn (ppm)	1.0	-	-	
Cu ppm)	0.2	-	-	
Zn(ppm)	0.8	-	-	

Appendix – IXX

Standards for classification of nutrient status of orange trees based on concentration of mineral elements 4 to 7 months old spring cycle leaves from non-fruiting terminals *

Element	Unit	Range on dry matter basis				
		Deficient (Less than)	Low	Optimum	High	Excess(More than)
N	%	2.2	2.2 – 2.4	2.5 – 2.7	2.8 3.0	3.0
P	%	0.09	0.09 – 0.11	0.12 – 0.16	0.17 – 0.29	0.30
K	%	0.7	0.7 – 1.1	1.2 – 1.7	1.8 – 2.3	2.4
Ca	%	1.5	1.5 – 2.9	3.0 – 4.5	4.6 – 6.0	7.0
Mg	%	0.20	0.20 – 0.29	0.30 – 0.49	0.50 – 0.70	0.80
S	%	0.14	0.14 – 0.19	0.20 – 0.39	0.40 – 0.60	0.60
Fe	ppm	35	35-49	50-120	120-200	250
Mn	ppm	18	18-24	25-49	50-500	1000
Cu	ppm	3.6	3.7-4.9	5-12	13-19	20
Zn	ppm	18	18-24	25-49	50-200	200

* Values are adapted from Smith (1966).

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VITA

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THESIS ABSTRACT

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a)	Title of the Thesis	:	**DIAGNOSTIC NORMS FOR NUTRITIONAL REQUIREMENT OF NAGPUR MANDARIN USING DRIS APPROACH**
b)	Name of Student	:	**Dnyaneshwar Shriram Kankal**
c)	Name and Address of Major Advisor	:	**Dr. S.K. Thakre** Ex. Professor and Head, Department of Agril.Chemistry and Soil Science,Dr.PDKV, Akola
d)	Degree to be awarded	:	Ph.D. (Agric.)
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ABSTRACT

Mandarin (*Citrus reticulata* Blanco) is a popular and extensively grown fruit crop in Vidarbha region of Maharashtra. The present study was undertaken to establish DRIS norms in Nagpur mandarin for fertility evaluation from both soil and leaf nutrient status to make meaningful fertilizer recommendations for achieving higher productivity. One hundred and fifty bearing orchards, seventy-five each from *ambia* and *mrig* flushes of 10 to 13 years old were selected from Western Vidarbha region. Composite soil and leaf samples were collected analyzed using standard procedures.

According to DRIS, orchards were divided into two sub-groups based on 'low' and 'high' yield performance as population – 'A' and population-'B' respectively. The cutoff value for dividing high and low yield was 400 fruits per tree for each orchard. Soil fertility and leaf nutrient norms were developed for each flush of Nagpur mandarin orchards in Western Vidarbha using DRIS.

Soil characteristics showed that the soils are neutral to moderately alkaline in reaction, non-saline in nature and medium to high in organic carbon . All the soils were slightly calcareous to calcareous in nature. In general higher nutrients and higher organic matter content and low $CaCO_3$ in soils were favourable conditions for higher yields. In high yielding sub-population particularly, the yield of *ambia* was comparatively more than *mrig* and so was the trend of available nutrients in soil.

Leaf nutrient status of both flushes indicated higher mean values of N, Ca, Mg, S and micronutrients whereas status of mean P and K was higher in low yielding orchards. Maximum nutrients (excepting Mg, Cu and Zn) were having higher concentration in *ambia* flush than in *mrig* flush and so was the yield performance.

DRIS norms as new ratings for soil fertility and leaf nutrient status were developed and divided into five classes *viz.* very low or deficient, low, optimum, high and excess. DRIS indices were derived for soil fertility and leaf nutrient status of low as well as high yielding orchards which have negative, positive and zero values. The nutrient with most negative index was considered relatively the most limiting i.e. most required where as positive index indicates relatively excessive quantity and lesser requirement. Zero index is with optimum balance. The set of recommendation based on DRIS indices *vis- a- vis* DRIS norms for the individual orchard if applied, will resulted in increase of yield of subsequent crop. Thus in making meaningful recommendation, which will have the highest chance of increasing yield profitably, DRIS indices, based on leaf analysis can be adopted for convenience and for correct reflection.DRIS indices are not only used for low yielding but also for those high yielding orchards in which yield can further increase economically.

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