RELATIVE EFFICIENCY OF DIFFERENT ROOTSTOCKS ON THE LEAF NUTRIENT CONTENT, YIELD AND FRUIT QUALITY OF SWEET ORANGE (Citrus sinensis (L) Osbeck) Cv SATHGUDI IN THE ALFISOLS OF CITRUS IMPROVEMENT PROJECT, TIRUPATI.

By

J. KUSUMA GRACE

THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
SRI VENKATESWARA AGRICULTURAL COLLEGE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
TIRUPATI - 517 502. (A.P.)

1997

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1997

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CERTIFICATE

Ms.J.KUSUMA GRACE *has satisfactorily prosecuted the course of research and that the thesis entitled* **"RELATIVE EFFICIENCY OF DIFFERENT ROOTSTOCKS ON THE LEAF NUTRIENT CONTENT, YIELD AND FRUIT QUALITY IN SWEET ORANGE (*Citrus sinensis* (L) OSBECK) cv. SATHGUDI IN ALFISOLS OF CITRUS IMPROVEMENT PROJECT, TIRUPATI"** *submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by her for a degree of any University.*

Date : 10.2.99

10.2.9

Major Advisor

ASSOCIATE PROFESSOR
Dept. of Soil Science & Agricultural Chemistry
S. V. AGRICULTURAL COLLEGE
TIRUPATI - 517 502

CERTIFICATE

This is to certify that the thesis entitled **"RELATIVE EFFICIENCY OF DIFFERENT ROOTSTOCKS ON THE LEAF NUTRIENT CONTENT, YIELD AND FRUIT QUALITY IN SWEET ORANGE (*Citrus sinensis* (L) OSBECK) cv. SATHGUDI IN ALFISOLS OF CITRUS IMPROVEMENT PROJECT, TIRUPATI"** *submitted in partial fulfilment of the requirements for the degree of* **MASTER OF SCIENCE IN AGRICULTURE** *of the* **Acharya N.G.Ranga Agricultural University, Hyderabad**, *is a record of the bonafied research work carried out by* **Ms.J.Kusuma Grace** *under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee.*

No part of the thesis has been submitted for any other degree or diploma. The published part has ben fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee

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J. Kusuma Grace

(J.KUSUMA GRACE)

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol/Abbreviation	Meaning/Expansion
B	Boron
Ca	Calcium
Cm	Centimeter
Cu	Copper
$dS\ m^{-1}$	deci siemens per meter
et al	and other workers
EC	Electrical conductivity
Fig	Figure
g	gram
i.e	which is to say
$Kg\ ha^{-1}$	Kilogram (s) per hectare
K	Potassium
m	meter
Mg	Magnesium
mg	milligram
Mn	Manganese
$me\ 100^{-1}g$	milli equivalent per 100 grams
ml	milli litre
mm	milli meter
nm	nanometers
N	Nitrogen
OC	Organic Carbon
P	Phosphorus
ppm	parts per million
S	Sulphur
Zn	Zinc
%	per cent
>	more than
<	less than

DECLARATION

I, Ms.J.KUSUMA GRACE *hereby declare that the thesis entitled* "RELATIVE EFFICIENCY OF DIFFERENT ROOTSTOCKS ON THE LEAF NUTRIENT CONTENT, YIELD AND FRUIT QUALITY IN SWEET ORANGE (*Citrus sinensis* (L) OSBECK) cv. SATHGUDI IN ALFISOLS OF CITRUS IMPROVEMENT PROJECT, TIRUPATI" *submitted to* Acharya N.G.Ranga Agricultural University, Hyderabad, *for the degree of Master of Science in Agriculture is the result of original research work done by me. I also declare that the material contained in the thesis has not been published earlier.*

Date : 10-2-97

J. Kusuma Grace

(J.KUSUMA GRACE)

ABSTRACT

Title	:	RELATIVE EFFICIENCY OF DIFFERENT ROOTSTOCKS ON LEAF NUTRIENT CONTENT, YIELD AND FRUIT QUALITY IN SWEET ORANGE (*Citrus sinensis* (L) Osbeck) cv SATHGUDI IN ALFISOLS OF CITRUS IMPROVEMENT PROJECT TIRUPATI.
Author	:	**J. KUSUMA GRACE**
Chairman of the Advisory Committee	:	Sri C. Ranganayakulu
Submitted for the award of degree	:	M.Sc (Ag)
Faculty	:	Agriculture
Discipline	:	Soil Science and Agricultural Chemistry
University	:	Acharya N.G.Ranga Agricultural University
Year of Submission	:	1997

An investigation was carried out on a citrus rootstock trial to study the relative efficiency of different rootstocks on nutrient content, yield and fruit quality of sweet orange in Haplustalf of Citrus Improvement Project, Tirupati.

The soils of the experimental site were red sandy loams to sandy clay loams. The surface soils were nonsaline neutral and statistically homogenous but for few differences in P, S, Fe and Mn which may not effect the major nutritional variation in the long run.

The available N, P and K in the surface soils were medium, low to medium and high respectively whereas Ca, Mg and S were found to be sufficient and micronutrients were above the critical limits.

The general study of relationship of soil nutrients it leaf nutrients of scion irrespective of kind of rootstock, it was observed that after 45 days of fertilizer application, significant positive correlations between soil and leaf nutrients were obtained for N with Mg, P with Zn, S with K, Ca and S while significant negative correlations, were observed for P with Cu, Ca with S, Mg with Fe, S with Cu and Fe with Mn.

Further, after 90 days of fertilizer application, significant positive correlations were obtained between N and Ca, Mg, Zn; Cu and S and soil Mn and leaf Mn while

significant negative correlations were obtained for P with Cu, Ca with K and S with K and Cu.

The general correlation study among the leaf nutrients of the scion irrespective of kind of rootstock it was observed that among the leaf nutrient, after 45 days of fertilizer application, significant positive correlations were obtained between N and P,K; P and Zn; K and Mg, S, Zn while significant negative correlation was obtained between Zn and Cu. Whereas after 90 days of fertilizer application, significant negative correlation was obtained only between K and B.

According to the study of the effect of different rootstocks in the absorption of nutrients by scion after fertilization which also reflects on the effects of rootstock on the absorption of nutrients, it was inferred that the correlations for soil and leaf nutrients on sathgudi rootstock were significant and positive between N and Mg; P and Ca; S and P; Zn and Cu; Mn and P while the association was negative between Mg and N.

On Rangpurlime rootstock, correlations were significant and positive for soil N, P, Zn, Cu with leaf Fe; Ca with Mn; Cu with P; Mn, B, Ca with Mn, P, Mn respectively while they were negatively significant between soil Ca and Mg with leaf Fe.

For Cleopatra mandarin rootstock, significant positive correlations were obtained between K and Mn with N; Fe with Cu while P and Ca had negative relationship.

For Troyer citrange rootstocks significant positive correlations were obtained for soil N, Fe with leaf Mg; soil Cu, Zn with leaf Mg; soil Cu, Zn with leaf P; and Fe with Mg and Copper. While it was negative between soil N, P, K with leaf P, Fe and S respectively.

On Trifoliate orange rootstock, significant positive correlations were obtained between soil K and S with Zn and Mg respectively while negative for soil N, K, S with leaf Fe, Cu and Zn respectively, and between Ca, Mg with Mn. Soil Fe and Cu with leaf N and P positively correlated but negatively with Ca in leaves.

In general, N, Mg, S, Fe and B were found to range between optimum to high, P high to K, Zn, Mn in low to optimum level, Cu optimum to excess and deficient levels of Ca in the leaves of Sathgudi sweet orange on different rootstocks.

The rootstocks showed an increase in the uptake of nutrients after 45 days of fertilizer application except in case of zinc, iron and boron which first showed a decrease and then an increase.

Among all the rootstocks, Rangpurlime recorded higher fruit weight, fruit length, diameter juice volume, juice percentage, rag weight, reducing non reducing and total sugars, and yield by weight while rind thickness and percentage, rag percentage, acidity and ascorbic acid content were the least.

Introduction

CHAPTER 1

INTRODUCTION

Citrus fruits occupy a prominent position among the popular and extensively grown tropical and subtropical fruits next to Mango and Banana. Citrus fruits are rich source of ascorbic acid (Vitamin C) which is essential for bones and teeth. Besides vit. C, citrus fruits also contain other vitamins (A and B), minerals such as Ca, P, Fe and alkaline salts. This fruit also contains high amount of potassium and low amount of sodium and thus have a therapeutic value (Atul chandra *et al* 1994).

Travelling far and wide, this highly potential commercial fruit crop now occupies over two million hectares of land spread over 50 countries throughout the world (Verma and Sharma (1993). US and Brazil are dominant countries in citrus juice production. Although, India is the original home of citrus, it ranks only sixth in the world as for as area and production are concerned and occupies an area of 348 thousand hectares (Hegde 1995).

The important commercial citrus fruits are Mandarin orange (Santhra), Sweet orange (Sathgudi/Mosambi) and Kagzi lime (Nimbu). Mandarin orange is concentrated in pockets of Maharashtra, Karnataka, Madhya Pradesh, Rajasthan, Punjab and Assam while, Sweet orange is grown in Maharashtra, Andhra Pradesh, Punjab and Rajasthan. Kagzi lime is grown throughout the country in scattered areas. Oranges alone occupy an area of 1.43 lakh hectares in our country (Hand book of Indian Agriculture 1995).

In India, Sweet oranges occupy second place among the citrus fruits grown in 24,407 ha producing 278.2 thousand tonnes and in Andhra Pradesh, it is being cultivated in 32,267 ha.

Citrus is generally grown on rootstocks. In India, the use of rootstocks in citriculture was started in 1940's. Studies indicated that rootstocks exert profound influence on vigour, productivity, fruit qualilty, disease resistance, drought endurance, nutrition and longevity of scions budded on them.

Several rootstock trials were conducted in different agro-climatic conditions in India using sweet orange as scion, and different rootstocks were suggested for different situations. In the rootstock trials conducted at Anantharajupet (A.P), during the early years of 1935-51, Jambheri was selected as the most suitable rootstock compared to nine other rootstocks. But subsequently, sweet orange orchards grown on Jambheri rootstock showed rapid decline which was attributed to its susceptibility to virus (Dodd's and Gumpf, 1991), soil nematodes, fungi and faulty horticultural practises. The earliler studies indicate that Rangpur lime is a better rootstock than rough lemon (Jambheri).

The performance of rootstock depends on many factors like the climatic conditions, soil nutrient status, lime, soil physical problems, nutrient availability, nutrient absorption capacity of rootstock, vigour, and resistance to diseases etc.

In the Lindcove trials conducted for three year period from 1977, the roostocks were found to have significant influence on leaf nutrient content. For most nutrients, rootstock effects on content were not clearly associated with yield. Those nutrients which are either low or deficient, mostly associated with yield indicating that current leaf analysis standards are applicable to most rootstocks. Fertilization regimes developed from leaf cannot be applied to adjacent groves on other rootstocks. (Clinton way 1990).

The native fertility of citrus soils is less important than the physical characteristics. Fundamental differences in the fertility of soils used in citriculture exist under different clilmatic conditions and are further affected by previous land use.

Soil analysis for diagnosing the nutritional status of a tree has serious limitations. The most important of these is lack of general correlation between tree behaviour and soil composition.

Leaf analysis is more critical than soil analysis in determining the nutrient levels in citrus and that is the reason we generally take a leaf sample at the same time as the soil sample says Dr.Lengyel (1990). The soil samples can be used in order to make recommendations in the area of soil ammendments but, in the case of nutrient levels such as potassium, leaf analysis is more important.

For the most rapid way of recovery, scientists are advising foliar application to be the best whereas the soil applied material would be less effective because the uptake would be too slow. For example, when we put nitrogen in the soil, the tree takes it up when its roots are active says Ms.Lovett (1991).

Hence, the nutrient uptake by the rootstocks depends on several factors which needs an insight to determine their efficiency in nutrient uptake.

Sathgudi, also called 'Cheeni' is the commercial variety of sweet orange grown in Andhra Pradesh. It gives the highest yields in comparison with several other varieties tested at Regional Fruit Research Station. Anantharajupet. Since, the prebearing age of seedlings is about eight years, vegetative propagation on suitable rootstock is inevitable.

Sathgudi, was recommended as a rootstock for its own scion based on the observations on the least susceptibility of trees to decline. But the early yields of sathgudi on its own rootstock were not appreciable.

It is well known that different varieties of mandarin oranges required specific combination of stock and scion for particular agro-climatic conditions. A combination which is satisfied under one set of climatic and soil condition may fail entirely in other conditions (Jalikop *et al* 1986).

In citrus, the influence of rootstocks on the nutrient composition of the scion leaves has been investigated by number of workers (Embleton *et al* 1973). Consistent and pronounced effects of rootstocks on the nutrient composition with respect to both macro and micro-nutrient elements have also been reported by many workers.

Taking all these into consideration, a detailed study was made on the rootstock trial on Sathgudi, laid during 1983 at Citrus Improvement Project, Tirupati. The rootstocks employed were as follows.

1. Sathgudi (*Citrus sinensis* Osbeck)
2. Rangpur lime (*Citrus limonia* Osbeck)
3. Cleopatra mandarin (*Citrus reshni* Tanaka)
4. Troyer citrange (*Poncirus trifoliata* (L) Raf x *Citrus sinensis* (L) Obseck)
5. Trifoliate orange (*Poncirus trifoliate* (L) Raf)
6. Jamberi (*Citrus jambhiri* Lush)

Hence, a wider approach is made in this study during the year 1996 to find out the soil nutrient status, leaf mineral composition and fruit quality and yield; the interrelations between them and the efficiency of different rootstocks on these were also studied with the following objectives.

1. To study the effect of different rootstocks on the yield and leaf nutrient contents of N, P, K, Ca, Mg, S, Zn, Cu, Fe, Mn and B.

2. To correlate the physical, physico-chemical and chemical characters of soil with the leaf nutrient content.

3. To study the effect of different rootstocks on quality characters of fruits like size, rind thickness, rag, juice, seed, TSS, brix, reducing and non-reducing sugars, ascorbic acid and titrable acidity.

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

The literature pertaining to the objectives specified in the research problem undertaken has been reviewed and is being presented under the following different heads for convenience and clarity.

2.1 Physical and physico-chemical properties of the soil

2.2 Fertility status of the soil

2.3 Rootstock effect on the mineral composition of citrus foliage

2.4 Rootstock effect on the fruit quality and yield

2.5 Factors affecting mineral composition of leaves

2.6 Leaf mineral composition in relation to yield and quality of citrus

2.7 Effect of fertilizer application on fruit yield and quality

2.1 PHYSICAL AND PHYSICO-CHEMICAL PROPERTIES OF THE SOIL

2.1.1 Physical Properties of the Soil

The soil physical properties are studied under the field council conditions and they are best evaluated from the insitu examination of the soil profile.

2.1.1.1 Colour. It is probably the most obvious feature of the soil and is related to specific physical, chemical and biological properties of the soil.

Ramaiah and Raghavendrachar (1936) observed that the mineral matter in combination with the organic matter was responsible for the variations of colour in a soil.

Chakravarthy and Barua (1983) observed that the colour hue of the soils of citrus growing belt of hill districts in Assam varied from 5 YR to 10 YR.

Venkataramanaiah (1993) showed that the colour of the soil profiles of healthy and declining orchards varied from yellowish red to very dark grey brown with hue which ranged from 2.5 YR to 10 YR.

2.1.1.2 Texture. As per the committee on Terminology (1956), the soil texture is defined as the relative proportions of the various soil separates in a soil material.

Bar-Akiva and Hamou (1974) reported that sweet orange fruits grown on Sandy clay loam soils were larger, had thicker peel, obtained more total acids and vitamin C in the juice than the fruits grown on loamy sands regardless of the fertilizer treatments.

Valle valder (1974) observed that the fruits of valencia orange on clay soils were less juicy and more acidic than fruits grown on sandy loam soils.

Chauhan *et al* (1984) observed that texture of the soil varied from sandy loam to loamy sand which is considered best for orchard. Heavy and impermeable soil which tends to puddle is not suitable for citrus cultivation because of high oxygen requirement of its roots.

Vijayasankar Reddy (!989) reported that the texture of Alfisols varied from sandy loam to clay loam. Venkataramanaiah (1993) reported that the texture of the profiles varied from sandy loam to sandy clay loam at surface horizons and sandy clay loam to clay at subsurface.

2.1.1.3 Structure. Soil structure plays a dominant role in plant growth relationships as it chiefly influences the amount and nature of porosity and regulates the moisture regime in the soils.

Bhargava *et al* (1973) observed granular to sub-angular blocky structure of citrus soils in the red soils of Tungabhadra catchment area.

Venkataramanaiah (1993) observed that all the profiles studied in Prakasam district of A.P. were found to have angular to sub angular blocky structures.

2.1.2 Physico-chemical Properties

2.1.2.1 Soil reaction (pH). Chapman (1960) considered the pH range of 5.5 to 7.5 to be ideal for optimum citrus growth. Dhingra *et al* (1965) reported that soil with pH values up to 8.5 are not harmful for citrus. Chada *et al* (1969) recorded that excellent citrus was raised in soils ranging from highly acidic (pH 4.5) to those containing free lime (pH 8.5).

Nijjar and Raghbir Singh (1971) observed that high pH heavy texture and poor nutrient status of the soils were responsible for low levels of micronutrients in the sweet orange leaves.

Reddy *et al* (1981) and Tuzcu *et al* (1986) reported that the alkaline nature of the soil accelerated the micronutrient imbalances in citrus plants.

Brar *et al* (1982) reported that soil pH had a negative correlation with micronutrient content of the soil and orange plant. Chauhan *et al* (1984) reported that pH of the soils varied from 8.21 to 8.71 and 30 per cent of the orchards were observed to have above the desired range.

Raina (1988), Vijayasankar Reddy (1989) and Vijay Kumar (1990) observed slight increase in pH with increasing depth in red and black soils of citrus grown areas in AP.

Venkataramanaiah (1993) reported that the pH of the soil varied from 7.8 to 8.7 in healthy and 8.0 to 8.9 in declining orchards which might be due to low organic matter in the soil.

2.1.2.2 Electrical Conductivity. Kanwar and Randhawa (1960) reported that maximum safe limit of EC in the rootzone of soil supporting healthy citrus plants in Punjab is 0.45 m.mhos cm^{-1} and any value above it noted to be injurious.

Nilangekar and Patil (1981) reported that soils of chlorotic citrus plants showed slightly higher EC values as compared to soils of healthy orchards.

Chauhan *et al* (1984) reported that the EC ranged from 0.06 to 0.38 m.mhos cm^{-1} which was in safe limit. Rajput and Haribabu (1985) recommended that soils in which the total concentration of salts exceeds 1000 ppm should be discarded for citrus cultivation.

Vijayasankar Reddy (1989) reported that the EC of soils showed an increasing trend with depth except in Alfisols of Tirupati which ranged from 0.139 to 0.233 m.mhos cm^{-1} which is the lowest.

Venkataramanaiah (1993) reported that mean value of electrical conductivity was significantly higher in declining (0.479 dSm^{-1}) than the healthy orchard profiles (0.44 dSm^{-1}) in Anantapur and Prakasam districts of A.P.

2.1.2.3 Organic carbon. Hayes (1960) reported that irrespective of the amount of available nutrients, the fruit trees do not flourish unless the supply of organic matter in the soil is maintained at a fairly high level. The deficiency of organic matter might have aggravated the harmful effects of high pH by weakening the buffering capacity of the soil.

Nijjar and Raghbir Singh (1971) reported that the sweet orange grown soils in Amristar district were generally poor in organic matter and it was still lower in the declined orchards and they also found that the lack of organic matter in the soils may be due to inadequate use of farmyard manure and intercropping with exhaustive crops.

Vepraskas and Wilding (1983) reported that the organic carbon was concentrated at the surface and decreased sharply with increasing depth. Similar observations were recorded by Raina (1988). Vijayasankar Reddy (1989), Verma *et al* (1990) and Venkataramanaiah (1993).

Chauhan *et al* (1984) reported that the organic carbon of soil varied from 0.17 to 0.42 per cent which was in the low range. Vijayasankar Reddy (1989) reported that organic carbon content of Alfisols was low and ranged from 0.225 to 0.495 per cent while in Inceptisols it varied from 0.300 to 0.630 per cent.

Venkataramanaiah (1993) reported that the orchard soils sampled in all the profiles were generally poor in organic carbon and ranged from 0.15 to 0.49 per cent in declining orchard soils and 0.22 to 0.5 per cent in the healthy orchard soils which may be due to the inadequate use of FYM.

2.2 FERTILITY STATUS OF THE SOIL

Kanwar *et al* (1963), Mann *et al* (1979) and Awasti *et al* (1984) reported higher Ca status in the sweet orange trees as compared to declining ones could be anticipated due to higher soil Ca status.

Sakamoto and Okuchi (1968) reported that leaf K was low in orange trees in the soils rich in exchangeable Ca and Mg while high leaf P was associated with high P in the soils.

Lucas and Knezek (1972) reported that low organic carbon and high soil P as contributory factors for zinc deficiency.

Nijjar and Raghbir Singh (1971) observed the deficiencies of N, Fe, Mn and Zn and surplus of P and K in most of the orange grown soils of Punjab.

According to Anderson and Albrigo (1977) orange leaf K was negatively correlated to soil P and Ca. They also observed positive correlation between leaf N and soil N, leaf P and soil P, leaf Ca and soil Ca, leaf Mg and soil Mg and Ca and pH. Bopaiah *et al* (1982) reported a positive correlation between soil P and leaf P.

Mann *et al* (1979), Awasthi *et al* (1984) and Vijayasankar Reddy (1989) reported positive correlation between soil exchangeable Ca and leaf Ca.

Vinay Singh and Tripathi (1983) reported that most of the citrus soils were adequate in available Fe, Mn, Cu and Zn. They also observed that concentration of available Cu and Zn showed a progressive decline with depth and the 120-180 cm layer contained the lowest amount.

Chauhan *et al* (1984) reported low P level (12-25 $Kg.ha^{-1}$), medium to high K content (206 to 1190 $Kg.ha^{-1}$), deficiency of Zn (0.28 to 1.12 ppm) and sufficient Fe (3.92 to 12.52 ppm) in the orchards of citrus.

Hume *et al* (1985) reported that increase in available N and K contents to citrus plants with higher levels of N and K in soils. Zhuang *et al* (1985) found that soils of high yielding citrus orchards contained 40-60 ppm of available P and 82-115 ppm of available K.

Goyal and Singh (1987) and Kuldeep Singh and Ahuja (1990) noticed that the available soil nitrogen decreased with depth in the profiles while phosphorous and potassium either decreased with depth or showed irregular pattern of distribution.

Raina (1988) reported that the nutrient status of citrus growing soils of Dhaulakuan, Himachal Pradesh were medium to high in organic carbon, low in available nitrogen, medium to high in available phosphorus and medium in available potassium. Available Mn and Zn were deficient while the Cu and Fe were found to be sufficient.

Vijaysankar Reddy (1989) reported that the soils where sweet orange is grown, contained low to medium available N (203 to 415 $Kg\ ha^{-1}$) low to high available P_2O_5 (15.4 to 92.6 kg.ha^{-1}) and medium available and medium available K_2O (172 to 283.2 Kg ha^{-1}). He also reported that the available Cu, Mn and Fe were above the critical limits, however the Zn content was found to be below the critical limit (0.67 to 1.2 ppm) in most of the soils.

Balangoudar and Satyanarayana (1990) reported that the sulphate content increased as the depth increased in the profiles which may be due to leaching of soluble sulphate to deeper layers and precipitated as gypsum crystals. It could also be due to higher clay content and soluble salts (EC) at lower depth, which must have been translocated along with clay fraction.

Kuldeep Singh *et al* (1990) observed that the available Fe, Mn and Zn were decreased with increasing depth. However, no regular pattern of distribution for available copper with respect to depth were observed in Semi arid alluvial soil profiles.

Venkataramaniah (1993) reported that the available soil N, P, K, Ca and S were found to be lower in declining orchards as compared to healthy ones while Mg showed a reverse trend. The available Cu, Mn and Fe were found to be above their critical limits but Zn was found to be below critical limit in the declining orchards.

2.3 ROOTSTOCK EFFECT ON THE MINERAL COMPOSITION OF CITRUS FOLIAGE

2.3.1 Nitrogen

Smith *et al* (1949) and Gaffer (1967) found lower leaf N content in Sweet oranges on Rough lemon than an Cleopatra mandarin. The study pointed out that trifoliate orange had the potentiality for increased absorption and accumulation of N than the rest which agree with the findings of Castle and Krezdorn (1975) who recorded higher leaf N content of 2.53 per cent on Trifoliate orange selections.

Wallace *et al* (1952; 1953) have reported higher leaf N content on trifoliate rootstock as compared to rough lemon. Similar findings were done by Iyengar 1982; Anjaneyalu and Ravishankar 1984.

Smith *et al* (1949) found higher nitrogen level in leaves of Valencia orange on rough lemon than sour orange rootstocks.

Chapman (1960) suggested the leaf analysis standards for assessing the citrus trees based on 4 to 10 months old spring cycle leaves from fruit bearing terminals (Table 1).

Heinz and Olson (1970) found that there was no significant differences in leaf N content of young grape fruit trees (***Citrus paradise***) budded on 16 different rootstocks.

Sharples and Hilgeman (1972) showed that significant differences existed between cultivars within species, between species and between years. Navel orange leaves contained significantly more N (2.51 percent) than Valencia orange (2.43 percent) followed by Kinnow mandarin (2.49 percent). The statistical analysis indicated that N levels were not influenced by rootstocks. The analysis showed that more N was taken up by Valencia on Rough lemon than on Sour orange.

Table 1. Leaf nutrient standards of citrus based on sampling from fruit bearing terminals (Chapman, 1960)

Element	Deficient	Low	Satisfactory (or) optimum	High	Excess (more than)
			(In per cent dry matter of leaf)		
Nitrogen	0.60-1.90	1.90-2.10	2.20-2.70	2.80-3.50	>3.60
Phosphorus	<0.07	0.07-0.11	0.12-0.18	0.19-0.29	>0.30
Potassium	0.15-0.30	0.40-0.90	1.00-1.70	1.80-1.90	>2.00
Calcium	<2.00	2.00-2.90	3.00-6.00	6.10-6.90	>7.00
Magnesium	0.05-0.15	0.16-0.20	0.30-0.60	0.70-1.00	>1.00
Sulphur	0.05-0.13	0.14-0.19	0.20-0.30	0.40-0.49	>0.50
			(In ppm of dry matter of leaf)		
Copper	<4.0	4.10-5.00	5.10-15.00	15.00-20.00	>20.00
Iron	<40.0	40.00-60.00	60.00-150.00	>150	-
Manganese	5.00-20.00	21.00-24.00	25.00-100.00	100.00-200.00	300.00-1000.00
Zinc	4.00-15.00	15.00-24.00	25.00-100.00	110.00-200.00	>200.00

Castle and Krezdorn (1975) noted lower leaf N (2.07 percent) in Orlando tangelo on Cleopatra mandarin rootstock and higher N content (2.45 percent) on Rangpur lime rootstock.

La-banauskas and Bitters (1974) observed that N concentration in leaves from Sweet Orange on Rubidoux trifoliate rootstocks were substantially lower (2.25 percent) than in the leaves from scions on English small trifoliate rootstock (2.54 percent).

Heinz and Shull (1975) observed that the N concentration levels were highest in leaves of *Citrus paradisi* Macf from trees on Alemow (2.84 percent) and Swingle citrumelo (2.82 percent) and lowest with 'Precoce de Valence' Sweet orange (2.44 percent) and Sunki rootstock (2.49 percent).

Sharma *et al* (1977) reported higher leaf N content in sweet oranges on Troyer and Carrizo Citrange rootstock.

Mehrotra *et al* (1982) showed that nutritional status of Mosambi orange leaves indicate that N was in the low range in all the combinations except Mosambi / Rangapur lime (2.40 percent) and Mosambi / Pectinifera (2.41 percent) which was in the optimum range which may be due to the poor nutritional status of sandy loam soil on which they were grown.

Mehrotra *et al* (1983) showed that N level of Pineapple orange leaves on Jatti Khatti and Kharna Khatta rootstocks was in the low range (2.20 to 2.27 percent) during both the years under study. The N level on Troyer and Carrizo which was in the optimum level (2.48 percent) during the year 1975 fell down to deficient level (2.12 percent) during the subsequent year, which may be due to poor nutritional status of sandy loam soils on which they were grown.

Iyengar *et al* (1984) showed that carrizo Citrange, Citrumelo, Trifoliate oranges and Rangpur lime resulted in significantly higher leaf N contents than those on rootstocks, Rough lemon and Kodakithuli mandarin.

Chauhan *et al* (1984) showed that leaf N content of various citrus orchards at Haryana varied from 1.5 to 2.9 percent as against the optimum value in the range of 2.4 to 2.8 percent as suggested by Reuther *et al* (1950). The data further revealed that 61 percent of the orchards were in low range of nitrogen and 39 percent in medium range rootstock (2.49 per cent).

Misra *et al* (1989) observed that Pant Lemon-I plant on Jambheri rootstock showed maximum nitrogen content in leaves (2.22 per cent) and minimum on Rangpur lime (1.95 per cent).

Esmaeil Fallahi (1991) showed that leaf N in 'Orlando' trees on Palestine sweet lime was higher (2.68 per cent) than leaf N in those on Carrizo citrange which is in agreement with Castle and Krezdorn (1975) in Florida.

Misra and Ranvir Singh (1993) showed that leaf nitrogen content of *Citrus limon* burm was higher (2.19 per cent) in own rooted plants and minimum (1.72 per cent) in plants on cleopatra mandarin rootstock. In general, the leaf N was found in deficient range when compared with the standards of Embleton *et al* (1973).

2.3.2 Phosphorous

Castle and Krezdorn (1975) showed that there was no statistical difference between the mean P content of leaves from the different rootstocks for either year. Similar results were observed by Iyengar *et al* 1982; Mehrotra *et al* 1982; Mehrotra *et al* 1983 and Misra and Ranvir Singh 1993.

Iyengar *et al* (1984) showed that the effect of rootstocks on leaf P content was similar to that observed in the case of N. The two trifoliate oranges, Carrizo citrange and Citrumelo behaved similarly and resulted in higher leaf P content (0.165 per cent) than the others.

Anjaneyalu and Ravishankar (1984) showed that accumulation of P was not influenced by various rootstocks.

Chauhan *et al* (1984) showed that phosphorus level varied from 0.075 to 0.120 per cent and was found to be deficient in about 30 per cent of orchards when compared with the standard as suggested by Reuther *et al* (1950).

Suryanarayana Reddy and Swamy (1986) showed that the P content of Sweet orange var Sathgudi leaves was marginally optimum in P_1 (0.111 per cent) and P_2 (0.112 per cent) and greater than P_o (0.098 per cent).

Iyengar and Keshava murthy (1988) observed that in Italian lemon the mean Pdff in young leaves increased from 0.61 per cent 15 days after application of P fertilizer to reach a maximum of 9.92 per cent at the end of 60 days. In mature leaves it increased from 0.4 to 7.29 per cent at the end of 45 days. The greatest increase in Pdff however occured between the 15th and 30th day. The dwarfing rootstock trifoliate orange and its two hybrids (Carrizo citrange and Citrumelo) derived greater amount of P from the fertilizer than the vigorous rootstocks.

Misra *et al* (1989) reported the maximum P content (0.193 per cent) in the leaves of lemon plants on cleopatra mandarin which may be due to the minimum content of nitrogen (1.95 per cent) present in them.

2.3.3 Potassium

Smith *et al* (1949) reported that Rusk citrange and Cleopatra mandarin produced the lower amount of K in their scion leaves. Gaffar (1967) reported a higher leaf K content on Rangpur lime than on cleopatra mandarin in Sweet oranges.

Sharples and Hilgeman (1972) showed that potassium content differed between cultivars and years. In mandarins, values were similar and low (0.67 per cent) but in or-anges, K levels were outstandingly higher in navel oranges (1.25 per cent).

Labanauskas and Bitters (1974) reported that K concentration was significantly lower (0.98 per cent) in the leaves from trees on Benecke trifoliate rootstock than in leaves from trees on Sweet orange rootstock (1.16 per cent).

Orlando tangelo trees with highest leaf K content were those on rough lemon (2.08 per cent) and sweet lime (2.11 per cent) but lowest on trifoliate orange selections (1.43 per cent) (Castle and Krezdorn 1975). These differences were assumed to be primarily due to the differential ability of the rootstock to absorb water and nutrients due to physical differences between the root system.

Iyengar *et al* (1982) showed that the effects due to rootstocks on the mandarin leaf content of K were significant at both samplings. Leaves on Rangpur lime had the highest K content (1.3 per cent) during both seasons followed by Rough lemon scion leaves on Trifoliate orange and Troyer citrange had the lowest K content (0.6 per cent).

Mehrotra *et al* (1982) reported that K content generally ranged between high to excess range in the trees except Musambi on Pectinefera (1.25 to 1.50 per cent) where it was in the optimum range. Musambi on Jambheri and Jatti Khatti were having optimum K levels (1.59 to 1.62 per cent) during 1975 but the same were in the high range (1.84 to 1.95 per cent) during the next year. Mehrotra *et al* (1983) also reported that the pineapple orange trees on Kharna Khatta had high level of K (1.78 to 2.12 per cent) which was significantly more than the trees on other rootstocks.

Iyengar *et al* (1984) and Anjaneyalu and Ravishankar (1984) reported results similar to that made by Iyengar *et al* (1982).

Desai *et al* (1986) showed that K uptake was found to be increased with every increase in the dose of respective nutrient.

Misra *et al* (1989) reported the results similar to that made by Mehrotra *et al* (1982). Esmaeil *et al* (1991) showed that Orlando tangelo trees on Batangas mandarin had significantly higher leaf K (1.58 per cent) than those on citranges and other rootstocks.

Misra and Ranvir singh (1993) reported that leaf potassium content of plants on various rootstocks differed significantly and the maximum was observed in own rooted lemon plants (1.42 per cent) followed by Kodakithuli and Trifoliate orange rootstocks and the minimum (0.92 per cent) in plants on Troyer citrange rootstocks. This indicate that various rootstock combinations translocate potassium differently.

2.3.4 Calcium

Smith *et al* (1949) and Shannon and Zaphir (1958) have reported higher Ca content in sweet orange leaves on Rough lemon than on Trifoliate on Cleopatra mandarin. However others, Wallace *et al* (1952) Gallo *et al* (1960) and Gaffar (1967) have found higher leaf Ca content in Sweet orange leaves on Rangpur lime and Trifoliate orange than on Roughlemon.

Sharples and Hilgeman (1972) showed that Ca uptake between scions was significantly different but there was no consistent relationship to cultivars within or between species and the usual inverse relationship to K was absent. Rough lemon induced less Ca uptake than Sour orange in all scions.

Labanaskas and Bitters (1974) showed that Valencia orange leaves from trees on English small trifoliate had a significantly lower Ca concentration (4.33 per cent) than the leaves from trees on Sweet orange (5.25 per cent).

Castle and Krezdorn (1975) reported that rootstock influenced the Orlando tangelo leaf Ca content more than any other nutrient studied and trees on Cleopatra mandarin, Sweet orange, Sour orange and Troyer citrange had the highest leaf Ca levels both years.

Mehrotra *et al* (1982) reported that Ca content of Musambi Sweet orange scion leaves was not affected significantly by any of the rootstocks. However, it was optimum on all the rootstocks except that Mosambi on Kharnakhatta and Rangpur lime had slightly low Ca status during one year. Similar results were reported by Mehrotra *et al* (1983) in orange leaves and Misra *et al* (1989) and Misra and Ranvir singh (1993) in lemon leaves.

Iyengar *et al* (1984) reported that lemon resulted in significantly higher leaf Ca content on Rough lemon (8.67 per cent) than all the other rootstocks. The Citranges, Citrumelo and Trifoliate oranges resulted in much lower leaf Ca contents which were significantly lower (6.73 to 6.98 per cent) than that on Rough lemon and the two mandarins (Cleopatra and Kodakithuli). Early work by Hass (1948) with Eureka lemon as scions had also indicated that rough lemon to be superior to Cleopatra mandarin in the uptake of Ca. However, Jones *et al* (1957) using Eureka lemon have reported Rangpur lime to be superior to Rough lemon and Cleopatra mandarin.

Anjeneyalu and Ravishankar (1984) showed that Satsuma mandarin leaves on Cleopatra mandarin recorded significantly the highest leaf Ca content (2.49 per cent) than all other rootstocks. Trifoliate orange recorded significantly the lowest leaf Ca contents (2.17 per cent) than Cleopatra mandarin and was on par with the rest. Similar observations have been recorded in Coorg and Kinnow mandarin scions (Iyengar *et al* 1982). On the contrary in sweet oranges, Gallo *et al* (1960) and Gaffar (1967) observed higher leaf Ca content on Rangpur lime and Trifoliate orange. Esmaeil *et al* (1991) reported that Orlando tangelo trees on savage citrange had significantly higher leaf Ca than those on other rootstocks.

2.3.5 Magnesium

Cooper and Gorton (1952) have reported higher leaf Mg content on Rough lemon and Rangpur lime than on Cleopatra mandarin under Florida conditions and in Western India by Gaffar (1967). Jones *et al* (1957) have reported higher leaf Mg content in Sweet orange leaves on cleopatra mandarin than on Rough lemon and Rangpur lime under Californian conditions of soil and climate. Similar results were reported in the leaves of mandarins. (Iyengar *et al* (1982); Iyengar *et al* (1984). This suggests that in addition to scion cultivars, soil and/or climatic factors may also influence the uptake of Mg by rootstocks to a great extent.

Sharples and Hilgeman (1972), Labanauskas and Bitters (1974), Misra *et al* (1989) and Misra and Ranvir Singh (1993) reported that the effect of rootstocks on leaf Mg were not statistically different.

Castle and Krezdorn (1975) reported that the Orlando tangelo leaf Mg content was generally highest in trees on Carrizo and Troyer citrange (0.81 per cent) and ranged to be the lowest values of 0.52 and 0.64 per cent from trees on sweet lime in 1970 and 1971 respectively.

Mehrotra *et al* (1982) reported that Musambi on pectinifera accuamulated Mg to an optimum level (0.25 to 0.30 per cent). Trees on Kharna khatta had minimum Mg content which was in the deficient range (0.11 to 0.16 per cent). High levels of K along with low N seemed to have depressed the Mg content in leaves.

Mehrotra *et al* (1983) have reported that the Mg level of the Pineapple orange trees on Kharna Khatta rootstock was the least (0.12 to 0.16 per cent) of all during both the years and the Mg content on Troyer and Carrizo were although more than Jatti Khatti and Kharna Khatta but was in the low range (0.12 to 0.18 per cent).

Anjaneyalu and Ravishankar (1984) showed that Satsuma mandarin leaves on Trifoliate orange recorded significantly the highest leaf Mg content (0.322 per cent) than the rest while Rangpur lime recorded significantly the lowest leaf Mg content (0.275 per cent) and was on par with others.

Esmaeil *et al* (1991) showed that leaf Mg concentrations in the trees on most rootstocks were negatively correlated to their K concentration. Therefore trees on Batangas mandarin and Ichang pummelo had lower leaf Mg (0.45 per cent) while those on Palestine sweet lime had higher leaf Mg (0.58 per cent) than those on most other rootstocks. However leaves from trees on Carrizo showed a high level of leaf Mg (0.62 per cent) inspite of their moderately high leaf K (1.23 per cent).

2.3.6 Sulphur

Iyengar *et al* (1982) reported that the S content of mandarin leaves was higher on Trifoliate orange and 'Carrizo' and 'Troyer' (0.39 per cent) citranges than on the other rootstocks in both flushes.

Iyengar *et al* (1984) showed that rootstocks did not result in any significant difference in the sulphate-S content of leaves.

2.3.7 Micronutrients

2.3.7.1 Zinc. Zinc content did not vary significantly under the influence of different rootstocks in the leaves of sweet orange (Chundawat *et al* 1981), in the leaves of satsuma mandarin (Anjaneyalu and Ravishankar 1984) and in Orlando tangelo leaves (Esmaeil Fallahi *et al* 1991), pectinifera was inefficient rootstock in Zn uptake with all the sion cultivars. Values of leaf Zn content of sions on other rootstocks fell in optimum range i.e 25-49 ppm.

Zinc level was found to be in the deficient range in all the trees of sweet orange (6-14 ppm) and Jaffa orange on different rootstocks (Mehrotra *et al* 1982; Mehrotra *et al* 1984). This low level of Zn may be due to the antagonistic effect of Cu content.

Iyengar *et al* (1984) reported that vigorous rootstocks Rough lemon, Cleopatra mandarin and Rangpur lime resulted in accumulation of more Zn in scion leaves than the dwarfing rootstocks like Tritofoliate oranges, Citranges and Citrumelo.

Misra *et al* (1989) reported that maximum Zn content (40 ppm) of lemon leaves was observed in plants on Jambheri rootstock which was at par with Sour orange, Troyer citrange and minimum (25 ppm) on Trifoliate orange rootstocks during 1982. In 1983, maximum Zn content (45 ppm) was observed in plants on Bhadri lemon and minimum (28.33) on cleopatra mandarin and Troyer citrange rootstocks. Similar observations were reported by Misra and Rannvir Singh (1993).

2.3.7.2 Iron. Valencia orange leaves from trees on Rubidoux trifoliate rootstock had a lower Fe concentration (54 ppm) than did leaves from trees on English small trifoliate (67 ppm) and Benecke trifoliate (64) rootstocks (Labanauskas and Bitters (1974).

Rootstocks showed no significant differences in Fe uptake (Chundawat *et al* 1981; Mehrotra *et al* 1982: Anjaneyalu and Ravishankar 1984 and Misra and Ranvir Singh 1993). The leaf Fe content of sweet oranges varied from 95-270 ppm which was well above the optimum range (50-120) thereby meaning that there is no restriction in selecting the rootstocks with respect to Fe uptake.

Vinay Singh (1982) reported that Fe status of sweet orange leaves at all the locations was adequate for growth of plants.

Highest Fe content in Coorg mandarin leaves was found on Trifoliate-GHL (231 ppm) rootstock and lowest on Rangpur lime rootstock (180 ppm) (Nache Gowda *et al* 1982). Fair child trees on Macrophylla had higher level of Fe (Esmaeil and Ross 1992).

Maximum Fe content (357.13 ppm) was noted in leaves of lemon from the plants on Karna Khatta rootstocks and minimum (130.94) on Jambheri rootstock (Misra *et al* 1989).

Orlando tangelo trees on *C. macrophylla* and Ichang pummelo had significantly higher leaf Fe (57 to 59 ppm) than those on all citranges and other rootstocks (Esmail Fallahi ***et al*** 1991).

2.3.7.3 Copper. Heinz and Shull (1975) showed that Chinese box-orange accumulated the highest leaf Cu content (10 ppm) but no other rootstock differed significantly.

Rootstocks did not result in any significant difference in the Cu content in leaves of sweet orange (Chundawat *et al* 1981); Coorg Mandarin (Nache Gowda *et al* 1982); Satsuma mandarin (Anjaneyalu and Ravishankar 1984; Iyengar *et al* 1984) lemon plants (Misra and Ranvir Singh 1993).

Leaf content of Cu in Coorg mandarin was more on Troyer citrange rootstock (40 ppm) (Nache Gowda *et al* 1982) Cu is known to depress the Zn level in leaves (Smith 1966; Mehrotra *et al* 1984).

Maximum Cu (10.3 ppm) was observed in lemon plants on Trifoliate orange and minimum (3.6 ppm) in plants on Cleopatra mandarin rootstocks. The maximum Cu content in leaves of plants on Trifoliate orange may be due to minimum content of Mn (36.6 ppm) in its leaves as both the elements have antagonistic effect in leaves of citrus (Misra *et al* 1989).

Esmaeil Fallahi *et al* (1991) reported that Orlando tangelo leaves from trees on Carrizo citrange had significantly higher leaf Cu (13.59 ppm) while those on Palestine sweet lime had lower leaf Cu (6.92) than those on other rootstocks.

2.3.7.4 Manganese. Sharples and Hilgeman (1972) reported that rough lemon rootstock significantly improved the Mn uptake compared to sour orange.

Different rootstocks did not result in any significant differences on Valencia orange trees (Labanauskas and Bitters 1975) and on Satsuma mandarin trees (Anjaneyalu and Ravishankar 1984) and lemon plants (Misra and Ranvir Singh 1993).

Mn in the leaves was significantly influenced by the rootstocks which varied from 35 to 100 ppm. Among the rootstocks, Jatti Khatti was found to be most efficient for sweet oranges (Chundawat *et al* 1981; Mchrotra *et al* 1982; Mehrotra *et al* 1983). Citranges (Carrizo and Troyer) and Citrumello rootstocks reported lower Mn content of the scion leaves (Mehrotra *et al* 1982; Nache Gowda *et al*1982; Iyengar *et al* 1982; Mehrotra *et al* 1983; Iyengar *et al* 1984; Misra *et al* 1989 and Esmacil Fallahi *et al* 1991).

Mn level in the Sweet orange leaves was found to be optimum (27-38 ppm) in all the rootstock combinations (Mehrotra *et al* 1982) and from low to optimum in Jaffa orange leaves (Mehrotra *et al* 1984). Mandarins on Cleopatra mandarin showed highest leaf Mn content (89 ppm) (Iyengar ***et al*** 1982), Coorg mandarin leaves on Trifoliate-GHL rootstock had highest content of Mn (61 ppm) (Nache Gowda *et al* 1982) and Trifoliate oranges resulted in higher leaf Mn content (102 ppm) (Iyengar *et al* 1984).

Orlando tangelo trees (Esmaeil Fallahi *et al* 1991) and Fair child trees (Esmaeil and Ross 1992) on Macrophylla rootstock had significantly higher levels of leaf Mn.

2.3.7.5 Boron. Heinz and Olson (1970) reported that boron accumulated to toxic level (264 ppm) in the leaves of trees on C 59.24 (Rangpur lime x Trifoliate orange) rootstock, and the lowest B content (100 ppm) was found in the leaves of trees on Severenia buxifolia rootstock.

Embleton *et al* (1973) showed that Alemow, Severenia buxifolia and Sour orange resulted in lower boron concentrations in Sion leaves than most other rootstocks.

Labanausakas and Bitters (1974) have shown that substantially lower concentration of boron (72 ppm) were found in the Valencia orange leaves from trees on Sweet orange rootstocks than in the leaves from trees on Trifoliate rootstock (92 to 111 ppm).

Heinz and Shull (1975) showed that leaf B concentrations were highest for trees on Gombru lemon (233 ppm) and Vangsay rootstocks (230) and lowest for trees on Chinese box-orange, Savage citrange and Sunki rootstocks (146 to 166 ppm).

Boron varied from high (220 ppm) to excess (288 ppm) range in the leaves of Mosambi sweet oranges grown on different rootstocks and the high B content was associated with low Ca (Mehrotra *et al* 1982; Mehrotra *et al* 1983 and Mehrotra *et al* 1984.

2.4 ROOTSTOCK EFFCT ON THE FRUIT QUALITY AND YIELD

2.4.1 Fruit Quality Parameters

2.4.1.1 Fruit weight. Chohan *et al* (1986) reported that the fruit weight of Valencia cultivan of sweeb orange was not influenced significantly by different rootstocks.

Bal and Chohan (1987) showed that the maximum fruit weight of kinnow mandarin was recorded on Jatti Khatli followed by Kharna Khatta which can be attributed to different agro climatic conditions.

Mustafa and Reddy (1990) reported that the highest mean fruit weight of Mosambi Sweet orange was obtained on Rough lemon.

Significantly highest fruit weight (152.0 g) was measured from Nagpur mandarin on Rangpur lime rootstock while for kinnow mandarin, the effect was at par among the rootstocks (Ghosh and Narayan Chattopadhyay 1993).

2.4.1.2 Fruit size. Fallahi *et al* (1989) showed that the fruits of Redblush grape fruit trees on Carrizo and Troyer citranges were largest (374 to 381g).

Tuzcu *et al* (1994b) showed that Washington Navel orange on *C.volkameriana* rootstock gave the large fruits.

2.4.1.3 Peel thickness. Bal and Chohan (1987) showed that not much differences in the peel as affected by different rootstocks were observed.

The rind weight of mandarin oranges ranged narrowly from 20.67 g on Kodakithuli stock to 21.92 g in Troyer citrange. The rootstocks differed significantly in rind thickenss which ranged from 0.24 cm in. Troyer citrange to 0.31 cm in trifoliate orange.

Troyer citrange produced minimum peel content (25.6 per cent) for Hamlin cv sweet oranges (Chohan *et al* 1988(a))

Esmaeil Fallahi *et al* (1989) had reported that Red blush grape fruit trees on Savage citranges had thinnest peel (7.4 mm) and on Taiwanica, Macrophylla. Sour orange and Khangra had significantly thicker peel (7.9 to 8.1 mm).

Harish Kumar *et al* (1993b) showed that the trees of sweet orannge Valencia late cultivar on Troyer and Carrizo citranges produced significantly less peel percentage.

Tuzcu *et al* (1994b) showed that Washington Navel orange on *C.volkameriana* rootstock gave the fruits with thick rind.

2.4.1.4 Juice content. Maximum percentage of volume of juice per fruit of Blood Red oranges was found on Triofoliate orange (Bhullar and Nauriyal 1975).

Coorg mandarin on Kharna Khatta gave fruits with low juice and TSS (Aiyappa *et al* 1976).

Chohan *et al* (1986) revealed that the juice content of Valencia late cultivar of sweet orange was not influenced significantly by different rootstocks.

Thornton and Dimsey (1987) showed that lower fruit juice content of Valenia orange on Rough lemon and Rangpur rootstocks resulted in lower TSS.

Esmaeil Fallahi *et al* (1989) has reported that fruits from Redblush grape fruit trees on Carrizo citrange had significantly higher volume of juice per fruit (171 ml) than those on Sour orange and *C. taiwanica.* Percent juice in fruit from trees on Palestine Sweet lime and Macrophylla was significantly higher (47.2 per cent).

Mustafa and Reddy (1990) reported that the highest juice percentage of Mosambi sweet orange was obtained on Rangpur lime. Harish Kumar *et al* (1993b) showed that the sweet orange Valencia late cultivar on Carrizo rootstock produced significantly maximum juice content.

Tuzcu ***et al*** (1994a) showed that juice content of Kutdiken lemon was not affected by rootstocks.

Washington Navel orange on *C.volkameriana* rootstock gave the large fruits with low juice content (Tuzcu *et al* 1994b).

2.4.1.5 Seed number. The number of seeds was found less (9.2) in the mandarin orange fruits from Rangpur lime rootstocks (Ghosh and Narayan Chattopadhyay 1993).

The seed content (number) in different rootstocks ranged from 16.83 (Rangpur lime) to 21.83 (Cleopatra mandarin) for mandarin oranges (Vijay Kumar *et al* 1989).

2.4.1.6 Acidity. Maximum acidity of Blood Red oranges was found on Trifoliate orange rootstocks (Bhullar and Nauriyal 1975).

Acidity of Valencia late cultivar of sweet orange was not influenced significantly by different rootstocks (Chohan *et al* 1986) Clementine commune recorded the lowest fruit acidity (0.89 per cent) on Alemow rootstock (Recupero and Russio 1988).

Acidity in the mandarin orange fruits ranged from 0.15 to 0.20 per cent in different rootstocks and was lowest on trifoliate orange rootstocks and highest onTroyer ctrange (Vijay Kumar *et al* 1989).

Highest percentage of acidity of Mosambi sweet oranges was obtained on Kodaikithuli rootstock (Mustafa and Reddy 1990).

Acidity of mandarin oranges was less (0.58 per cent) on Rangpurlime rootstock than on Rough lemon (0.60) (Ghosh and Narayan Chattopadhyay 1993).

2.4.1.7 Ascorbic acid. Coorg mandarin on Kharka Khatta gave fruits with high acid (Aiyappa *et al* 1976) Hamlin cv Sweet orange produced the maximum vitamin C content (31.4 mg 100^{-1} ml juice) on Troyer citrange rootstock.

Ascorbic acid content of mandarin oranges ranged from 61.53 mg per 100 ml of juice. It was highest on Kodaikithuli and lowest on Trifoliate orange and Troyer citrange (Vijay Kumar *et al* 1989).

Mosambi sweet oranges recorded highest ascorbic acid content with Rough lemon rootstock (Mustafa and Reddy 1990).

Vitamin C content of the Mandarin orange fruits was more (35.41 mg 100^{-1} ml juice) on Rangpurlime than on Rough lemon (Ghosh and Narayan chattopadhyoya 1993).

2.4.1.8 Sugars. Thornton and Dimsey (1987) showed that the lower sugar levels of Valencia orange on Rough lemon and Rangpur rootstocks resulted in lower total soluble solids.

Total sugar content of the mandarin orange fruits was more on (10.20 per cent) on Rangpur lime than on Rough lemon rootstocks (9.60 per cent) (Ghosh and Narayan Chattopadhyay 1993).

2.4.1.9 Rag. Not much differences in rag content of the fruits as affected by different rootstocks was observed in the case of Kinnow mandarin (Bal and Chohan 1987).

2.4.1.10 Total soluble solids. Highest percentage of TSS of Blood Red oranges was found on Trifoliate orange rootstock (Bhullar and Nauriyal 1975).

Coorg mandarin on Kharna Khatta gave fruits with low TSS (Aiyappa *et al* 1976).

Maximum total soluble solids (10.1 to 10.4 per cent) (TSS) was noted in mandarin fruits on *C.pectinifera* during both the years which was significantly higher than those on other rootstocks (Mehrotra *et al* 1982). Maximum TSS (9.0 to 9.2 per cent) in Pineapple orange was produced on Troyer and Carrizo citranges Mehrotra *et al* (1983). Total solbule solids per cent of Jaffa oranges was significantly higher on Troyer and Rangpur lime rootstocks (Mehrotra *et al* 1984).

Maximum TSS of Valencia orange cultivar of sweet oranges was found on Rangpur lime rootstocks (Chohan *et al* 1986) and on Troyer citrange (8.6 per cent) for Hamlin cv sweet orange (Chohan *et al* 1988).

Red blush grape fruit trees on Savage citranges had highest levels of TSS (10.6 per cent) content and soluble solids (Esmaeil Fallahi *et al* 1989).

Highest TSS of Mosambi sweet orange was obtained on Pomeroy-trifoliate (Mustafa and Reddy 1990).

Carrizo rootstock significantly produced more TSS (9.4 per cent) in fruit juice of sweet orange valencia late cultivar (Harish Kumar *et al* 1993b).

Total soluble solids of mandarin oranges was more (12.6 per cent) in Rangpur lime than in Rough lemon rootstocks (12.0) (Ghosh and Narayan Chattopadhyay 1993).

2.4.1.11 Fruit number. Mehrotra *et al* (1982) reported that the number of fruits produced by Musambi trees on various rootstocks did not differ significantly. However, the maximum number of fruits (211.7 to 218.0) was produced by trees budded on Jatti Khatti rootstocks during both the years. Similar results were reported by Mehrotra *et al* (1983).

Mehrotra *et al* (1984) showed that Jaffa orange produced maximum number of fruits on Citrumelo and lowest on Rangpur lime rootstocks.

Mustafa and Reddy (1990) reported that the highest number of fruits per tree of Mosambi sweet oranges was obtained on Rangpur lime rootstock.

Maximum number of fruits (160 to 175) was counted from Mandarin orange trees budded on Rangpur lime rootstock for both Nagpur and Kinnow mandarin but the result was not statistically significant (Ghosh and Narayan Chattopadhyay, 1993).

2.4.2 Fruit Yield and Quality

Mehrotra *et al* (1983) reported that in a rootstock trial for pineapple orange with four rootstocks, different rootstocks did not significantly affect the fruit yield (in number) but fruit quality was improved on some rootstocks.

Bal and Chohan (1987) reported that not much differences in the fruit quality of Kinnow mandarins as affected by different rootstocks were observed.

Mean yields were highest for trees of *Citrus paradisi* Macf on Carrizo closely followed by Troyer citrange and lowest on kharna khatta. Fruit quality was also best on the two citrange rootstocks (Chohan *et al* 1988b).

According to Sharma and Ranvir Singh (1989), Jambheri was the maximum yielder and Rangpur lime was the poorest yielder among all the rootstocks tried for Pant Lemon-I.

Montervede (1989) showed that yield of Valencia orange were highest on *C.volkameriana*, Rough lemon and Carrizo citrange and lowest on Rangpur lime.

Mustafa and Reddy (1990) reported that the highest mean yield per Mosambi sweet orange trees was obtained on Rangpur lime rootstock.

Vijaykumar *et al* (1990) reported that the highest cumulative yield by weight of Mandarin oranges were obtained on Rangpur lime followed by Rough lemon.

Survival of Sweet orange Valencia late cultivar was highest on Jatti khatti and mean yield was almost in equal range on Jatti khatti, Kharna khatta and Carrizo rootstock. (Harish Kumar *et al* 1993b).

Ghosh and Narayan Chattopadhyay (1993) reported that for Mandarin oranges, Rough lemon was the most vigorous rootstock while Rangpur lime supported a higher fruit yield and quality.

Citrus volkameriana gave the highest yield for all mandarin cultivars but citrange roostocks produced high quality fruits (Akgul and Tuzcu 1993). But *C.volkameriana* negatively affected the fruit yield and quality for Red blush grape fruit (Tuzcu *et al* 1994b).

2.4.3 Rootstocks

Chohan *et al* (1988a) showed that for Hamlin sweet oranges, Jatti khatti proved to be the best rootstock followed by Cleopatra. Not much significant differences were observed with respect to physico-chemical parameters of fruit amongst different rootstocks.

Carrizo citrange followed by Rough lemon and then Troyer citrange are reported as best rootstocks for sweet orange cv Mosambi (Ramkumar and Gangapathy 1992).

Fruit quality attributes of different sweet orange cultivars on different rootstocks were not affected significantly except in case of Mosambi and Jaffa (Harish Kumar *et al* 1993(a))

Harish Kumar *et al* (1993a) proved that for Mosambi cultivar of sweet orange, Pectinifera proved to be the best rootstock; Jatti khatti for Pine apple and Jaffa cultivars; Cleopatra for Blood red cultivars and Kharna khatta for Valencia late cultivar of sweet oranges. But Jatti khatti proved to be the most invigorating rootstock for Blood Red Sweet Orange (Bhullar and Nauriyal 1975).

2.5 FACTORS AFFECTING MINERAL COMPOSITION OF LEAVES

2.5.1 Fertilizer Application

It was reported by many workers that the levels of a given element in the fertilizer usually reflected in the concentration of these elements in the leaves (Smith 1966; Embleton *et al* 1973).

Glonti (1970) observed that N application increased the N content and also P and K contents of orange leaves.

Rees and Koo (1975) stated that the increased N application to the plant resulted in higher leaf N and Mg contents but lower P and K level. Keily *et al* (1972) found that increasing rate of P application raised leaf P and N level. K application increased leaf K and Cu but reduced the Ca content of the leaves.

High levels of K along with N seemed to have depressed the Mg content in the Mosambi sweet orange leaves (Mehrotra *et al* 1982). Similar results were reported in Pine apple orange leaves (Mehrotra *et al* 1983).

Brar *et al* (1982) observed a positive correlation between the leaf P and Zn contents. Basso *et al* (1983) observed a positive correlation between leaf P and K contents. Murthy *et al* (1983) reported that potassium application increased the leaf K but phosphorus application decreased leaf K.

Application of higher levels of N decreased the pH and exchangeable K significantly in all the trials. Application of P and K at higher levels significantly increased the available P and exchangeable K respectively. Nitrogen application at N_1 and N_2 levels significantly increased leaf N in Coorg Mandarin on Rough lemon and decreased leaf K in Coorgmandarin on Rangpur lime (Murthy *et al* 1983).

Increase in the N, P and K content of sweet orange leaves was evident with every increase in the dose of respective nutrient. N was found to be antagonistic to P and K uptake and synergistic to Ca and Mg uptake. Phosphorus was antagonistic to N and K uptake and synergistic to Ca uptake. Potassium exhibited antagonism towards P, Ca and Mg and synergism towards N uptake (Desai *et al* 1986).

Before manuring N, P and K contents of the sweet orange cv sathgudi leaves were not significantly different among the trees and trees were deficient in N (1.36 to 1.45 per cent), P (0.076 to 0.082 per cent) and optimum level in K content (0.082 to 0.087 per cent). After manuring the N and P content increased to optimum (2.33 to 2.49) and (0.111 to 0.112) respectively and K content rose to high level (1.19 to 1.25). The leaf N content was influenced by applied P and K levels (Suryanarayana Reddy and Swamy 1986).

Misra *et al* (1989) reported that the maximum content of phosphorus (0.154 per cent) in leaves of the lemon plants on Cleopatra mandarin may be due to the minimum content of nitrogen (1.95 per cent) present in them.

2.5.2 Rootstocks

The differential responses of the rootstock to absorb and accumulate N could be mainly due to the selectivity of the rootstock species to absorb N differentially. Satsuma mandarin leaves on Cleopatra had higher leaf Ca content but lower leaf K content while Trifoliate orange which had lower leaf Ca content recorded higher leaf K content thus indicating a trend of antagonism for the accumulation of Ca and K ions. In addition to scion cultivars, soil and/or climatic factors may also influence the uptake of Mg by rootstocks to a great extent (Anjaneyalu and Ravishankar 1984).

Studies using ^{32}P labelled fertilizer has shown that the dwarfing rootstock trifoliate orange and its two hybrids Carrizo and Citrumelo are more efficient in the absorption of fertilizer P than those vigorous rootstocks like Rangpur lime and Cleopatra mandarin (Iyengar and Keshava Murthy 1988).

2.5.3 Crop load

Milella *et al* (1968) reported that as the fruit develops, it competes for nutrients with leaves, thereby nutrients move to fruits from the nearby leaves. The same was reported by several workers (Deidda and Viridis 1969; Ortuno *et al* 1970; Gallo *et al* 1977; Patange and Patil 1981; Raciti 1981; Intriglilo 1985 and Zhuang *et al* 1985).

Lesser amount of P and K in the leaf sample from healthy trees might be due to the fact that trees were bearing fruits at the time of leaf sampling and higher amounts of those nutrients were utilised in fruit development process (Ahlawati *et al* 1982).

2.6 LEAF MINERAL COMPOSITION IN RELATION TO YIELD AND QUALITY OF CITRUS

According to Oches *et al* (1961) the nitrogen was referred as 'balance wheel' of citrus nutrition because of the fact that the efficiency of other nutrients was based on it.

Ishihara (1976) found that optimum leaf N content of Satsuma orange was within the range of 2.8 to 3.0 per cent.

Good correlations between leaf N content and yield of oranges have been reported by many workers (Smith 1969; Jones *et al* 1970; Liu *et al* 1985; Vijaysankar Reddy 1989) while Okada (1983) noticed inconsistent correlation between leaf N and fruit yield of oranges. Dhillon and Dhatt (1988) found that a positive non-significant correlation between leaf N and fruit yield in both healthy and declining kinnow trees.

Calvert (1970) Koo *et al* (1974) reported that an increase in leaf N level led to a reduction in acidity of fruit juice.

Embleton *et al* (1980) found that an increase of leaf N led to a reduction in fruit size, percentage of juice, ascorbic acid content of juice and an increase in peel thickness.

N content in the leaf was directly related to fruit size, weight and number of fruits, juice content and skin thickness (Marchal 1984; Vijayasankar Reddy 1989 and Venkataramanaiah 1993).

Embleton *et al* (1971) observed that too much or too little P in the orange tree was associated with reduced yield and obtained highest yields when the leaf P content was between 0.130 to 0.165 per cent.

Moss (1972) stated that high leaf P was associated with high juice content, low acidity and thin peel in Washington navel orange.

Takidze (1972) observed a direct correlation between leaf P content and yield of sweet orange and highest yields occurred when leaf P content was 0.2 per cent.

Embleton *et al* (1973a) reported a negative correlation between leaf P and fruit size, quality and vitamin C content of the orange juice. However, he found a positive correlation between leaf P and percentage of juice in the fruit.

Ghosh *et al* (1981) found a positive correlation between leaf P status and fruit yield of citrus.

Dhillon and Dhatt (1988) and Venkataramanaiah (1993) found that foliar leaf P showed the positive and significant correlation with healthy but non-significant effect on yield of declining kinnow plants.

Smith and Rasmussen (1961) found that a leaf K content of 0.9 per cent was adequate to maintain full production potential of sweet orange.

Embleton *et al* (1973a) observed that increased K content of leaf was associated with increase in acidity and vitamin C content of the orange juice.

According to Coetzee (1980) normal leaf K level was between 0.8 to 1.5 per cent varying with different cultivars and the critical level was about 0.7 to 0.8 per cent.

Raciti and Scuderi (1980) found that the acid content of the fruit juice was positively correlated with leaf K and leaf K was negatively correlated with leaf Ca.

Liu *et al* (1985) reported a negative correlation between the leaf K content and yield of orange.

Vijaysankar Reddy (1989) and Venkataramanaiah (1993) reported a positive and non-significant correlation between leaf K content and yield of oranges.

Kiely *et al* (1972) reported a higher fruit weight and peel thickness to the higher Ca in soils.

Embleton *et al* (1967) showed that ascorbic acid content decreased with increased doses of N but it increased with increased doses of K.

Munshi *et al* (1979) reported that acid content of sweet orange juice increased with low N, P and high K and Mg while low lime concretions decreased it.

Hossain *et al* (1985) found that 12 to 13 year old healthy mandarin orange plants produced 65.3 kg fruits per plant when leaf N, P and K contents varied between 1.95 and 2.10, 0.09 and 0.12 and 0.9 and 1.03 per cent respectively. While Zhuang *et al* (1985) observed that the N, P, K, Ca, Mg ratio in the leaves of typical high yielding orchards was 1:0.05:0.43:0.97:0.10 and they suggested that leaf N, P, K, Ca and Mg values should be between 2.7 and 3.3, 0.12 and 0.15, 1.0 and 1.8, 2.3 and 2.7 and 0.25 and 0.38 per cent respectively for getting high yields of orange.

According to Desai *et al* (1986) the fruit weight of sweet oranges was significantly increased by N and K. Productivity as evidenced by number of fruits and weight, at harvest and juice recovery was improved with N, P and K applications. Vitamin C and TSS revealed better trend with increased K application and acidity was increased with N application and decreased with P and K application.

The total yield both in number and weight of sweet orange fruits was significantly higher in treatments receiving N and P but showed no response to the potash levels. Similarly, fruit weight, percentage of juice, TSS and citric acid tended to increase with increase in nitrogen level (Suryanarayana Reddy and Swamy 1986).

Dhillon and Dhatt (1988) observed that the fruit yield was significantly higher in the healthy trees (622 fruits per tree) as compared with declined trees (233 fruits per tree). They also found that positive correlation between foliar N, P, K and fruit yield in both healthy and declined Kinnow trees.

Chahil (1988) recorded the fruit yield from 420 to 750 fruits per tree in survey of Kinnow orchards.

Vijaysankar Reddy (1989) observed that the fruit yield (number and weight of fruits) was positively and significantly correlated with leaf N and P.

Ghosh (1990) revealed that a significant improvement on fruit production (number and weight) was obtained by treatment with N (500g per plant per year), P at lower level (100g per plant) and K at highest level (400g per plant). The highest percentage of TSS and total sugars were recorded in the fruits treated with 500g N and 400 g.K. P had no significant effect in this respect.

2.7 EFFECT OF FERTILIZER APPLICATION ON THE FRUIT YIELD AND QUALITY

Citrus crop requires generous supply of nutrients not only for the development of vegetative structures, flowers and fruits but also to give a regular harvest of high quality fruits (Sadhu 1988).

2.7.1 Nitrogen

Reuther and Smith (1952), Dhillon *et al* (1961), Suryanarayana Reddy and Swamy (1986) and Mann and Sandhu (1988) reported that vitamin C content of fruit juice decreased with increased dose of nitrogen.

Dhillon *et al* (1961), Aso and Dastur (1970) Reese and Koo (1975) and Suryanarayana Reddy and Swamy (1986) reported that N application increased the TSS, TSS/acid ratio and sugar content of sweet orange fruit juice.

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Significant increase in fruit yield following N application has been demonstrated by several workers (Aso and Dastur 1970; Govind and Prasad 1976; Shawky *et al* 1979; Shamasundaram *et al* 1984; Suryanarayana Reddy and Swamy 1986 and Vijayasankar Reddy 1989).

Increase in rind thickness following the N application has been demonstrated by several investigators (Azzony *et al* 1970; Chapman 1982; Mann and Sandhu 1988; Vijaysankar Reddy 1989).

2.7.2 Phosphorus

Numerous studies showed that P fertilization affected the fruit quality to a great extent depending on the type of citrus fruit and levels of P used. Increased fruit size with P application was shown by Rossel t *et al* (1962) and Suzuki *et al* 1977 in oranges.

P application increased the percentage of juice in the oranges (Smith *et al*1963, Moss 1972 and Gardener and Rath 1983). Ascorbic acid content in the orange juice was lowered consistently by P application (Smith *et al* 1963; Bar-Akiva *et al* 1968).

Gardner and Rath (1983) reported that in Campbell valencia orange, annual application of P_2O_5 at 250g per tree increased the yield and improved quality by increasing solid/acid ratio, percent juice content and decreasing peel thickness.

2.7.3 Potassium

Embleton *et al* (1967) and Weir *et al* (1978) found that K application increased the juice percentage. Koo and Reese (1971) and Embleton *et al* (1973) showed increasing trend in total soluble solids of sweet orange due to K application. While no significant effect of K on total soluble solids was evident from the works of Hilgeman *et al* (1976).

The direct relationship between K application and fruit size has been demonstrated by several investigations. (Keily ***et al*** 1972; Rees and Koo 1975; Chapman 1982).

Tsotsonava and Marshaniya (1973) observed that application of K fertilizer resulted in 11-34 per cent increase in yield of Satsuma orange compared with NP treatment only.

Combined application of fertilizers (NPK, NK and PK) was found in many cases to help in obtaining higher fruit yields than with the application of single element (Weir *et al* 1978).

Shamasundaram *et al* (1984) observed no significant relationship of applied P or K with yield.

Misra *et al* (1985) reported that higher levels of K from 200-600g per tree was found to promote growth and yield in mandarin orange.

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

A rootstock trial on Sathgudi Sweet Orange was laid out in the year 1983 at Citrus Improvement project, Tirupati. Studies were conducted during the year 1996 on this trial to evaluate the relative efficiency of different rootstocks on the nutrient absorption, translocation and the performance of sweet orange. The site of experimentation is located at an altitude of 182.9m above Mean sea level at 13° North latitude and 79° East longitude.

3.1 MATERIALS

The following six rootstocks were used for Sathgudi Sweet Orange (*Citrus sinensis* (L) Osbeck).

a. Sathgudi
b. Rangpur lime
c. Troyer citrange
d. Cleopatra mandarin
e. Jambheri
f. Trifoliate orange

3.2 EXPERIMENTAL DESIGN

The trial was laid out in a Randomized Block Design with 6 treatments and 4 replications with 6 trees per replication. Studies were conducted on these 12 year old trees at different intervals of time i.e before fertilization of the field, after fertilization and at harvest of fruits.

3.3 CULTURAL PRACTICES

The following manures and fertilizers are appliled per tree per annum.

Manures and Fertilizers applied	Kg/tree
FYM	40
Castor cake	9
Urea	1.63
SSP	2.2
MOP	0.69

3.4 COLLECTION AND PROCESSING OF SOIL SAMPLES

The soil samples were collected in each plot from two different depths i.e., 0-15 cm and 15-30 cm. Six soil samples of each replication were mixed according to their respective depths and made into composite sample. For each replication, two composite samples were obtained for two depths i.e. 0-15 cm and 15-30 cm. These samples were air died, pound with wooden hammer passed through a 2 mm sieve and stored in polyethelene bags for further analysis. One representative soil profiles were also taken in the field.

3.5 COLLECTION AND PROCESSING OF FOLIAR SAMPLE

Foliar sampling was done thrice during the period of experimentation in the months of January, March and July. The third and fourth leaves from the terminal bud of a branch from all the four sides of the tree were collected as specified. Care was taken to avoid diseased, insect attacked, and abnormal leaves and the collected leaves were preserved in polyethelene bags during transport to the laboratory. These samples were subjected to various treatments successively as follows.

a. tap water wash

b. dil. Hcl wash (8ml/litre of water)

c. distilled water wash

d. Redistilled water wash

The washed samples were air dried for sometime in shade to exhaust the major moisture content and finally dried in hot air oven at 60 ± 5°C. The dried samples were powdered and preserved in butter paper bags. Equal amounts of the powdered foliar samples were taken from six plants of each replication (as mentioned in 3.2), thoroughly mixed and composited to get one single sample per each replication.

3.6 METHODS

The analytical methods employed for the determination of physical properties and chemical characteristics of soils and concentration of different nutrients in the foliar tissues are as follows.

3.6.1 Soil Texture

The soil texture was determined by feel method.

3.6.2 Soil Reaction

The soil reaction was determined in 1:2 soil-water suspension (Jackson 1967).

3.6.3 Electrical Conductivity (E.C)

The electrical conductivity was determined in 1:2 soil-water suspension using the electrical conductivity bridge Systronix 305 (Piper 1950).

3.6.4 Soil Organic Carbon

Soil organic carbon was determined by Walkley and Black's method (Jackson 1967).

3.6.5 Available Nitrogen

The available nitrogen content of the soils was estimated by alkaline permanganate method (Subbiah & Asija 1956).

3.6.6 Available Phosphorus

Available phosphorus was estimated by Olsen's extractant (0.5 M Sodium bicarbonate of pH 8.5) followed by the development of blue colour and the concentration was determined at 660 nm by spectronic-20 (Olsen *et al* 1954).

3.6.7 Available Potassium

Available potassium was extracted with neutral normal ammonium acetate solution and the content was determined using Flame photometer Systronix model 121 (Jackson 1967).

3.6.8 Exchangable Calcium and Magnesium

Exchangable calcium and magnesium were extracted with neutral normal ammonium acetate and the content was determined volumetrically using EDTA titration method (Vogel 1978).

3.6.9 Available Sulphur

Available sulphur was extracted with 1% NaCl followed by the development of turbidity with barium chloride and the concentration was determined using spectronic - 20 at 440 nm (Piper 1950).

3.6.10 Available Boron

The available boron in the soils is determined colorimetrically by curcumin determinative procedure (Lal Singh 1988).

3.6.11 DTPA Extractable Micronutrients

The content of DTPA extractable micronutrients i.e., Fe, Mn, Cu and Zn in soil was estimated using 1:2 soil to extractant ratio (Lindsay and Norvel 1978). The concentration of each nutrient was determined using Atomic Absorption spectrophotometer (Model 170-0036, Hitachi, Japan) at an air pressure of 1.6 Kg cm^{-2} using acetylene gas. The micronutrients were estimated at the following wavelength and discharge current

Element	Wavelength (nm)	Discharge current (mA)
Fe	248.3	10.0
Mn	274.5	7.5
Cu	324.8	10.0
Zn	213.8	10.0

3.7 FOLIAR ANALYSIS

Wet Digestion of Foliar Material

One gram of the oven dried plant sample was digested with diacid (HNO_3 and $HClO_4$). After predigestion with nitric acid, the samples were diluted to a known volume (100 ml) with redistilled water and filtered (Jackson 1967). This filtrate was used for the estimation of P, K, Ca, Mg, S, Fe, Cu, Mn and Zn adopting the standard procedures mentioned below.

3.7.1 Nitrogen

The nitrogen content of foliar tissue was estimated by microkjeldahl method (A.O.A.C. 1970).

3.7.2 Phosphorus

The phosphorus content of foliar tissue was determined by Vanadomolybdate method using Spectronic-20 at 470 nm (Jackson 1967).

3.7.3 Potassium

The concentration of potassium in diacid extract was determined using Flame photometer (Jackson 1967).

3.7.4 Calcium and Magnesium

The calcium and magnesium contents of leaf samples were estimated by titrating the diacid extract with 0.01N EDTA (Vogel 1978).

3.7.5 Sulphur

Sulphur in diacid extract was determined by turbidometric method using Spectronic 20 at a wavelength of 440 nm (Vogel 1978).

3.7.6 Boron

The total boron in foliar tissues was estimated by Cucumin procedure (Jackson 1967).

3.7.7 Micronutrients

The diacid extract was fed to Atomic Absorption Spectrophotometer and the concentration of Fe, Mn, Cu and Zn were determined (Vogel 1978).

3.8 YIELD AND FRUIT QUALITY CHARACTERS

3.8.1 Yield

The yield of fruits per each tree were recorded in number and finally averaged for each replication.

3.8.2 Size

The fruit size was measured both in diameter and length using vernier callipers.

3.8.3 Rind thickness

The rind thickness was measured by vernier callipers after slicing into small pieces.

3.8.4 Number of segments

Each fruit was cut into two halves and the number of segments were counted.

3.8.5 Seed

The number of seeds in six fruits per each replication were recorded and the mean value was calculated.

3.8.6 Rag

The juice from the fruits (after removing the peel) was completely squeezed out and the left over material i.e., rag is estimated by weighing on a balance.

3.8.7 Juice content

The juice from the fruits in each replication was extracted with a glass bur and expressed as percent of gross fruit weight.

3.8.8 Brix (TSS)

The fruit juice was analysed for total soluble salts with the help of hand refractometer.

3.8.9 Ascorbic acid (Vitamin 'C')

The ascorbic acid content of orange fruits was determined following the procedure given in AOAC (1970).

3.8.10 Reducing sugars

The reducing sugars were estimated titrimetrically by Shaffer Somogyi Micro method (Ranganna 1977).

3.8.11 Non-reducing sugars

The method given by Ranganna (1977) was adopted for calculating the non-reducing sugar content of fruit juice.

3.8.12 Titrable Acidity

Titrable acidity was estimated by titrating a known quantity of juice against standard 0.1 N NaOH solution using phenolphthalein as indicator and expressed as citric acid (AOAC 1970).

3.9 STATISTICAL ANALYSIS

The data was subjected to statistical scrutiny by adopting the procedure for RBD after finding out the missing value for Rangpur lime rootstock (Snedecor and Cochran 1967). As all the plants on Jambheri rootstock declined, it was not included under statistical analysis. Simple correlations were also worked out to find out the extent of correlation between soil and leaf nutrient concentration.

Results

CHAPTER 4

RESULTS

The results obtained from the investigation carried out to track the efficiency of different rootstocks on sweet orange with respect to their foliar nutrient content, fruit quality and fruit yield are presented in this chapter.

As an initial step, one representative profile was dug from the experimental site and soil samples were collected and studied to characterize the morphological, physical, physico-chemical and chemical characters of the orchard. Further, the surface soil samples and leaf samples were analysed at different intervals for the nutrient concentration. Finally, the fruit quality and yield were assessed. The data obtained for all these investigations were interpreted in this chapter under various subtitles. Correlations were also worked out to obtain the relationship between various parameters of soil and foliar tissues.

4.1 SOIL SITE DESCRIPTION

The description of the site from which the profile was taken is furnished below.

Physiographic unit	:	Plain land
Parent material	:	Granite
Climate	:	Semiarid
Rainfall	:	700 to 1000 mm

Landform	:	Upland
Slope gradient	:	0-1 per cent
Erosion	:	Very slight
Runoff	:	Very slow
Drainage	:	Moderately well
Ground water	:	> 10.0 m
Flooding	:	No
Soluble salt	:	Normal
pH suspected	:	Between 7.0 to 7.5
EC	:	0.2 to 0.3 dS m^{-1}
Stone size (dia)	:	< 2.5 cm
Stoniness	:	< 3 percent
Rockout crops	:	Neem, pongamia and scrubs
Crop	:	Citrus
Present land use	:	Cultivable orchard land

4.1.1 Soil Profile Description

Soil profile was described for their morphological characteristics in the field as per the procedure laid down in the soil survey manual of All India and Land Use Organization (1970).

Horizon	Depth (cm)	Morphological characters
A_2	0-40	Diffused boundary, yellowish red 5 YR 4/6 (dry) and red 2.5 YR 4/6 (wet), sandy loam, no concretions, sub angular blocky, slightly hard (dry), loose (moist) no cutans, fine to coarse roots, no effervescence with dilute HCl.
B_1	40-88	Diffused boundary, yellowish red 5 YR 4/6 (dry) and red 2.5 YR 4/6 (moist), sandy clay loam, no mottles, sub angular blocky, very hard (dry), firm (moist), sticky (wet), no cutans, sparse coarse roots, fine sized pores, no effervescence with dil. HCl.
B_{1t}	88-100	Diffused boundary, yellowish red 5 YR 4/6 (dry) red 2.5 YR 4/6 (moist) sandy clay and highly moist, no mottles, sub angular blocky, hard (dry), firm (moist), sticky (wet), clay cutans present, very fine roots, no effervescence with dil, HCl.
B_{2t}	100-150 and above	Diffused boundary, yellowish red 5 YR 4/6 (dry) and red 2.5 YR 4/6 (moist), sandy clay, gravel mixed at 130 cm and highly moist, no mottles, subangular blocky, hard (dry), firm (moist), sticky (wet), clay cutans present, very fine sparse roots, no effervescence with dil, HCl, argillic horizon.

Classification : Haplustalf

4.1.2 Physical Characteristics of the Profile

4.1.2.1 Colour. The colour of the soils varied from yellowish red to dark red with hue ranging from 5 YR to 2.5 YR (moist) towards deeper layers.

4.1.2.2 Texture. The description of texture of the soils is presented in table 2. The texture of the soils varied from sandy loam to sandy clay. The clay percentage increased with increase in depth clay cutans were also observed in third and fourth layers indicating argillic horizon.

Table 2: Physical and Physico-chemical characteristics of the profile

S. No	Horizon	Depth (cm)	pH	EC	Organic carbon	Sand	Silt	Clay	Textural class
1.	A_2	0-40	7.1	0.2	0.39	70.10	13.1	16.8	Sl
2.	B_1	40-88	7.2	0.2	0.36	67.84	6.0	26.16	Scl
3.	B_{1t}	88-100	7.5	0.2	0.32	66.84	6.0	27.16	Scl
4.	B_{2t}	100 to >150	7.8	0.3	0.27	62.24	5.0	32.76	Sc

Table 3: Chemical characteristics of the profile

S. No	Horizon	Depth (cm)	Macronutrients			Secondarynutrients			Micronutrients				
			N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
			(kg ha^{-1})			me 100^{-1}g soil		ppm	ppm				
1.	A_2	0-40	219.5	32.8	278.8	2.96	2.17	24.7	3.3	10.2	1.40	19.2	1.06
2.	B_1	40-88	203.8	37.6	281.6	2.64	1.93	29.2	3.1	9.4	1.25	18.8	0.93
3.	B_{1t}	88-100	219.5	34.6	253.4	3.10	1.63	31.6	2.8	8.7	1.50	17.4	0.78
4.	B_{2t}	100->150	203.8	26.3	302.0	3.30	1.86	39.7	2.3	7.6	1.21	15.3	0.63

4.1.2.3 Structure. The structure of profile was subangular blocky.

4.1.3 Physico-chemical Characteristics of the Profile

4.1.3.1 Soil reaction. The soils were neutral to slightly alkaline with pH ranging from 7.1 to 8.1 and increased with increase in depth of the profiles (table 2)

4.1.3.2 Electrical conductivity. The soils were found to be non saline with an EC ranging from 0.2 to 0.3 dS m^{-1} and showed an increasing trend with depth (table 2).

4.1.3.3 Organic carbon. The percent organic carbon content of the soils ranged from 0.4 to 0.27 showing a decreasing trend with depth. The surface depth had higher percent of organic carbon compared to the lower layers and it was least in the last depth.

4.1.4 Chemical Characteristics of the Profile

The chemical characteristics of the profile are given in table 3.

4.1.4.1 Available nitrogen. The available nitrogen content in the soils ranged from 219.52 to 203.84 Kg ha^{-1} showing a decreasing trend with the depth.

4.1.4.2 Available phosphorus. The profile showed a decreasing trend in available P content and varied from 37.62 to 26.2 Kg ha^{-1}. The soil showed a higher P content of 37.6 kg ha^{-1} at 40-88 depth.

4.1.4.3 Available potassium. The available potassium in the profile varied between 253.4 to 302.0 Kg ha^{-1} and was the highest at last depth and increased with depth except at 88 to 100 cm where it has dropped to 253.4 kg ha^{-1}.

4.1.4.4 Available calcium. The available calcium status in the profiles ranged from 2.64 to 3.30 m.e. 100^{-1}g of soil and showed an increasing trend with depth except at 40 to 88 cm where it showed a slight decrease than at 0-40 cm depth.

4.1.4.5 Available magnesium. The available magnesium in the profile showed a decreasing trend and ranged from 2.17 to 1.86 me 100^{-1} g soil except a slight increase at 100 to 150 cm depth.

4.1.4.6 Available sulphur. The available S status of soils showed an increasing trend with the depth and ranged from 24.71 to 39.7 ppm.

4.1.4.7 Available micronutrients. The available Zn, Fe, Cu, Mn and B status of profile had decreased with increasing depth and ranged from 3.3 to 2.3, 10.2 to 7.6, 19.2 to 15.3 and from 1.06 to 0.63 respectively while available Cu status of the soil decreased upto 88 cm and increased at 88 to 100 cm depth.

4.2 SOIL ANALYSIS

Soil samples from two different depths (0-15 and 15-30 cm) in the Sathgudi tree basins grown on different rootstocks were collected at two different periods i.e. before and after fertilizer application and analysed for various physico-chemical and chemical parameters, the results of which are presented below.

4.2.1 Physico-chemical Characteristics of the Soil

The data on physico-chemical characteristics of the soil before and after fertilizer application are presented in Table 4.

Table 4: Physico-chemical characteristics of the soil before and after fertilizer application

Treatment	Before Fertilizer application				After fertilizer application			
	pH		EC (dS m^{-1})		pH		EC (dS m^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sathgudi	7.00	7.15	0.26	0.20	7.10	7.38	0.15	0.15
Rangpurlime	7.17	7.20	0.20	0.10	7.35	7.55	0.23	0.10
Cleopatra mandarin	7.10	7.05	0.25	0.23	7.20	7.18	0.23	0.13
Troyer citrange	7.02	7.15	0.23	0.13	7.05	7.18	0.18	0.18
Trifoliate orange	7.02	7.17	0.28	0.23	7.13	7.30	0.28	0.23
Jambheri	7.10	7.20	0.28	0.13	7.05	7.23	0.23	0.18
F test	NS	NS	NS	NS	NS	*	NS	NS
SEm	8.84	0.10	9.30	6.58	0.12	0.12	8.08	5.10
CD at 5%	-	-	-	-	-	0.25	-	-

NS Non significant
* Significant at 5% level

4.2.1.1 Soil reaction. No significant differences were observed in soil pH at both the depths before fertilizer application in different rootstocks. The pH values varied from 7.0 to 7.2 and were neutral in reaction.

After fertilizer application also, no significant differences were observed in soil pH at 0-15 cm depth and the pH ranged from 7.05 to 7.35 but at 15-30 cm depth there was significant difference in soil reaction and the soils are neutral to slightly alkaline in reaction with pH fluctuating between 7.2 to 7.6. The soil pH was maximum 7.55 in Rangpur lime basins which was on par with Sathgudi and Trifoliate orange rootstock basins. The pH was leading to 7.18 in Cleopatra mandarin and Troyer citrange.

4.2.1.2 Electrical conductivity. Significant differences were not observed in soil EC at both the depths in different rootstocks basins both before and after fertilizer application.

4.2.2 Available Macronutrient Status of Soil

The data on available macronutrient status of soil before and after fertilizer application in different rootstock tree basins are presented in tables 5 and 6.

4.2.2.1 Nitrogen. Before and after fertilizer application, the results indicated no significant differences in N content of soils at both the depths in different rootstock basins and the available N status was observed to be low to medium.

4.2.2.2 Phosphorus. Before fertilizer application, highly significant differences were observed in the available P status of soils which was medium. At 0-15 cm

Table 5 : **Available macronutrient status of the soil before fertilizer application**

Treatment	N (Kg ha^{-1})		P (Kg ha^{-1})		K (Kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sathgudi	248.84	254.80	41.91	30.12	338.80	428.60
Rangpurlime	205.18	235.20	31.92	26.43	285.60	343.35
Cleopatra mandarin	219.52	237.08	35.24	31.34	322.40	348.50
Troyer citrange	251.26	243.04	30.15	26.50	381.40	412.400
Trifoliate orange	223.44	286.16	35.10	32.52	487.20	477.55
Jambheri	268.58	274.40	20.45	15.08	369.60	349.10
F test	NS	NS	**	**	NS	NS
SEm	31.19	25.67	3.37	2.97	77.05	78.75
CD at 1%	-	-	7.08	6.24	-	-

NS Non significant
** Significant at 1% level

Table 6 : Available macro nutrient status of the soil after fertilizer application

Treatment	N (Kg ha^{-1})		P (Kg ha^{-1})		K (Kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sathgudi	278.32	270.56	39.52	32.64	327.20	414.00
Rangpurlime	231.28	243.04	27.12	24.19	285.70	279.30
Cleopatra mandarin	243.04	250.88	30.35	28.59	323.60	343.40
Troyer citrange	257.55	313.68	29.23	24.32	391.20	335.80
Trifoliate orange	290.08	290.08	32.82	28.29	411.60	488.40
Jambheri	286.16	274.00	19.96	15.06	355.60	331.90
F test	NS	NS	**	**	NS	*
SEm	26.08	42.38	2.80	2.43	46.83	66.97
CD	-	-	5.80	5.11	-	140.64

NS Non significant
* Significant at 5% level
** Significant at 1% level

depth, significantly highest soil P status was recorded in Sathgudi rootstock basins 41.91 kg ha^{-1} which was at par with Cleopatra mandarin and Trifoliate orange basins while Jambheri basins had the least (20.45 kg ha^{-1}).

At 15-30 cm depth, significantly high P status was recorded in Trifoliate orange basins (32.5 kg ha^{-1}) which was at par with Cleopatra mandarin and Sathgudi rootstock basins. Jambheri basins recorded significantly least soil P status (15.08 kg ha^{-1}).

After fertilizer application also, the phosphorus status of soil was observed to be medium and significant at both 0-15 and 15-30 cm depths.

At 0-15 cm depth, significantly highest soil P status of 39.5 kg ha^{-1} was recorded in Sathgudi basins while Jambheri basins had the least P status of 20.0 kg ha^{-1}. The remaining four basins of other rootstocks were at par with each other in their P status.

At 15-30 cm depth, significantly highest soil P status was observed in Sathgudi basins (32.6 kg ha^{-1}) which was at par with Cleopatra mandarin and Trifoliate orange basins while least P status of 15.1 kg ha^{-1} was recorded in Jambheri basins.

4.2.2.3 Potassium. Before and after fertilizer application, significant differences were not observed in K status of soils in different rootstock basins except at 15-30 cm depth after fertilizer application. The soils had high potassium status.

At 15-30 cm depth, after fertilizer application, Trifoliate orange basins had significantly higher soil K status of 488.40 kg ha^{-1} whereas the others were at par.

4.2.3 Available Secondary Nutrient Status of Soil

Data on available secondary nutrient status of the soils before and after fertilizer application are presented in tables 7 and 8.

4.2.3.1 Calcium. Before and after fertilizer application, soils in different rootstock basins did not differ significantly in their Ca status except at 15-30 cm depth after fertilizer application. It ranged from 2.6 to 3.9 and 2.5 to 4.3 at 0-15 and 15-30 cm depths respectively.

After fertilizer application at 15-30 cm depth, Trifoliate orange basins had significantly higher Ca status of 4.38 me 100^{-1} g soil whereas Sathgudi basins had significantly least available Ca status which was at par with Rangpur lime, Cleopatra mandarin and Troyer citrange basins, with values ranging from 2.62 to 3.44 me 100^{-1} g soil.

4.2.3.2 Magnesium. The results similar to Ca status were observed indicating no significant differences in Mg status of soils at both the depths before and after fertilizer application.

4.2.3.3 Sulphur. Before fertilizer application, the differences in S status of soils at both the depths in different rootstock basins were significantly high. At 0-15cm depth, Sathgudi basins had significantly highest S status of 26.8 ppm.

Table 7 : Available Secondary nutrient status of soil before fertilizer application

Treatment	Ca (me 100^{-1} g)		Mg (me 100^{-1} g)		S (ppm)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sathgudi	2.78	2.53	2.50	2.52	26.79	23.05
Rangpurlime	2.60	2.57	2.55	1.94	23.86	20.75
Cleopatra mandarin	3.36	2.91	2.39	2.24	24.56	20.61
Troyer citrange	3.08	3.10	2.26	2.09	20.52	18.81
Trifoliate orange	3.20	3.24	2.60	2.24	23.52	20.49
Jambheri	3.48	3.31	2.93	2.46	24.30	21.00
F test	NS	NS	NS	NS	**	**
SEm	0.50	0.42	0.55	0.39	0.89	0.94
CD	-	-	-	-	**1.88**	**1.98**

NS Non significant
* Significant at 1% level

Table 8 : **Available secondary nutrient status of soil after fertilizer application**

Treatment	Ca (me 100^{-1}g)		Mg (me 100^{-1}g)		S (ppm)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sathgudi	2.76	2.62	2.51	3.18	25.67	19.91
Rangpurlime	3.64	2.69	2.95	2.36	19.54	18.72
Cleopatra mandarin	2.85	2.88	2.75	2.28	20.15	19.31
Troyer citrange	3.19	3.44	2.78	2.65	18.15	17.22
Trifoliate orange	3.91	4.38	2.33	3.10	21.08	18.94
Jambheri	3.53	3.76	3.05	2.64	20.22	18.12
F test	NS	**	NS	NS	**	**
SEm	0.58	0.48	0.59	0.38	1.00	0.67
CD	-	1.02	-	-	2.10	1.42

NS Non significant
** Significant at 1% level

While Troyer citrange basins had the least S status of 20.5 ppm whereas the others were statistically at par with each other.

At 15-30 cm depth, Sathgudi basins had significantly high S status 23.1 ppm followed by Jambheri. Troyer citrange basins recorded the least (18.81 ppm) which was at par with Rangpur lime, Cleopatra mandarin and Trifoliate orange basins.

After fertilizer application, highly significant differences were observed in S status of soils at both the depths.

At 0-15 cm depth, Sathgudi basins had significantly high S status of 25.7 ppm followed by Trifoliate orange basins while Troyer citrange basins had the least (18.2 ppm) which was at par with Jambheri, Cleopatra mandarin and Rangpur lime.

At 15-30 cm depth also, significantly high S status was observed in Sathgudi basins (19.9 ppm) which was at par with Cleopatra mandarin, Trifoliate orange and Rangpur lime basins. Troyer citrange basins had least S status of 17.2 ppm which was at par with Jambheri basins.

4.2.4 Available Micronutrient Status of Soil

Data on the micronutrient status of soils before and after fertilizer application are presented in tables 9 and 10.

4.2.4.1 Zinc. Before and after fertilizer application, the soils did not differ significantly in their Zn status at both the depths. However, it ranged from 4.5

Table 9 : **Available micronutrient status of soil before fertilizer application (ppm)**

Treatment	Zn		Fe		Cu		Mn		B	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sathgudi	6.85	6.40	9.45	8.80	2.26	1.45	20.40	17.53	1.03	1.02
Rangpurlime	6.45	5.65	8.55	8.30	1.71	1.11	20.50	18.63	1.09	1.09
Cleopatra mandarin	6.60	6.20	9.00	8.85	1.86	1.10	20.20	18.88	1.05	1.03
Troyer citrange	4.53	4.25	9.95	9.65	2.04	1.16	20.00	17.68	1.00	0.99
Trifoliate orange	6.10	5.20	7.70	7.55	1.81	1.15	19.05	17.20	1.04	1.03
Jambheri	5.25	4.90	7.50	7.50	1.74	1.30	19.13	16.83	0.97	0.96
F test	NS	NS	**	**	NS	NS	**	**	NS	NS
SEm	1.21	1.22	0.48	0.43	0.34	0.27	0.45	0.48	6.55	0.06
CD	-	-	1.02	0.92	-	-	0.96	1.02	-	-

NS Non significant
* Significant at 1% level

to 6.9 and 4.3 to 6.40 ppm at 0-15 and 15-30 cm depths respectively before fertilizer application and from 3.40 to 4.9 and 1.9 to 3.2 ppm at 0-15 and 15-30 cm depths respectively after fertilizer application. However, the Zn status of soils was found to decrease after fertilizer application. Zinc status of the soil was the lowest in Troyer citrange basin and the highest in Sathgudi basin.

4.2.4.2 Iron. Before fertilizer application, the soils showed highly significant differences in their Fe status at both the depths in different rootstock basins.

At 0-15 cm depth, Troyer citrange basins had significantly higher soil Fe status of 10 ppm which was at par with Sathgudi and Cleopatra mandarin. Jambheri basins had the least Fe status (7.50 ppm) which was at par with Trifoliate orange.

At 15-30 cm depth also, Troyer citrange basins had significantly higher soil Fe status of 9.7 ppm which and the least is seen in Jambheri basins (7.50 ppm).

After fertilizer application also, soils showed significantly high differences in their Fe status at both the depths in different rootstock basins.

At 0-15 cm depth, Sathgudi basins had significantly highest Fe status of 11.00 ppm which was at par with Troyer citrange, whereas Jambheri basins recorded the least (7.6 ppm) and was at par with Rangpur lime and Trifoliate orange basins.

At 15-30 cm depth also Sathgudi basins had significantly higher soil Fe status (9.7 ppm) while the least was in Jambheri basins (6.80 ppm).

Table 10 : Available micronutrient status of soil after fertilizer application (ppm)

Treatment	Zn		Fe		Cu		Mn		B	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sathgudi	4.85	2.08	11.00	9.65	2.20	1.30	17.50	14.08	1.01	0.99
Rangpurlime	4.33	1.93	8.70	8.45	2.04	1.16	18.30	17.30	1.10	1.06
Cleopatra mandarin	4.55	2.95	8.90	8.20	1.71	1.33	17.70	17.25	1.04	1.02
Troyer citrange	3.40	2.13	10.30	9.50	1.84	1.29	17.50	13.25	0.98	0.97
Trifoliate orange	3.75	2.23	7.90	6.85	1.79	1.21	17.10	16.53	1.03	1.02
Jambheri	4.05	3.18	7.55	6.80	1.64	1.70	17.15	14.53	0.97	0.96
F test	NS	NS	**	**	NS	NS	NS	**	NS	NS
SEm	1.02	1.13	0.62	0.70	0.40	0.37	1.03	0.84	6.22	6.23
CD	-	-	1.31	1.47	-	-	-	1.76	-	-

NS Non significant
** Significant at 1% level

4.2.4.3 Copper. The soils in different rootstock basins did not differ significantly in their Cu status at both the depths before and after fertilizer application. However, before fertilizer application it ranged from 1.7 to 2.3 and 1.10 to 1.5 ppm at 0-15 and 15-30 cm depths respectively while it was from 1.6 to 2.3 and 1.2 to 1.70 ppm at 0-15 and 15-30 cm depths respectively after fertilizer application.

4.2.4.4 Manganese. Before fertilizer application in different rootstock basins, soils showed highly significant differences in their Mn status at both the depths.

At 0-15cm depth, it ranged from 19.1 to 20.50 ppm and the highest Mn was observed in Rangpur lime basins and the least was in Trifoliate orange basins which was at par with Jambheri basins.

At 15-30 cm depth, the soil Mn status varied between 16.8 and 18.9 ppm and the highest Mn status was observed in Cleopatra mandarin basins which was at par with Rangpur lime basins while Jambheri basins recorded the least which was at par with others.

After fertilizer application, the results were not significant in the Mn status of soils in different rootstock basins at 0-15 cm depth and ranged from 17.10 to 18.30 ppm. But at 15-30 cm depth, the soils differed significantly in their Mn status and ranged from 13.3 to 17.3 ppm. The highest Mn status was observed in Rangpur lime basins and was par with Cleopatra mandarin and Trifoliate orange basins. The least soil Mn status was observed in Troyer citrange basins which was at par with Jambheri and Sathgudi basins.

4.2.4.5 Boron. The soils did not differ significantly in their B status in different rootstock basins at both the depths before and after fertilizer application before fertilizer application. However, before fertilizer application it ranged from 0.97 to 1.09 and 0.96 to 1.09 ppm at 0-15 and 15-30 cm depths respectively while after fertilizer application, it varied between 0.97 to 1.10 and 0.96 to 1.06 ppm at 0-15 and 15-30 cm depths respectively.

In summarizing the availability of different nutrients in the soils in general, before and after fertilizer application, the following conclusions were drawn.

Available N in soils ranged from 205.18 to 286.16 kg ha^{-1} and was in medium range and available P fluctuated between 15.06 to 41.91 kg ha^{-1} which was in low to medium range while available K was high in the soil and varied from 279.3 to 488.4 kg ha^{-1}. Available Ca, Mg and S varied between 2.53 to 4.38 and 2.09 to 3.18 me 100^{-1} g soil and 17.22 to 26.79 ppm respectively and were found to be sufficient.

Among the soil available micronutrient, Zn, Fe, Cu and Mn varied between 1.93 to 6.85, 6.8 to 11.0, 1.1 to 2.2 and 13.25 to 20.5 respectively and were all above the critical limits, and were sufficient. Boron status in soils fluctuated between 0.96-1.1 ppm and was found to be normal.

On observation of the nutritional status of the experimental field, statistically it was concluded that the field is almost homogeneous but for few differences in phosphorus, iron and manganese status. These statistically significant differences might be due to some differences in clay content and genetic characteristics. However, these differences may not affect the major nutritional variations in horticultural plants.

4.3 FOLIAR ANALYSIS

4.3.1 Macronutrient Concentration of Sathgudi Sweet Orange Leaves as Effected by Different Rootstocks

The data on per cent leaf nitrogen phosphorus and potassium concentration of Sathgudi sweet orange on different rootstocks is presented in table 11.

4.3.1.1 Nitrogen. Leaf nitrogen concentration of Sathgudi sweet orange on different rootstocks did not differ significantly before and 90 days after fertilizer application and it ranged from 2.15 to 2.47 and 2.30 to 2.73 per cent respectively.

But after 45 days of fertilizer application, Sathgudi on different rootstocks varied significantly in the per cent leaf N concentration and Rangapurlime rootstock had significantly highest leaf N content of 3.05 per cent and was at par with Sathgudi rootstock. Troyer citrange rootstock had least N content of 2.60 per cent which was at par with Cleopatra mandarin and Trifoliate orange rootstock.

The leaf N concentration was in the optimum range of 2.35 to 2.47 per cent in the initial period but fell in optimum to high range (2.60 to3.05) and in optimum range (2.30 to 2.73 per cent) at 45 and 90 days after fertilizer application respectively.

Table 11 : Effect of different rootstocks on percent N,P,K content in the leaves of Sathgudi sweet orange

Treatmennt	N			P			K		
	Period from fertilizer application			Period from fertilizer application			Period from fertilizer application		
	Before	After 45 days	After 90 days	Before	After 45 days	After 90 days	Before	After 45 days	After 90 days
Sathgudi	2.35	2.94	2.52	0.19	0.38	0.25	1.08	1.68	1.57
Rangpurlime	2.29	3.05	2.60	0.20	0.35	0.28	1.00	1.49	1.45
Cleopatra mandarin	2.15	2.63	2.72	0.19	0.36	0.24	0.85	1.18	1.23
Troyer citrange	2.47	2.60	2.73	0.30	0.31	0.26	0.93	1.31	1.17
Trifoliate orange	2.33	2.61	2.30	0.23	0.37	0.25	0.84	1.25	1.17
F test	NS	**	NS	NS	NS	NS	**	**	**
SEm	0.17	0.15	4.80	0.22	4.28	3.04	5.59	5.79	8.60
CD at 1%	-	0.33	-	-	-	-	0.12	0.12	0.18

NS Non significant
* Significant at 1% level

Fig. 1: Concentration of nitrogen in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application

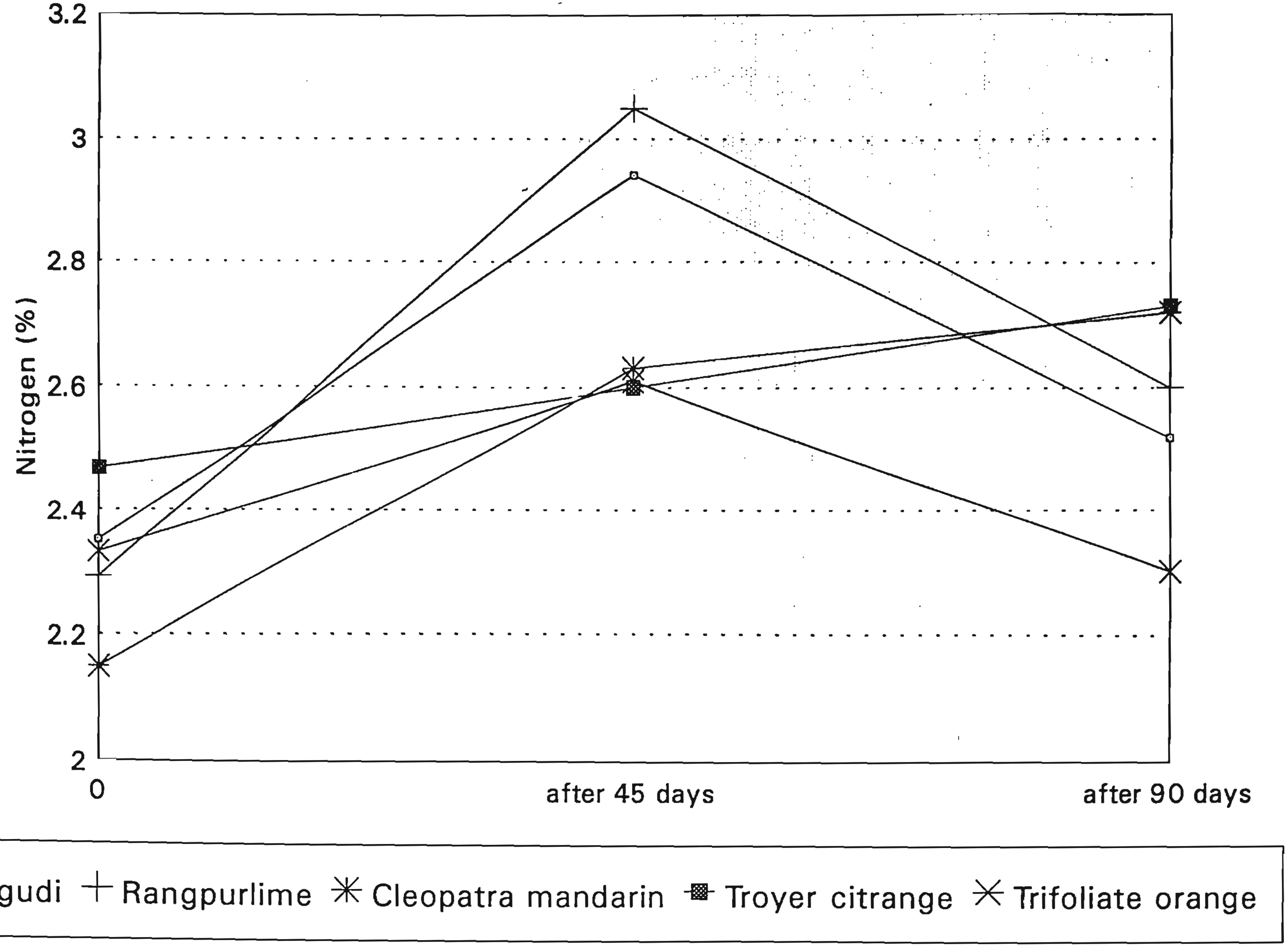
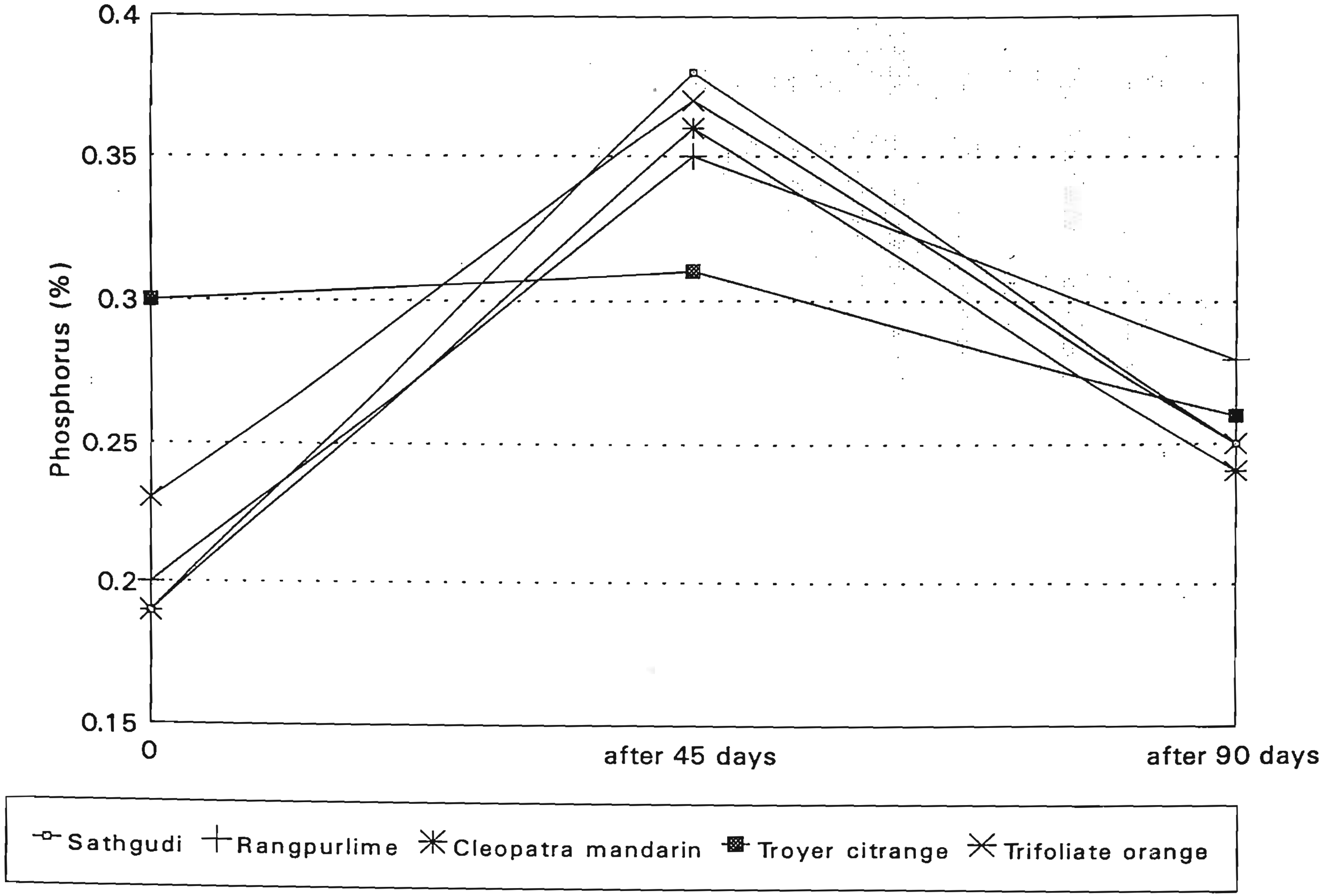


Fig. 2 : Concentration of Phosphorus in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



Sathgudi sweet orange on all rootstocks except on Troyer citrange had high levels of P in their leaves before fertilizer application which increased to excess concentration of P in their leaves after 45 days of fertilizer application and reduced to optimum after 90 days after manuring, but with higher value than before fertilization. While Troyer citrange had excess levels of P in their leaves before and after 45 days of fertilizer application which was dropped to high levels of P after 90 days of application (Fig. 2).

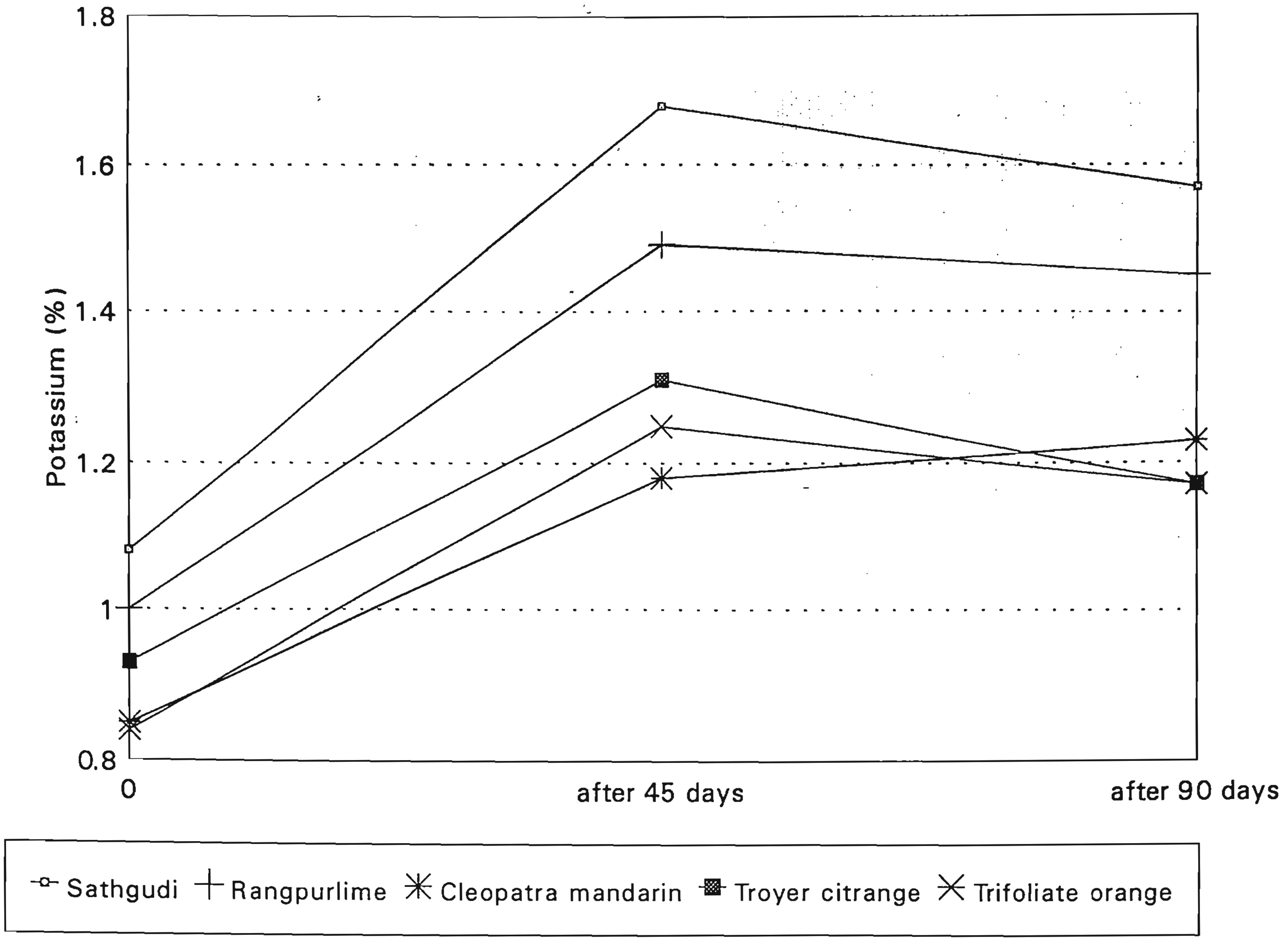
4.3.1.3 Potassium. The results indicated that the differences among different rootstocks in their leaf K content were highly significant at all the periods of analysis.

Before fertilizer application, the leaf K concentration varied between 0.84 to 1.08 per cent on different rootstocks and was in low to optimum range. Sathgudi recorded significantly highest K content of 1.08 per cent on its own rockstock and was at par with Rangpur lime while Trifoliate orange had the least (0.84) which was at par with Cleopatra mandarin and Troyer citrange.

After 45 days of fertilizer application, leaf K concentration ranged optimally from 1.18 to 1.68 per cent and highest per cent leaf K was observed in Sathgudi (1.68) while the least was in Cleopatra mandarin (1.18) which was at par with Trifoliate orange.

After 90 days of fertilizer application, the per cent leaf K ranged optimally from 1.17 to 1.57 and Sathgudi had the highest per cent leaf K (1.57) which was at par with Rangpur lime (1.45).

Fig. 3 : Concentration of potassium in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



Trifoliate orange and Troyer citrange had significantly lower and equal amounts of per cent leaf K (1.17) and were on par with Cleopatra mandarin.

Sathgudi and Rangpur lime rootstocks had optimum levels of K in their leaves at all the periods of sampling whereas Cleopatra mandarin, Troyer citrange and Trifoliate orange behaved similarly and showed low levels of K in their leaves before fertilizer application but reached to optimum levels 45 days after, fertilizer application and slightly reduced after 90 days except in Cleopatra mandarin, where slight increase was noticed after 90 days of fertilization (Fig. 3).

4.3.2 Secondary Nutrient Concentration of Sathgudi Sweet Orange Leaves on different Rootstocks

The data on per cent leaf calcium, magnesium and sulphur concentration of Sathgudi sweet orange on different rootstocks is furnished in table 12.

4.3.2.1 Calcium. The analysis resulted in highly significant differences in leaf Ca content of Sathgudi sweet orange on different rootstocks at all periods from fertilizer application.

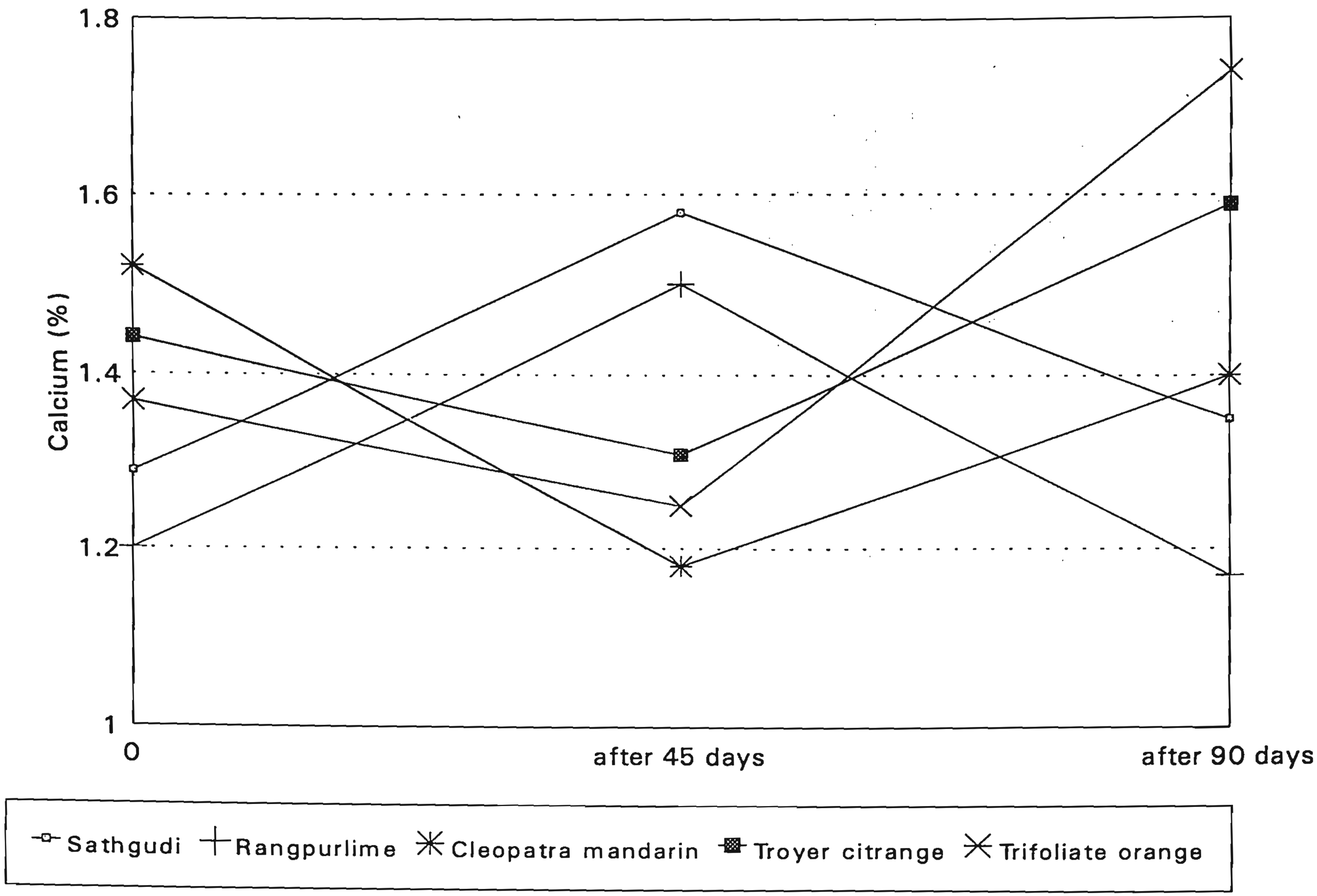
Before fertilizer application, per cent leaf Ca content varied from 1.23 to 1.52 and was in deficient range (Chapman, 1960). Cleopatra mandarin had significantly highest per cent leaf Ca content of 1.52 and was at par with Troyer citrange (1.44) while Rangpur lime had the least (1.23) which was at par with Sathgudi.

Table 12 : Effect of different rootstocks on percent Ca, Mg, S content in the leaves of Sathgudi sweet orange

Treatmennt	Ca			Mg			S		
	Period from fertilizer application			Period from fertilizer application			Period from fertilizer application		
	Before	After 45 days	After 90 days	Before	After 45 days	After 90 days	Before	After 45 days	After 90 days
Sathgudi	1.29	1.58	1.35	0.51	0.61	0.66	0.33	0.42	0.40
Rangpurlime	1.23	1.50	1.17	0.55	0.60	0.70	0.37	0.37	0.41
Cleopatra mandarin	1.52	1.18	1.40	0.73	0.60	0.58	0.35	0.38	0.43
Troyer citrange	1.44	1.31	1.59	0.61	0.71	0.76	0.32	0.35	0.37
T rifoliate orange	1.37	1.25	1.74	0.61	0.62	0.67	0.34	0.35	0.42
F test	**	**	*	*	**	NS	NS	NS	NS
SEm	8.27	7.51	0.20	6.72	3.57	9.64	4.94	3.04	2.62
CD	0.17	0.16	0.44	0.14	7.72	-	-	-	-

NS Non significant
* Significant at 5% level
** Significant at 1% level

Fig.4 : Concentration of calcium in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



After 45 days from fertilizer application, the per cent leaf Ca concentration varied from 1.18 to 1.58 and was in the deficient range (Table 1). Sathgudi recorded highest per cent leaf Ca content (1.58) and was at par with Rangpur lime while Cleopatra mandarin had the least (1.18) which was at par with Troyer citrange and Trifoliate orange.

After 90 days from fertilizer application, per cent leaf Ca concentration varied from 1.17 to 1.74 and was in deficient range. Trifoliate orange had significantly highest per cent leaf Ca of (1.74) while Rangpur lime had the least (1.17) and was at par with others.

Sathgudi sweet orange leaves on different rootstocks showed a similar trend having deficient Ca levels at all the P those periods of sampling (Fig. 4).

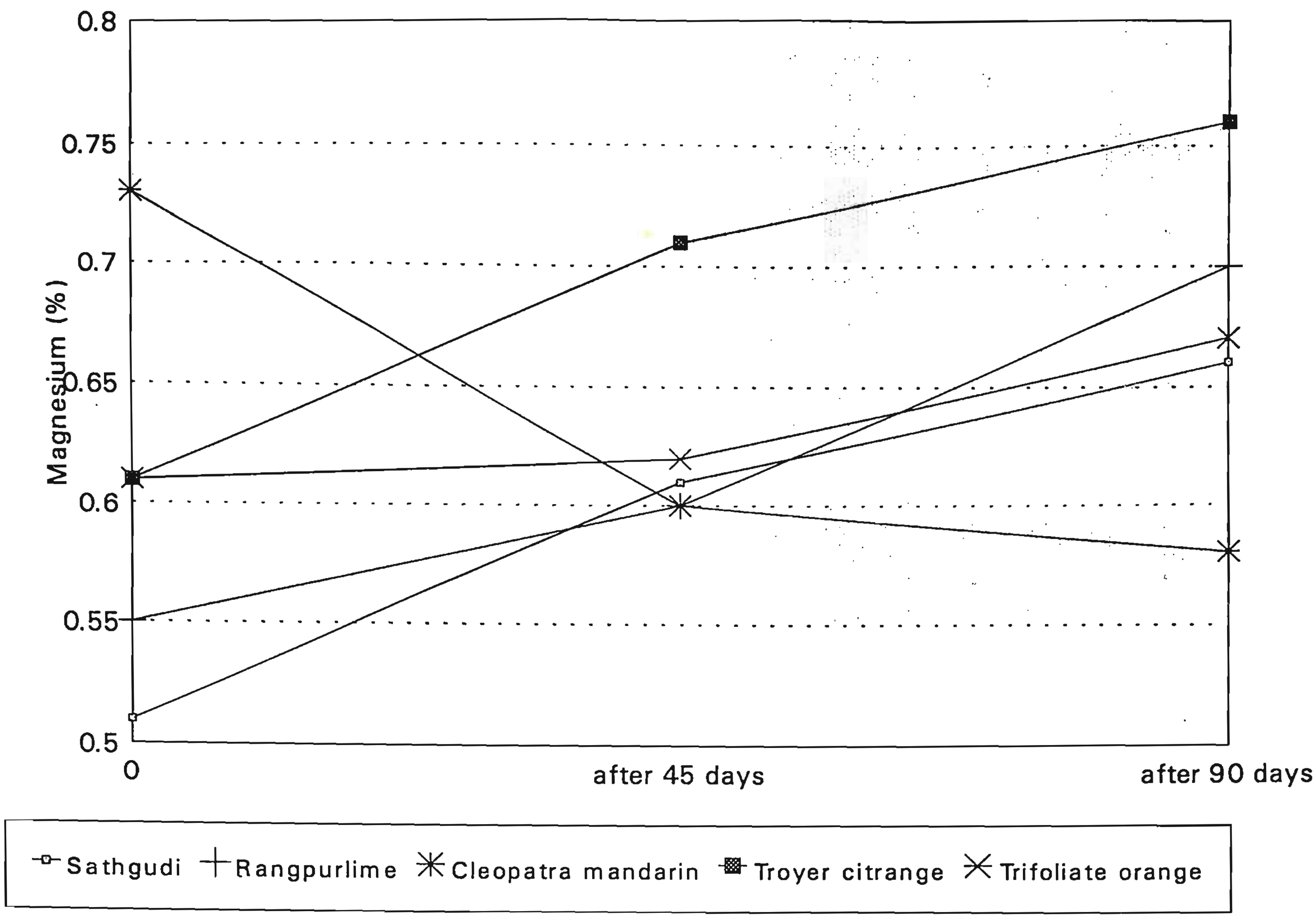
4.3.2.2 Magnesium. The differences in per cent leaf Mg concentration of Sathgudi sweet orange on different rootstocks were significant at initial stages, highly significant after 45 days and non significant after 90 days of fertilizer application.

At the initial stage, Cleopatra mandarin had significantly high per cent, leaf Ca content (0.72) while Sathgudi had the least (0.51) and was at par with others.

After 45 days after fertilizer application, Troyer citrange had high leaf Mg (0.71 per cent) while the least was in Rangpur lime.

After 90 days, Troyer citrange showed numerically higher per cent leaf Mg (0.76) and least was in Cleopatra mandarin (0.58).

Fig. 5 : Concentration of magnesium in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



During all the three periods of analysis, the leaf Mg content was in the optimum to high range which varied from 0.51 to 0.73, 0.60 to 0.76 per cent respectively.

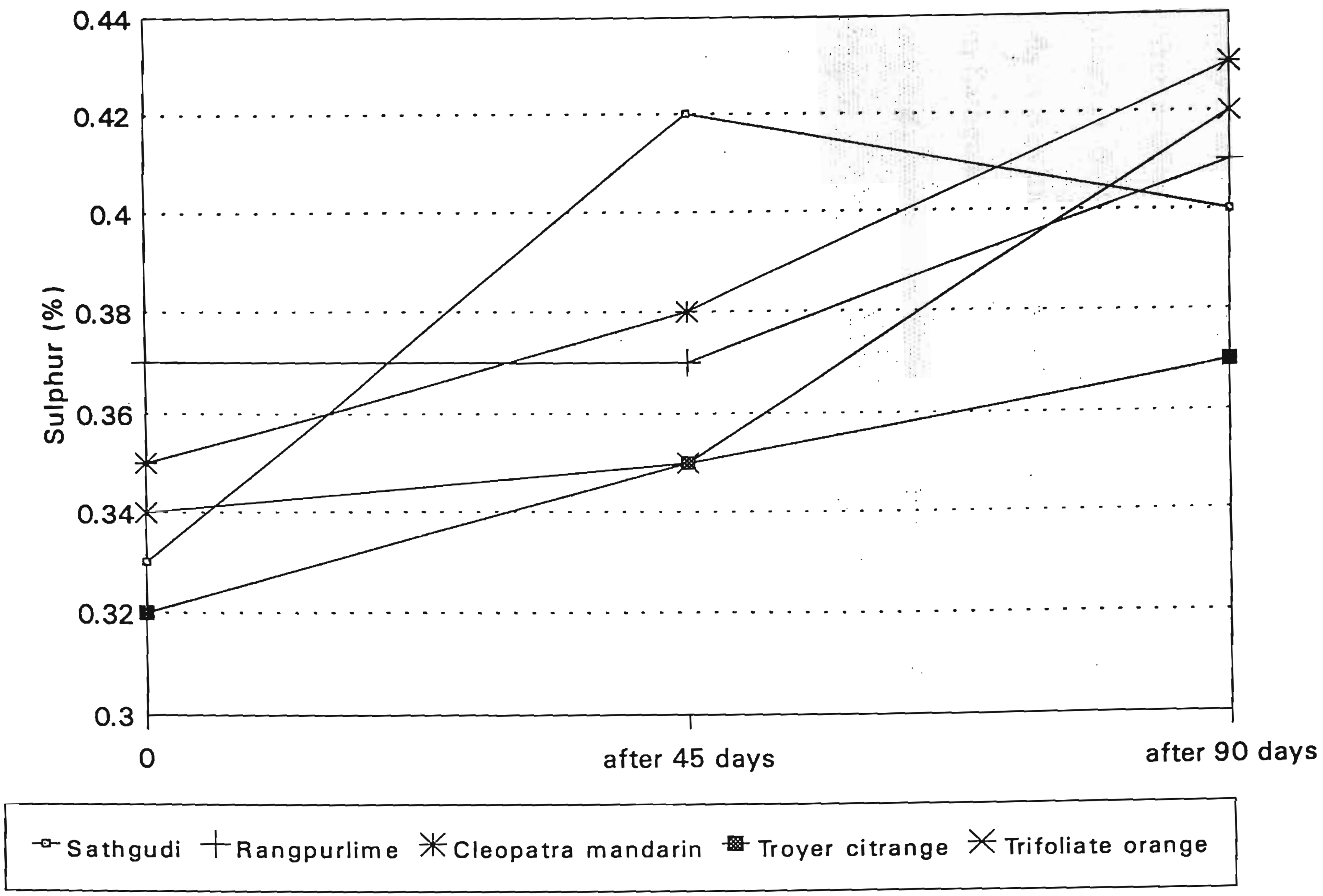
Sathgudi sweet orange on Sathgudi and Trifoliate rootstocks behaved similarly in their Mg uptake showing optimum levels at all the periods of sampling. But Rangpur lime rootstock had optimum levels of magnesium in their leaves before and after 45 days of fertilizer application but it reached to high level after 90 days period. In Cleopatra mandarin rootstock, the high concentration of Mg in its leaves before fertilizer application has reached to optimum level after fertilizer application. In the case of Troyer citrange rootstock, it showed optimum levels of N before fertilizer application but reached high levels after fertilizer application (Fig. 5).

4.3.2.3 Sulphur. The results indicated no significant differences in leaf sulphur content of Sathgudi sweet orange on different rootstocks at different periods from fertilizer application.

However, before fertilizer application, leaf sulphur content ranged optimally from 0.32 to 0.37 per cent and Rangpur lime had numerically highest leaf S content (0.37) and Troyer citrange had the least (0.32).

After 45 days period, leaf sulphur content ranged optimally high from 0.35 to 0.42 per cent and Sathgudi recorded numerically highest leaf S content (0.42 per cent) while Troyer citrange and Trifoliate orange recorded the least (0.35).

Fig. 6 : Concentration of sulphur in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



After 90 days after fertilizer application, leaf S content ranged optimally high 0.37 to 0.43 per cent and Cleopatra mandarin had numerically high leaf S content (0.43) while Troyer citrange had the least (0.37).

Rangpur lime, Cleopatra mandarin and Trifoliate orange rootstocks behaved similarly in their S uptake showing optimum levels before and after 45 days of fertilizer application but had high S concentration after 90 days of fertilizer application. Sathgudi sweet orange on Troyer citrange rootstock had optimum levels of S in its leaves at all the intervals from fertilizer application where as on Sathgudi it had optimum S concentration before fertilizer application but high levels were observed after 45 and 90 days of fertilizer application (Fig. 6).

4.3.3 Micronutrient Concentration of Sathgudi Sweet Orange Leaves on Different Rootstocks

The data on micronutrient concentration of Sathgudi sweet orange leaves on different rootstocks is furnished in table 13.

4.3.3.1 Zinc. The rootstocks did not differ significantly in their leaf zinc content after 90 days period whereas differences were significant before and after 45 days from fertilizer application.

At the initial period, the leaf Zn concentration varied from 18.5 to 28.6 ppm and was in low to optimal range. Trifoliate orange had significantly highest leaf Zn content (28.6 ppm) and was on par with Sathgudi (28.2) followed by Rangpur lime (24.0). Cleopatra mandarin had the least Zn content (18.5) which was on par with Troyer citrange.

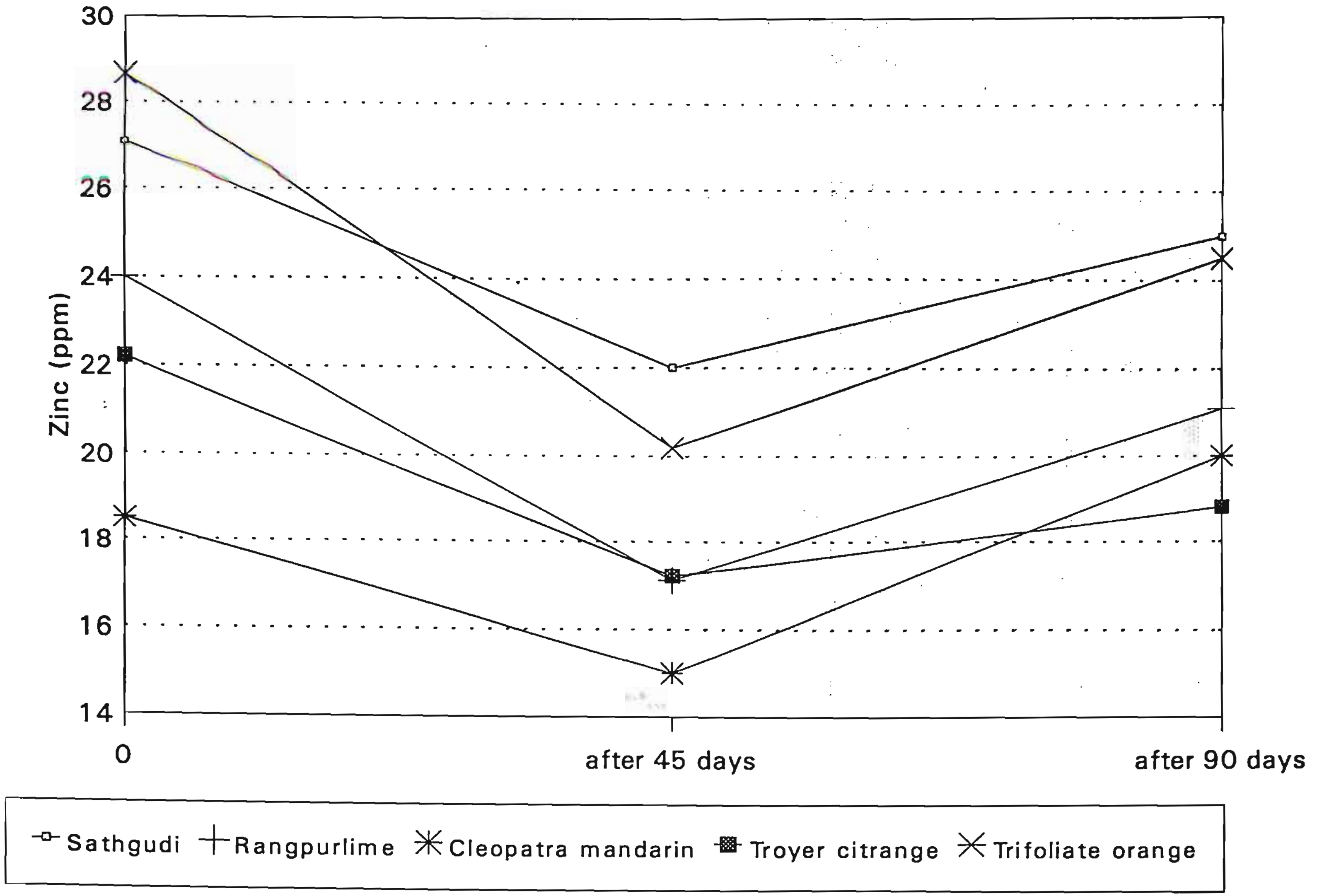
Table 13 : Effect of different rootstocks on Zn, Fe, Cu, Mn and B content (ppm) in the leaves of Sathgudi Sweet Orange

Treatment	Zn			Fe			Cu			Mn			B		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Sathgudi	27.1	22.0	25.0	144.0	103.5	104.5	14.5	15.8	13.6	36.6	36.8	32.3	105.0	87.5	95.0
Rangpurlime	24.0	17.1	21.1	134.8	88.8	92.8	20.0	20.2	17.9	36.6	37.0	32.0	133.2	112.5	119.2
Cleopatra mandarin	18.5	15.0	20.0	151.0	112.2	110.0	17.1	18.3	15.8	44.7	45.0	38.4	96.2	85.0	92.5
Troyer citrange	22.2	17.2	18.8	154.0	91.8	117.0	19.3	20.1	18.0	23.5	24.3	22.0	155.0	126.2	141.2
Trifoliate orange	28.7	20.2	24.5	152.2	135.5	137.8	16.0	17.0	15.8	45.5	45.6	39.6	178.75	138.7	143.8
F test	**	*	NS	NS	NS	NS	**	**	**	**	**	**	**	**	**
SEm	2.42	2.27	2.70	18.29	20.46	20.36	1.13	0.89	1.16	2.23	2.29	2.17	7.16	9.25	9.40
CD	5.23	4.91	-	-	-	-	2.44	1.93	2.52	4.82	4.94	4.70	15.46	19.9	20.31

(a. Before fertilizer application b. After 45 days c. After 90 days)

NS Non significant
* Significant at 5% level
** Significant at 1% level

Fig.7 : Concentration of zinc in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



After 45 days after application, leaf Zn content was low to optimum and ranged from 15.0 to 22.0 ppm. Significantly high leaf Zn content was observed in Sathgudi (22.0) and was on par with Trifoliate orange (20.3) while Cleopatra had the least (15.0) which was on par with Rangpur lime and Troyer citrange.

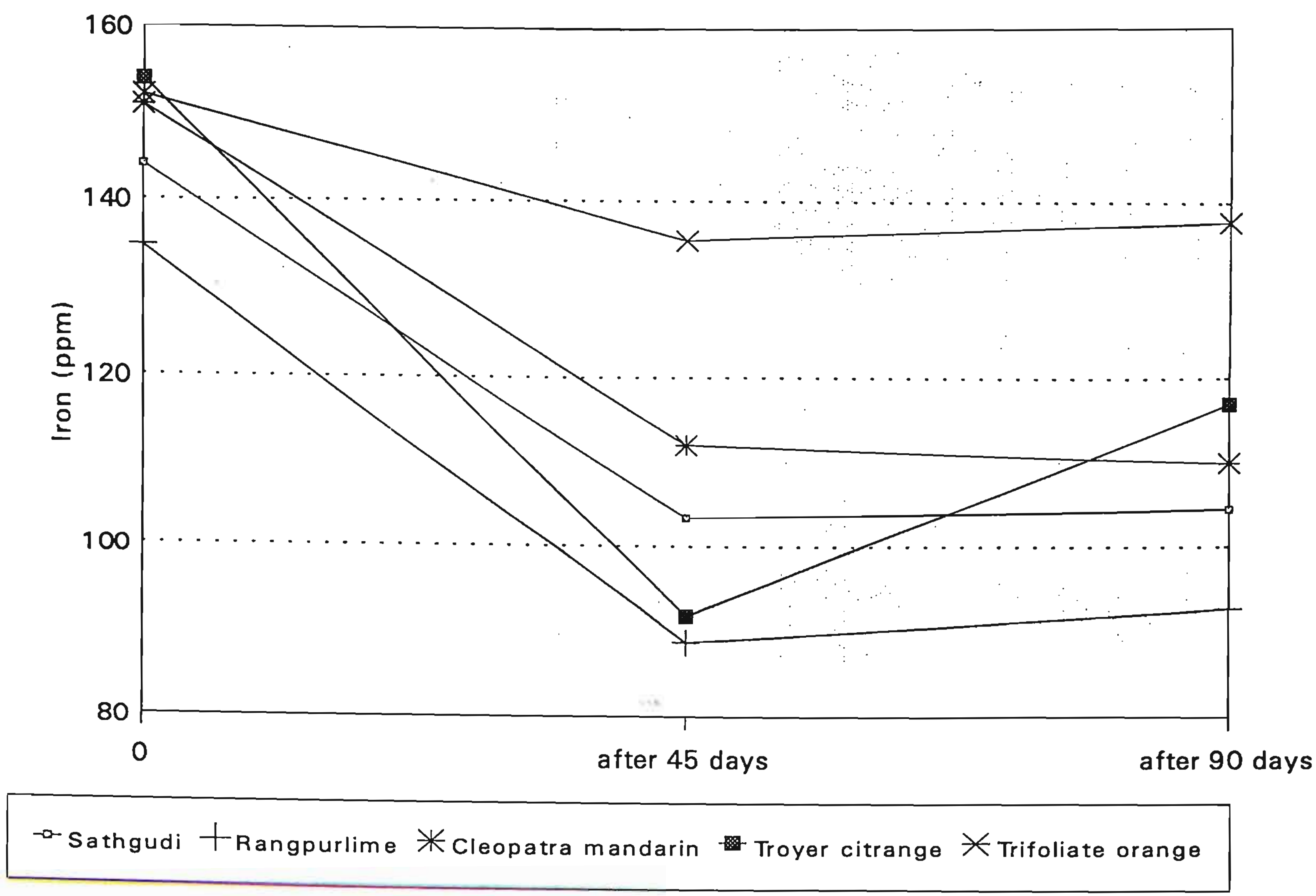
After 90 days after fertilizer application leaf Zn content varied from 18.8 to 25.0 ppm which was observed to be low. Numerically high leaf Zn concentration was observed in Sathgudi (25 ppm) and least in Troyer citrange (18.8).

As depicted in figure (7), Sathgudi sweet orange on Rangpur lime, Cleopatra mandarin and Troyer citrange rootstock showed similar trend in their nutrient concentration having low levels of Zn before and after fertilizer application. Whereas Sathgudi rootstock recorded low levels of Zn only at 45 days after fertilizer application and it was deficient before and after 90 days of fertilizer application. Before fertilizer application, Sweet orange leaves on Trifoliate orange rootstock were deficient in Zn but rose to low levels after fertilizer application (Fig. 7).

4.3.3.2 Iron. The results indicated that the rootstocks did not differ significantly in their leaf Fe content at different periods after fertilizer application.

However, initially, leaf Fe content ranged high from 134.8 to 154.0 ppm. Troyer citrange had numerically highest leaf Fe content (154 ppm) while in Rangpur lime, the least content was recorded.

Fig.8 : Concentration of iron in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



After 45 and 90 days after fertilizer application, Trifoliate orange recorded numerically high leaf Fe content (135.5 and 137.8 ppm) while Rangpur lime recorded least (88.8 and 137.8 ppm) respectively. During this period, the leaf Fe concentration ranged from optimum to high and varied from 88.8 to 137.8 ppm.

Sathgudi and Rangpur lime rootstocks showed a similar trend in their Fe uptake having optimum levels before and after fertilizer application whereas Sweet orange leaves on Cleopatra mandarin, Troyer citrange and Trifoliate orange rootstocks had high concentration of Fe before fertilizer application but fell to optimum range after fertilizer application (Fig. 8).

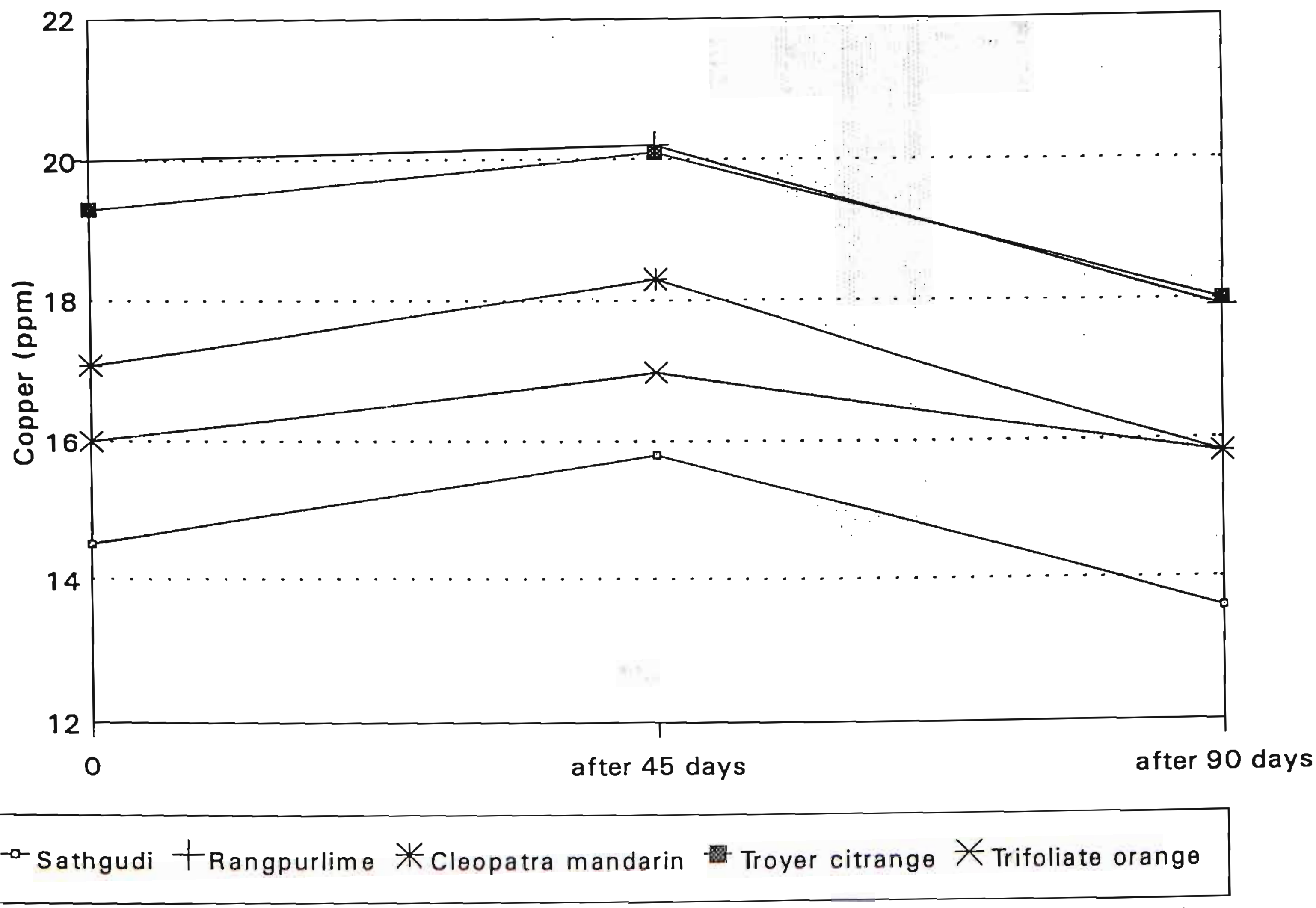
4.3.3.3 Copper. The results indicated highly significant differences among different rootstocks at different periods from fertilizer application. The leaf Cu content ranged optimum to high (Table 1) and varied from 14.5 to 20.0, 15.8 to 20.2 and 13.6 to 18.0 ppm before and after 45 and 90 days respectively.

Initially, Rangpur lime had the highest leaf Cu content (20.0 ppm) and was at par with Troyer citrange (19.4) while least was recorded in Sathgudi (14.5) which was at par with Trifoliate orange.

After 45 days from fertilizer application, Rangpur lime maintained highest leaf Ca content (20.2 ppm) and was at par with Troyer and Cleopatra while Sathgudi had the lowest which was at par with Trifoliate orange.

After 90 days after fertilizer application, Troyer citrange had the highest leaf Cu content (18.0 ppm) and was at par with Rangpur lime while least was observed in Sathgudi (13.6 ppm).

Fig.9 : Concentration of copper in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



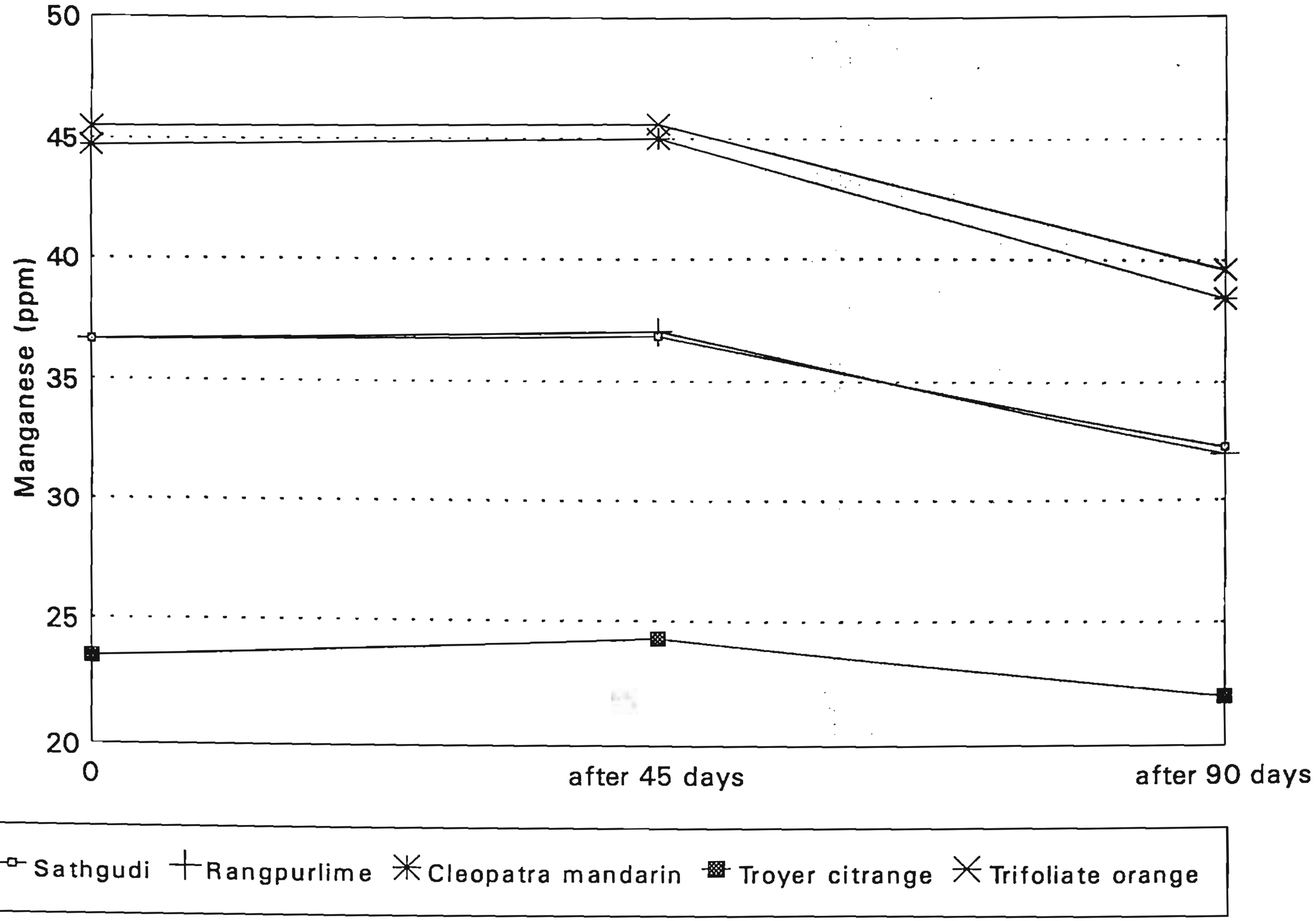
Leaves of Sathgudi sweet orange on Rangpur lime and Troyer citrange rootstocks showed similar levels of nutrients i.e high concentration before and after 90 days of fertilizer application and excess after 45 days of fertilizer application. On the other hand, Cleopatra mandarin and Trifoliate orange rootstocks showed high levels of Cu in their leaves at the periods of sampling. But Sathgudi had optimum leaf Cu concentration before and after 90 days of fertilizer application and it was high at 45 days of fertilizer application (Fig. 9).

4.3.3.4 Manganese. The differences in leaf Mn content of Sathgudi Sweet Orange on different rootstocks were highly significant at all periods from fertilizer application. The leaf Mn content fell in the optimal range (Table 1) and varied from 23.5 to 45.5, 24.3 to 45.6 and 22.1 to 39.6 ppm before, and after 45 and 90 days after fertilizer application respectively.

Initially, Trifoliate orange had the highest leaf Mn content (45.5 ppm) and was at par with Cleopatra mandarin (44.7) followed by Rangpur lime which had significantly lower leaf Mn content (36.6) compared to Trifoliate and was at par with Sathgudi while Troyer citrange recorded the least (23.5 ppm) among all the rootstocks.

After 45 days after fertilizer application, Trifoliate orange contained the highest leaf Mn content (45.6 ppm) and was statistically at par with Cleopatra mandarin (45.0) followed by Rangpur lime (37.0) which was at par with Sathgudi while Troyer citrange had significantly least Mn content (24.3) among all the rootstocks.

Fig.10 : Concentration of manganese in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



After 90 days after fertilizer application, Trifoliate orange maintained highest leaf Mn (39.6 ppm) and was on par with Cleopatra mandarin (38.4) followed by Sathgudi (32.3) which was at par with Rangpur lime while Troyer citrange recorded significantly lowest Mn content (22.1) among all the rootstocks.

Sathgudi sweet orange leaves on all the rootstocks had optimum levels of Mn except Troyer citrange which had low concentration of Mn in its leaves at all the periods from fertilizer application (Fig. 10).

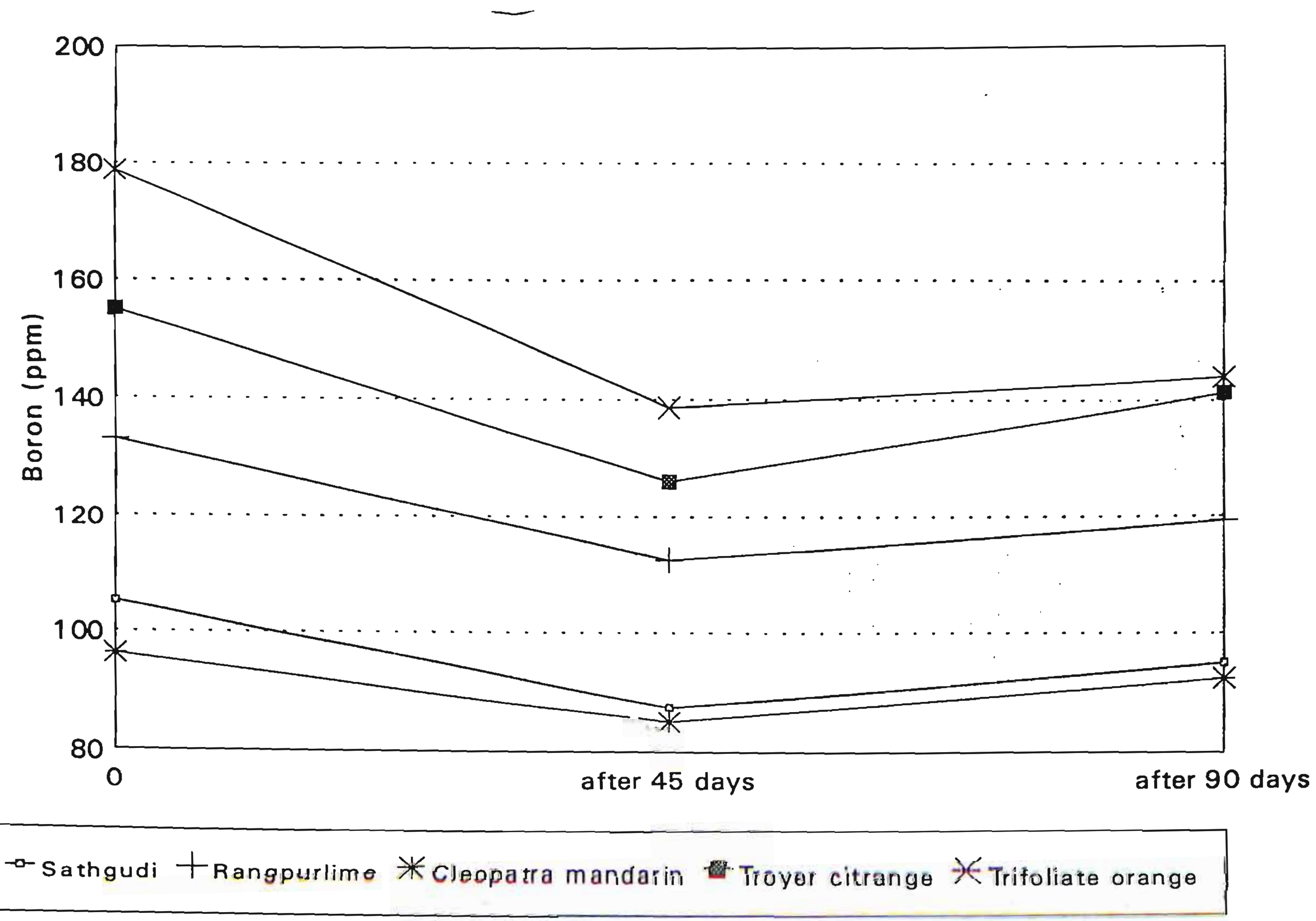
4.3.3.5 Boron. The results indicated that highly significant differences in the leaf boron content among different rootstocks at all periods from fertilizer application.

At the initial period, Trifoliate orange had significantly highest leaf B concentration (178.8 ppm) followed by Troyer citrange (155) and Rangpur lime (133.3). Cleopatra recorded the least B concentration (96.3) and was at par with Sathgudi (105 ppm).

After 45 days of fertilizer application, Trifoliate orange had significantly highest leaf boron concentration (138.8 ppm) which was at par with Troyer citrange followed by Rangpur lime whereas least was recorded in Cleopatra (85 ppm) and was on par with Sathgudi.

After 90 days of fertilizer application also, significantly highest leaf B concentration was maintained in Trifoliate orange (143.8 ppm) which was on par

Fig.11 : Concentration of boron in leaves of Sathgudi sweet orange on different rootstocks before and after fertilizer application



with Troyer citrange (141.3) followed by Rangpur lime while Cleopatra had the least (92.5) which was at par with Sathgudi.

Sathgudi sweet orange on Rangpur lime, Troyer citrange and Cleopatra rootstocks showed higher concentration of B in its leaves before and after fertilizer application whereas on Cleopatra mandarin rootstock, the B concentration was optimum at all the three periods of sampling. Sathgudi sweet orange on its own rootstock behaved differently and had high concentration of B in its leaves before fertilizer application but fell to optimum level after fertilizer application (Fig. 11).

4.4 FRUIT ANALYSIS

4.4.1 Physical Characteristics of Sathgudi Sweet Orange Fruits on Different Rootstocks

The data on the fruit physical characteristics of Sathgudi sweet orange on different rootstocks is furnished in table 14. (Fig 12)

4.4.1.1 Fruit weight. The results indicated that highly significant differences in Sathgudi fruit weight on different rootstocks. Significantly highest fruit weight of 189.67g was recorded in the fruits on Rangpur lime rootstock which was at par with Sathgudi, Cleopatra mandarin and Troyer citrange rootstock while Trifoliate orange rootstock recorded the least of 145.86g.

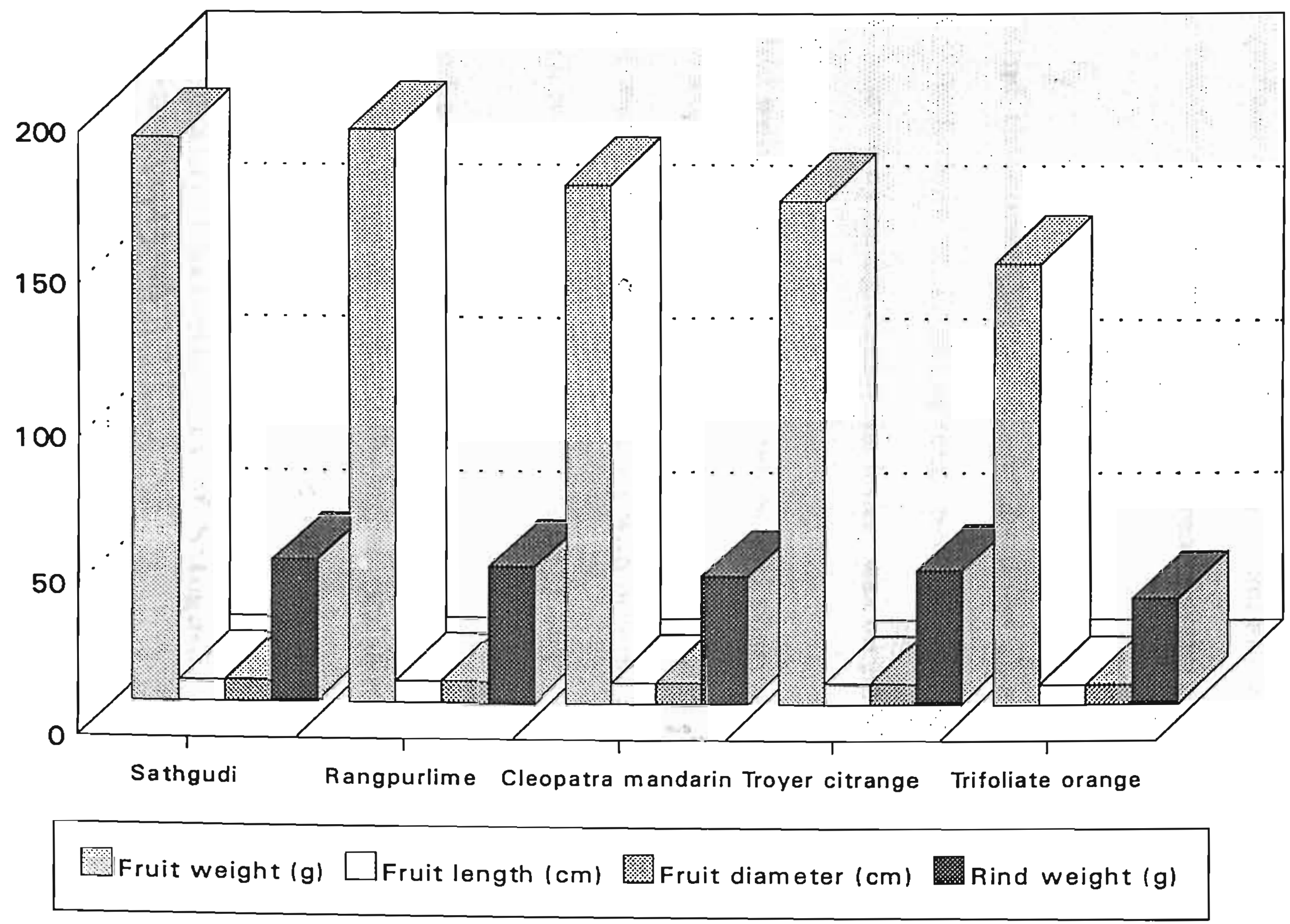
4.4.1.2 Fruit length. Highly significant differences were observed in the fruit length of sweet orange on different rootstocks. Fruits on Rangpur lime and Sathgudi rootstocks recorded highest fruit length (6.89 cm) and were at par with Troyer citrange (6.79) and Cleopatra rootstock (6.76). Fruits on Trifoliate orange

Table 14 : Effect of different rootstocks on the fruit physical characters of Sathgudi sweet orange

Treatment	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Rind thickness (mm)	Rind wight (g)	Rind percentage (%)
Sathgudi	186.89	6.89	7.00	0.40	47.59	5.02
Rangpurlime	189.67	6.89	7.11	0.36	45.45	4.89
Cleopatra mandarin	171.26	6.76	6.75	0.38	42.44	4.97
Troyer citrange	166.25	6.79	6.81	0.41	44.56	5.18
Trifoliate orange	145.86	6.40	6.43	0.33	35.06	4.91
F test	**	**	**	NS	*	NS
SEm	12.05	0.15	0.17	3.81	3.94	0.11
CD	26.03	0.33	0.38	-	8.52	-

NS Non significant
** Significant at 5% level
* Significant at 1% level

Fig. 12 : Fruit physical characters of Sathgudi sweet orange on different rootstocks



rootstock recorded significantly lowest fruit length (6.4) among all the rootstocks.

4.4.1.3 Fruit diameter. Sathgudi sweet orange on different rootstocks showed highly significant differences in fruit diameter. Fruits on Rangpurlime rootstock showed significantly highest fruit diameter (7.11 cm) and was at par with others except on Trifoliate orange rootstock which recorded the least fruit diameter of 6.43.

4.4.1.4 Rind thickness. Rootstocks did not differ significantly in the rind thickness of fruit. However, Troyer citrange recorded the highest rind thickness (0.41 mm) followed by Sathgudi and the lowest was on Rangpur lime (0.36).

4.4.1.5 Rind weight. Significant differences were observed in the rind weight of Sathgudi sweet orange on different rootstocks. Sathgudi recorded significantly highest rind weight (47.59g) and was at par with others except with Trifoliate orange which recorded the lowest rind weight of 35.06g.

4.4.1.6 Rind percentage. Rootstocks did not differ significantly in the rind percentage of fruits. However, numerically highest rind percentage was recorded on Troyer citrange (5.18 per cent) and least was with Rangpur lime (4.89).

4.4.2 Fruit Quality Characteristics of Sathgudi Sweet Orange on Different Rootstocks

The data on fruit quality characters of Sathgudi sweet orange on different rootstocks is furnished in table 15 (Fig. 13).

Table 15 : Effect of different rootstocks on fruit quality characters in Sathgudi Sweet orange

Treatment	No.of Segments	No.of seeds	Seed weight (g)	Juice volume (ml)	Juice weight (g)	Juice (%)	Rag weight (g)	Rag (%)
Sathgudi	10.39	17.36	1.09	95.82	106.85	7.14	35.08	4.33
Rangpurlime	10.39	19.81	1.39	100.47	104.16	7.28	35.49	4.31
Cleopatra mandarin	10.48	21.06	2.40	85.56	87.15	7.07	32.30	4.33
Troyer citrange	10.60	22.46	1.17	76.83	79.43	6.79	34.14	4.53
Trifoliate orange	10.83	22.83	0.93	64.23	67.48	6.57	30.87	4.65
F test	NS	NS	**	**	**	*	NS	NS
SEm	0.21	2.35	0.15	8.75	7.27	0.23	2.10	0.15
CD	-	-	0.33	18.91	15.7	0.51	-	-

NS Non significant
* Significant at 5% level
** Significant at 1% level

4.4.2.1 Number of segments. Rootstocks did not differ significantly in the number of segments in fruits. However, the number of segments ranged from 10.39 to 10.83 and Trifoliate orange recorded highest number of segments (10.83) followed by Troyer citrange (10.60) and with the least being in Sathgudi and Rangpur lime (10.39).

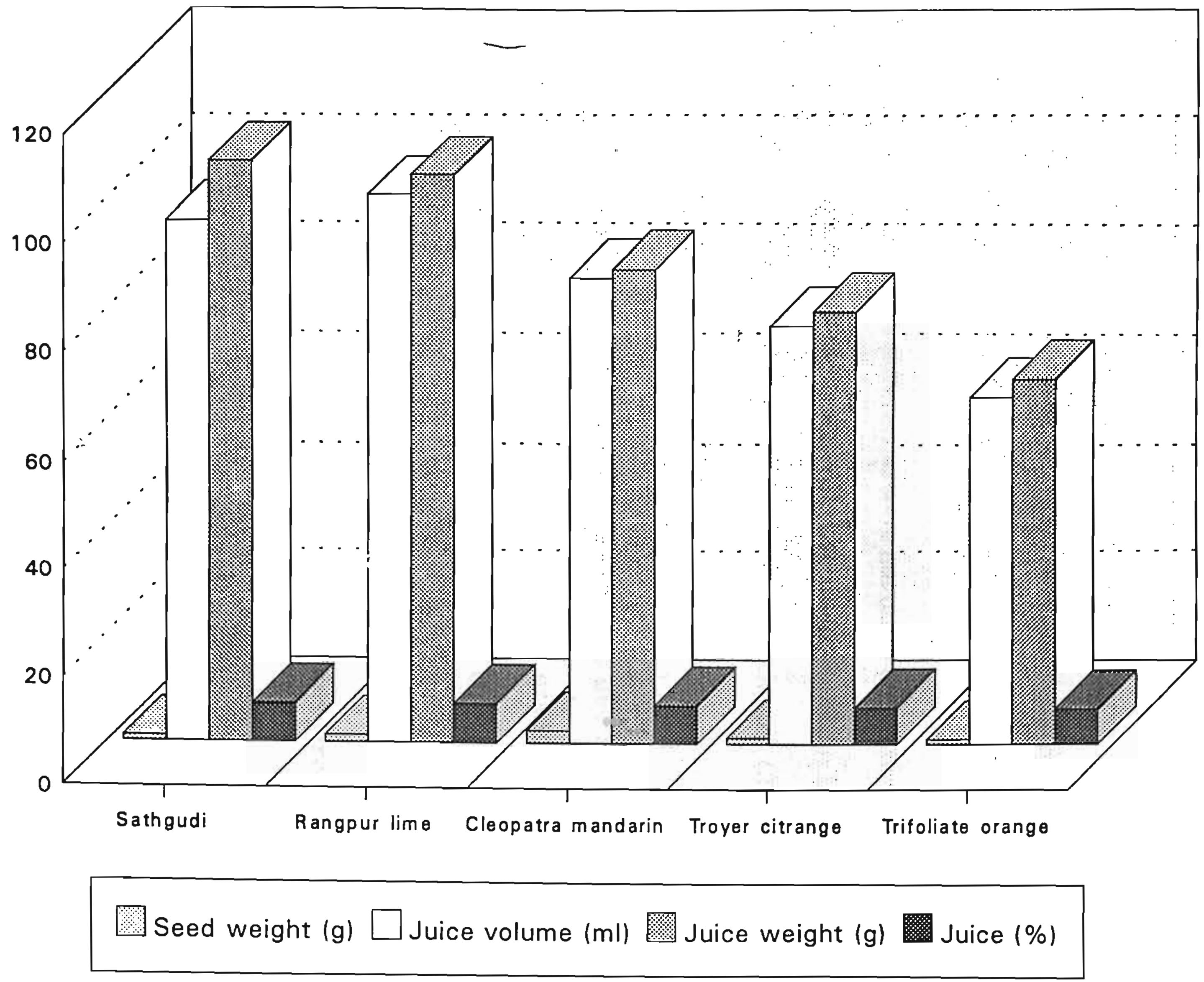
4.4.2.2 Number of seeds. Rootstocks did not show any significant difference in the seed number which ranged from 17.36 to 22.83. However, Trifoliate orange recorded numerically highest seed number (22.83) followed by Troyer citrange (22.46) while Sathgudi recorded the least (17.36).

4.4.2.3 Seed weight. The results indicated that highly significant differences in seed weight of fruits on different rootstocks and ranged from 0.93 to 2.40 g. Significantly greater seed weight of 2.40 g was recorded in Cleopatra mandarin. Rangpur lime showed significantly lower seed weight compared to Cleopatra mandarin and was at par with Troyer and Sathgudi while Trifoliate orange had significantly lowest seed weight of 0.93 g.

4.4.2.4 Juice volume. Differences were highly significant in the juice volume of Sathgudi sweet orange on different rootstocks and ranged from 64.23 to 100.47 ml. Significantly highest juice volume was recorded on Rangpur lime (100.47 ml) and was at par with Sathgudi and Cleopatra mandarin while the least was recorded on Trifoliate orange (64..23) which was at par with Troyer citrange.

4.4.2.5 Juice weight. The results indicated that highly significant differences in juice weight among different rootstocks, Sathgudi had significantly highest

Fig.13 : Fruit quality characters in Sathgudi sweet orange on different root stocks



juice weight (106.85g) which was at par with Rangpur lime (104.16) followed by Cleopatra (85.56). Lowest juice weight was observed in Trifoliate orange (67.48) and was at par with Troyer citrange.

4.4.2.6 Juice percentage. The results indicated that significant differences in juice percentage of Sathgudi sweet orange were recorded on different rootstocks, significantly highest juice percentage was noted on Rangpur lime (7.28 per cent) and was at par with the others except with Trifoliate orange which had the least juice percentage (6.57) was observed.

4.4.2.7 Rag weight. Significant differences were not observed in the rag weight of Sathgudi sweet orange on different rootstocks. However, Rangpur lime showed numerically highest rag weight (35.49 g) followed by Sathgudi (35.08) while Trifoliate orange recorded the least (30.87 g).

4.4.2.8 Rag percentage. No significant differences were observed in the rag percentage among different rootstocks. However, Trifoliate orange recorded the highest value (4.65 per cent) followed by Troyer citrange while lowest was in Rangpur lime (4.31).

4.4.3 Chemical Characters and Yield of Sathgudi Sweet Orange Fruits on Different Rootstocks

Data on the chemical characteristics and yield of the fruits is furnished in Table 16 (Fig. 14).

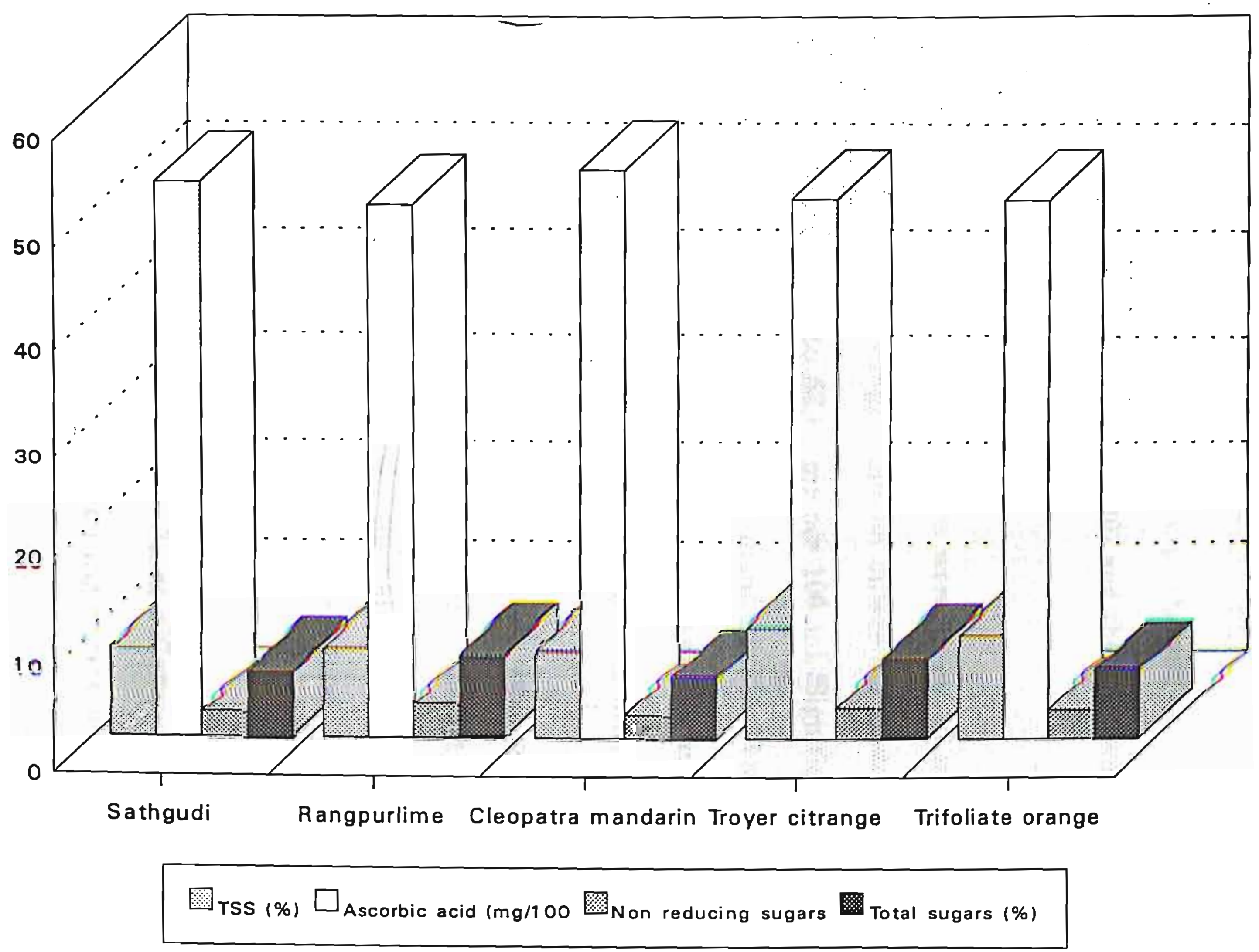
4.4.3.1 Total soluble solids (TSS). The results indicated that there were significant differences in TSS content of Sathgudi sweet orange on different

Table 16 : Effect of different rootstocks on fruit chemical characters and yield in Sathgudi sweet orange

Treatment	TSS (%)	Acidity (%)	Ascorbic acid (mg/100 ml juice)	Reducing sugar (%)	Non-reducing sugars (%)	Total sugars (%)	yield (no)	Yield (wt kg)
Sathgudi	8.34	1.40	52.60	3.71	2.45	6.17	198.57	26.80
Rangpurlime	8.46	1.13	50.48	4.39	3.37	7.79	251.76	40.39
Cleopatra mandarin	8.29	1.18	53.83	3.31	2.22	5.53	155.45	25.53
Troyer citrange	10.51	1.33	51.14	4.14	2.98	7.55	254.79	31.64
Trifoliate orange	9.71	1.58	51.17	3.85	2.78	6.33	227.75	23.59
F test	*	NS	*	NS	**	**	NS	NS
SEm	0.94	0.25	1.12	0.45	0.23	0.43	60.30	7.61
CD	2.03	-	2.43	-	0.50	0.93	-	-

NS Non significant
** Significant at 5% level
* Significant at 1% level

Fig.14 : Fruit chemical characters in Sathgudi sweet orange on different root stocks



rootstocks. TSS content ranged from 8.29 to 10.51 per cent. Troyer citrange recorded the highest TSS (10.51) which was at par with Trifoliate orange (9.71) while the lowest was in Cleopatra mandarin (8.29) and was at par with others.

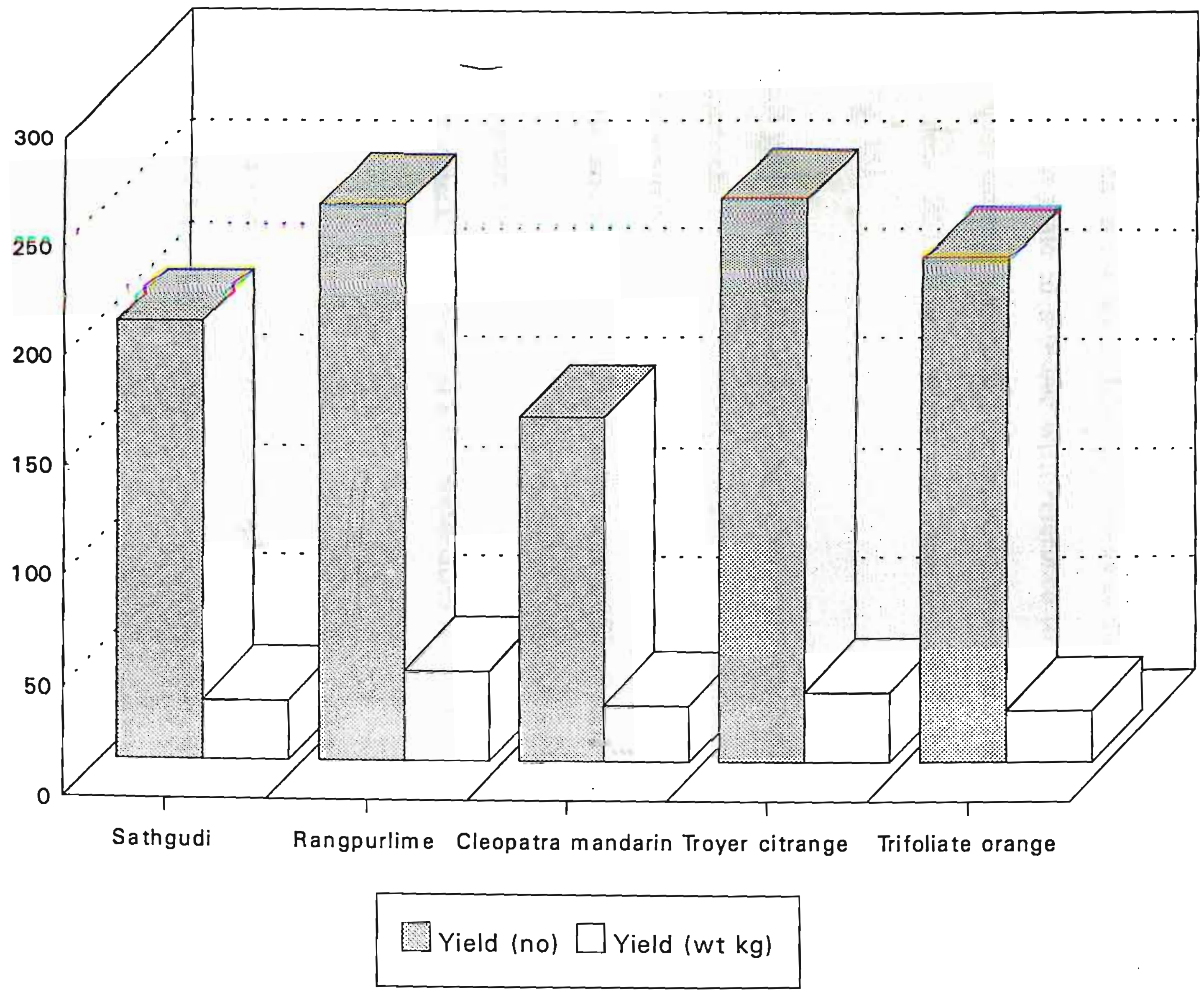
4.4.3.2 Acidity. Different rootstocks did not result in any significant differences in the acidity of fruits. However, Trifoliate orange showed numerically higher value (1.58 per cent) followed by Sathgudi (1.40) and the least was recorded by Rangpur lime (1.13).

4.4.3.3 Ascorbic acid. Significant differences were observed in the ascorbic acid content of Sathgudi sweet orange fruits on different rootstocks. Ascorbic acid content ranged from 50.48 to 53.83 mg per 100 ml. Significantly highest ascorbic acid content was recorded on Cleopatra mandarin (53.83 mg per 100 ml) and was at par with Sathgudi (52.60) while the lowest ascorbic acid content was observed in Troyer citrange (51.14) which was at par with others.

4.4.3.4 Reducing sugars. No significant differences were observed among different rootstocks in the reducing sugar content of sweet orange fruits. However, Rangpur lime recorded numerically higher per cent of reducing sugars (4.39) followed by Troyer citrange (4.14) while the least was observed in Cleopatra mandarin (3.31).

4.4.3.5 Non-reducing sugars. Highly significant differences were observed among different rootstocks in per cent non-reducing sugar content of the fruits. Rangpur lime had significantly highest percentage of non-reducing sugars (3.37) and was at par with Troyer citrange (2.98) followed by Trifoliate (2.78) while Cleopatra mandarin had the least (2.22) which was at par with Sathgudi (2.45).

Fig. 15 : Fruit yield of Sathgudi sweet orange on different root stocks



4.4.3.6 Total Sugars. Different rootstocks resulted in highly significant differences in the total sugar content of fruits on different rootstocks. Rangpur lime showed significantly highest total sugar content (7.79 per cent) which was at par with Troyer citrange (7.55) whereas the least was observed on Cleopatra mandarin (5.53) which was at par with Trifoliate orange and Sathgudi.

4.4.3.7 Fruit yield (number). Different rootstocks did not result in significant differences in fruit yield in number with reference to Sathgudi sweet orange. However, Troyer citrange recorded numerically highest value (254.79) followed by Rangpur lime (251.76) and least was recorded on Cleopatra mandarin (155.45). (Fig 15)

4.4.3.8 Fruit yield (weight). Significant differences were not observed among different rootstocks in the fruit yield (weight) of Sathgudi sweet orange and Rangpur lime recorded numerically highest yield of 40.39 kg followed by Troyer citrange (31.64) and least was on Trifoliate orange (23.59 kg).

On summarization of all the yield and quality attributes of sweet orange on different rootstocks exhibited the characteristics as follows.

Sathgudi

It recorded more fruit length, rind weight and juice weight and less seed number and segment number.

Rangpurlime

Higher fruit weight, length, diameter, juice volume, juice percentage, rag weight, reducing, non-reducing and total sugars and yield by weight were observed on it while rind thickness and percentage, rag percentage, acidity, ascorbic acid content were the least.

Cleopatra mandarin

It recorded high seed weight and ascorbic acid content and least TSS, reducing, non-reducing and total sugars and yield (number).

Troyer citrange

It recorded more rind percentage, TSS and yield (number).

Trifoliate orange

It recorded more rind thickness, segment number, seed number and acidity while fruit weight, length, diameter, rind weight, seed weight, juice volume, juice weight, juice percentage, rag weight and yield by weight were less.

4.5 CORRELATION ANALYSIS

4.5.1 Correlation Co-efficients between Soil Physico-chemical Parameters and Soil Available Nutrients

Simple correlation coefficients worked out between soil pH, EC and soil nutrients after fertilizer application are presented in table 17.

Significant positive correlation was observed between soil pH and Mn (0.460*) where as the rest of the correlations were non-significant. EC showed significant correlations with soil nutrients. Significant positive correlation was

Table 17 : **Correlation coefficients of soil pH, EC with soil nutrients**

Soil Parameters	Soil nutritients											
	EC	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
pH	-0.158	-0.328	-0.332	-0.262	-0.069	0.067	0.263	0.073	-0.353	0.015	0.460*	0.134
Ec	-	0.437	-0.072	0.676**	0.547*	0.218	-0.043	0.344	-0.485*	0.212	-0.079	0.003

* Significant at 5% level.
** Significant at 1% level.

Table 19 : Correlation coefficients between soil physico-chemical parameters and leaf nutrients

Soil physico-chemical parameters	Leaf nutrients										
	N	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**Fe**	**Cn**	**Mn**	**B**
	After 45 days period										
pH	0.062	0.149	0.341	0.363	0.052	0.358	-0.006	0.071	0.128	0.22	0.008
EC	-0.299	0.266	-0.358	-0.283	0.236	-0.468*	-0.126	0.080	-0.127	0.061	0.177
	After 90 days period										
pH	0.126	0.128	0.283	-0.158	-0.002	0.068	0.015	-0.065	0.201	0.140	-0.045
EC	0.056	0.046	-0.249	-0.073	0.035	0.133	0.355	-0.012	-0.155	0.053	0.212

* Significant at 5% level.

obtained with K and Ca (0.676** and 0.547* respectively) while significant negative correlation was obtained with Fe (-0.485*).

4.5.2 Correlation Coefficients between Soil Physico-chemical Parameters and Leaf Nutrients

The correlation coefficients worked out between soil pH, EC and soil nutrients after 45 and 90 days after fertilizer application are presented in table 18.

Among all the correlations worked out, significant negative correlation was obtained between soil EC and soil S (-0.468*) after 45 days period and the rest of the correlations were found to be non-significant.

4.5.3 Correlation Coefficients between Soil and Leaf Nutrients

Simple correlation coefficients worked out between soil nutrients after fertilizer application and leaf nutrients after 45 days after fertilizer application are presented in table 19.

Significant positive correlation was observed between soil N and leaf Mg (0.446*). Phosphorus showed significant positive correlation with Zn (0.497*) while highly significant negative correlation was observed between soil P and leaf Cu (-0.712**).

Significant negative correlation was observed between soil Ca and leaf S (-0.483*). Soil S showed highly significant positive and negative correlations of 0.562** and -0.742** with leaf S and Cu respectively, while significant positive

Table 19 : Correlation coefficients between soil nutrients and leaf nutrient content after 45 days of fertilizer application

Soil nutrients	Leaf nutrients										
	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	-0.204	-0.037	-0.148	-0.133	0.446*	-0.188	0.095	0.043	-0.080	-0.164	0.257
P	0.003	0.266	0.288	0.171	-0.320	0.214	0.497*	-0.177	-0.712**	0.122	-0.226
K	-0.311	0.323	-0.177	-0.189	0.086	-0.351	0.198	0.130	-0.374	0.099	0.121
Ca	-0.213	-0.047	-0.222	-0.143	0.025	-0.483*	-0.044	-0.164	-0.008	0.115	0.318
Mg	-0.076	0.005	0.207	0.149	-0.232	-0.243	0.205	-0.514*	-0.292	-0.058	-0.162
S	0.142	0.369	0.517*	0.460*	-0.208	0.562**	0.399	0.156	-0.742**	0.326	-0.306
Zn	-0.244	0.434	0.120	0.098	0.163	0.022	0.190	-0.040	-0.261	-0.145	-0.059
Fe	0.334	-0.093	0.431	0.339	-0.024	0.137	0.223	-0.180	0.026	-0.489*	-0.380
Cu	0.148	0.419	0.194	0.220	-0.031	0.129	0.210	0.031	-0.277	-0.128	-0.052
Mn	0.301	0.092	-0.017	0.035	-0.537	0.131	-0.218	-0.174	0.202	0.576	-0.082
B	-0.009	0.092	-0.051	-0.093	-0.085	-0.014	-0.094	0.124	0.060	0.087	0.138

* Significant at 5% level.
** Significant at 1% level.

correlation coefficients of 0.517* and 0.460* were obtained with K and Ca respectively.

Among the soil micronutrient, only soil Fe showed significant negative correlation with Mn (-0.489).

Simple correlation coefficients worked out between soil nutrients after fertilizer application and leaf nutrients after 90 days after fertilizer ampliation are presented in table 20.

The correlations showed that N had significant positive correlation with Ca, Mg and Zn. Among these, the highest positive significant correlation was obtained with Ca (0.558*) followed by Mg (0.475*) and Zn (0.454*). Highly significant negative correlation was observed between soil P and leaf Cu (-0.744**).

Calcium showed significant negative correlation with K (-0.530*) while significant positive and negative correlations were obtained for soil S with leaf K (0.550*) and Cu (-0.711*) respectively.

Of the soil micronutrients, significant positive correlations were observed between soil Cu with leaf S (0.449*) and soil Mn and leaf Mn (0.535*).

4.5.4 Correlation Coefficients Among the Leaf Nutrients

Simple correlation coefficients worked out among the leaf nutrients after 45 days after fertilizer application are presented in table 21.

Table 20: Correlation coefficients between soil nutrients and leaf nutrient content after 90 days of fertilizer application

Soil nutrients	Leaf nutrients										
	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	0.334	-0.331	-0.217	0.558*	0.475*	-0.281	0.454*	0.103	-0.054	-0.100	0.198
P	-0.135	-0.246	0.164	0.339	-0.082	0.082	0.432	0.040	-0.744**	0.194	-0.278
K	0.019	0.010	-0.438	0.368	-0.135	-0.069	0.378	0.308	-0.347	0.181	0.161
Ca	-0.154	-0.087	-0.530*	0.335	0.075	-0.364	0.260	0.108	0.039	0.158	0.316
Mg	0.005	0.067	-0.186	0.191	-0.175	-0.158	0.325	-0.048	-0.303	-0.027	-0.070
S	-0.168	-0.163	-0.550*	0.129	-0.272	0.247	0.256	0.029	-0.711**	0.267	-0.386
Zn	0.353	0.078	0.267	-0.105	0.254	0.154	0.348	-0.211	-0.254	-0.114	-0.095
Fe	0.174	0.163	0.322	0.084	0.201	-0.258	-0.020	-0.262	0.041	-0.391	-0.334
Cu	0.422	0.262	0.144	-0.043	-0.375	0.449*	0.045	0.205	-0.373	-0.079	-0.051
Mn	-0.231	-0.033	-0.212	-0.121	-0.294	0.072	-0.113	-0.095	0.080	0.535*	-0.143
B	-0.171	-0.054	0.216	-0.410	0.134	0.184	-0.124	0.059	-0.092	-0.011	0.136

* Significant at 5% level.
** Significant at 1% level.

Table 21 : Correlation coefficients among leaf nutrients after 45 days of fertilizer application

Leaf nutrients	Leaf nutrients									
	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	-0.076	0.528*	0.632**	-0.440	0.064	0.063	-0.257	-0.018	0.022	-0.206
P		0.261	0.060	-0.227	0.253	0.521*	0.175	-0.295	0.261	-0.235
K			0.909	-0.213	0.459*	0.562**	-0.379	-0.344	-0.231	-0.269
Ca				-0.088	0.343	0.259	-0.399	-0.281	-0.259	-0.213
Mg					-0.027	-0.315	0.268	0.297	-0.429	0.211
S						0.191	0.085	-0.100	0.194	-0.250
Zn							-0.003	-0.499*	-0.001	0.122
Fe								0.049	0.425	0.156
Cu									-0.266	0.194
Mn										-0.155

* Significant at 5% level.
** Significant at 1% level.

Table 22 : **Correlation coefficients among leaf nutrients after 90 days of fertilizer application**

Leaf nutrients	Leaf nutrients									
	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	0.049	-0.001	0.037	0.033	0.188	0.088	0.100	0.163	-0.200	-0.207
P		0.026	-0.333	-0.113	0.423	-0.029	-0.006	0.257	-0.121	0.111
K			-0.368	0.012	0.083	0.239	-0.346	-0.217	-0.130	-0.478*
Ca				0.053	-0.174	0.196	0.414	-0.244	0.127	0.206
Mg					-0.409	0.125	-0.426	0.347	-0.382	0.372
S						0.235	0.190	-0.200	0.401	-0.050
Zn							-0.078	-0.335	0.299	-0.138
Fe								-0.028	0.230	0.214
Cu									-0.145.	0.321
Mn										-0.266

* Significant at 5% level.

Significant positive correlation coefficients were obtained for N, P, K with other nutrients. Highly significant positive correlation was observed between N and Ca (0.632**) followed by N and K (0.528*) and P and Zn (0.521*) while K showed highly significant positive correlation with Zn (0.562**) followed by S (0.459*).

Zinc showed significant negative correlation only with Cu (-0.499*).

Simple correlation coefficients worked out among the leaf nutrients after 90 days after fertilizer application are presented in table 22.

Among all the correlations, only potassium showed significant negative correlation with B (-0.478*) while the rest were non-significant.

4.5.5 Correlation Coefficients between Soil Nutrients and Leaf Nutrients of Sathgudi Sweet Orange on Different Rootstocks after Fertilizer Application.

Correlation coefficients between soil nutrients and leaf nutrients of Sathgudi sweet orange on different rootstocks after fertilizer application were worked out and the results are furnished below rootstock wise.

Sathgudi

Soil N and P had significant positive correlation with leaf Mg (0.787*) and Ca (0.757*) respectively (Table 23). While the soil Mg had negative association with leaf nitrogen (-0.787*). Soil S had significant positive relationship with leaf P (0.764**) and among the micronutrients soil Zn, Cu and Mn had positive

Table 23 : **Correlation coefficients between soil and leafnutrients of Sathgudi sweet orange on Sathgudi rootstock after fertilizer application**

Soil nutrients	Leaf nutrients										
	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	0.428	0.018	-0.039	-0.129	0.787*	0.355	0.131	0.311	0.183	0.166	-0.459
P	0.018	0.700	0.507	0.757*	0.235	0.430	0.103	-0.162	0.425	0.407	-0.247
K	-0.039	-0.071	0.622	0.043	-0.357	-0.124	-0.159	0.677	-0.518	-0.231	0.001
Ca	-0.147	0.127	-0.695	0.082	-0.039	-0.251	-0.456	-0.029	0.214	0.314	0.013
Mg	-0.787*	0.104	-0.329	0.129	-0.246	0.179	0.214	0.595	-0.241	-0.387	0.117
S	0.399	0.764*	0.375	0.458	-0.127	0.326	0.059	0.128	0.367	0.592	-0.486
Zn	0.420	0.862**	0.325	0.432	0.511	0.326	0.159	0.260	0.288	0.560	0.400
Fe	0.390	0.413	0.686	0.071	-0.018	0.447	0.234	-0.519	0.541	0.529	-0.155
Cu	0.377	0.719*	-0.022	0.527	-0.463	0.282	0.059	0.507	0.185	0.455	-0.516
Mn	0.556	0.774*	0.397	0.307	-0.266	0.510	0.339	0.489	0.677	0.524	-0.351
B	-0.273	0.493	0.474	0.052	0.226	-0.309	0.237	0.605	0.131	0.196	0.489

* Significant at 5% level
** Significant at 1% level

Table 24 : Correlation coefficients between soil and leaf nutrients of Sathgudi sweet orange on Rangpur lime rootstock after fertilizer application

Soil nutrients	Leaf nutrients										
	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	0.914**	0.460	0.032	-0.000	-0.089	-0.304	0.599	0.507	-0.270	0.050	-0.172
P	0.799*	0.494	0.665	0.463	-0.621	-0.457	-0.221	0.108	0.343	0.079	-0.662
K	-0.116	0.342	-0.387	-0.169	-0.111	0.159	-0.207	0.248	-0.135	-0.078	0.273
Ca	0.281	-0.160	0.150	0.680	-0.636	-0.689	-0.404	-0.712*	0.470	0.758*	-0.544
Mg	0.037	0.417	0.006	0.488	-0.561	-0.481	-0.379	-0.846**	0.248	0.686	-0.424
S	0.277	0.376	-0.068	0.100	0.095	0.284	-0.640	-0.140	0.320	0.378	0.426
Zn	0.839**	0.644	0.437	0.450	-0.480	-0.436	-0.416	0.151	0.493	0.277	-0.410
Fe	0.015	0.104	0.195	0.383	-0.608	-0.453	0.111	-0.184	-0.124	0.148	-0.578
Cu	0.829*	0.866**	-0.195	0.386	-0.675	-0.311	-0.124	0.044	0.295	0.079	-0.060
Mn	0.140	0.079	-0.199	0.674	-0.504	-0.025	-0.512	-0.590	0.663	0.711*	0.092
B	0.560	0.706*	0.264	-0.285	0.095	0.329	0.271	0.615	-0.240	-0.629	-0.026

* Significant at 5% level
** Significant at 1% level

associations with leaf P (0.862**, 0.719* and 0.774) and the rest of the association were statistically nonsignificant.

Rangpur lime

The macronutrients, of N and P in the soil had significant positive relationship with leaf N (0.914* and 0.799*) (Table 24). Calcium and magnesium of soil had negative relationship with leaf Fe (-0.712* and -0.846**) but soil Ca had positive relationship with leaf Mn (0.758*). The micronutrients ie Zn and Cu in the soil had significant positive association with leaf N (0.839** and 0.829*) whereas soil Cu also had positive relationship with leaf P (0.866**). The soil Mn showed positive correlation with leaf Mn (0.711*). Soil B showed significant positive correlation with leaf P (0.706*).

Cleopatra mandarin

Soil P had significant negative association with leaf K (-0.817*) while soil K had significant positive association with leaf N (0.758*) (Table 25). Ca in soil had negative relationship with Mg in leaf (-0.722*) while Mn in the soil had positive association with leaf N (0.709*). Soil Fe showed significant positive correlation with leaf Cu (0.785*).

Troyer citrange

Nitrogen in the soils had significant negative relationship with P (-0.753*) while Zn in leaves had positive association (0.899**) (Table 26). But P in soil had negative correlation with leaf Fe (-0.801*). Soil K showed significant negative relationship with leaf S (-0.791*). Among the micronutrients, the soil Fe and Cu

Table 25 : Correlation coefficients between soil and leaf nutrients of Sathgudi sweet orange on Cleopatra mandarin rootstock after fertilizer application

Soil nutrients	Leaf nutrients										
	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	-0.221	0.192	-0.163	0.234	-0.169	0.474	0.241	-0.167	0.352	0.418	-0.210
P	0.388	0.186	-0.817*	-0.099	-0.310	0.116	0.242	0.318	0.156	0.170	0.155
K	0.758*	-0.104	0.273	0.553	-0.530	0.402	0.186	-0.151	0.106	0.446	-0.551
Ca	0.569	-0.079	-0.279	0.499	-0.722*	-0.189	0.258	0.278	0.080	0.284	0.032
Mg	0.259	0.359	-0.234	0.183	-0.376	-0.235	-0.056	-0.398	0.260	0.605	-0.196
S	-0.520	0.039	0.176	-0.131	0.010	0.196	-0.285	0.496	-0.293	-0.140	0.082
Zn	-0.262	0.427	-0.617	-0.502	-0.113	-0.355	-0.323	0.229	0.579	0.181	-0.013
Fe	0.359	0.530	0.115	0.038	0.197	-0.396	-0.245	0.392	0.785	0.530	-0.592
Cu	0.490	0.411	-0.016	-0.273	-0.541	-0.151	-0.057	0.057	0.265	0.399	0.017
Mn	0.709*	0.246	0.292	0.532	-0.437	0.298	0.176	-0.161	0.055	0.604	-0.462
B	0.402	0.239	0.239	-0.654	-0.195	-0.139	-0.294	0.496	-0.405	-0.639	0.645

* Significant at 5% level

Table 26 : Correlation coefficients between soil and leafnutrients of Sathgudi sweet orange on Troyer citrange rootstock after fertilizer application.

Soil nutrients	Leaf nutrients										
	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	0.689	-0.753*	-0.171	0.616	0.940**	-0.134	0.899**	0.064	-0.119	-0.481	0.073
P	0.207	0.406	0.692	-0.237	-0.047	0.009	0.014	-0.801*	0.308	0.215	0.019
K	0.344	0.206	0.128	-0.003	0.403	-0.791*	0.568	-0.517	0.408	0.090	-0.684
Ca	0.015	-0.329	-0.594	0.223	0.624	-0.665	0.444	-0.087	-0.033	-0.328	0.511
Mg	0.264	-0.326	0.041	0.131	0.623	-0.666	0.341	-0.087	0.009	-0.296	0.168
S	0.215	0.342	0.450	0.182	-0.318	0.298	-0.089	-0.111	-0.425	-0.203	0.568
Zn	0.459	-0.049	0.525	0.046	0.433	-0.139	0.445	-0.532	-0.095	-0.103	0.107
Fe	-0.147	0.281	0.656	-0.667	-0.025	0.078	-0.121	0.132	0.795*	0.805*	0.441
Cu	0.082	0.734*	0.603	-0.247	-0.172	0.342	-0.049	-0.227	-0.047	0.170	0.360
Mn	-0.314	0.691	0.503	-0.552	-0.365	-0.484	0.336	-0.696	0.448	0.422	-0.561
B	-0.423	0.359	-0.380	-0.121	-0.174	-0.712	-0.181	-0.552	-0.019	0.143	-0.477

* Significant at 5% level
** Significant at 1% level

Table 27 : Correlation coefficients between soil and leafnutrients of Sathgudi sweet orange on Trifoliate orange rootstock after fertilizer application

Soil nutrients	Leaf nutrients										
	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
N	-0.054	0.078	0.559	-0.020	-0.055	-0.076	-0.039	-0.707*	-0.086	-0.420	0.055
P	0.079	0.238	0.168	-0.109	-0.385	-0.427	-0.257	-0.629	-0.482	-0.065	0.169
K	-0.224	-0.176	-0.209	0.197	-0.298	-0.099	0.721*	-0.677	-0.789*	-0.740*	-0.412
Ca	-0.311	-0.083	-0.118	0.171	-0.125	-0.042	0.460	-0.832	-0.719*	-0.704*	-0.203
Mg	-0.132	-0.249	-0.273	0.281	-0.229	-0.216	0.524	-0.630	-0.829*	-0.734*	-0.474
S	0.260	0.387	0.021	-0.559	0.329	0.030	-0.796*	0.400	0.548	0.864**	0.122
Zn	0.114	0.657	0.607	-0.665	0.060	-0.441	-0.278	-0.644	0.174	0.294	-0.341
Fe	0.775*	0.801*	0.196	-0.754*	-0.458	-0.623	-0.482	-0.213	-0.391	0.497	-0.567
Cu	0.828*	0.821*	0.547	-0.821*	-0.516	-0.637	-0.406	-0.195	0.115	0.559	-0.498
Mn	-0.223	-0.007	-0.096	-0.193	0.461	-0.309	-0.609	-0.003	0.232	0.423	0.612
B	0.019	-0.388	-0.303	0.232	0.188	0.070	-0.454	0.622	0.273	0.487	-0.060

* Significant at 5% level
** Significant at 1% level

had significant positive relationship with Cu (0.795*) and P (0.734*) of leaves respectively. Soil N and Fe showed significant positive correlation with leaf Mg (0.940**) and Cu (0.805*) respectively.

Trifoliate orange

The results presented in Table 27 indicated that soil N had significant negative association with leaf Fe (-0.707*) while soil K had significant positive relationship with leaf Zn (0.721*). Soil K, Ca and Mg had significantly negative relationships with leaf Cu and Mn.

Sulphur in the soils had significant negative association with leaf Zn (-0.796*) and positive correlation with leaf Mn (0.864**). Soil Fe and Cu were significantly correlated with leaf N and P positively but negatively with Ca leaves.

Discussion

CHAPTER 5

DISCUSSION

The results furnished in the preceding chapter are discussed in this chapter under different subheads.

5.1 Soil analysis

5.2 Foliar analysis

5.3 Fruit analysis

5.4 Correlation analysis

5.1 SOIL ANALYSIS

5.1.1 Physical and Morphological Characters of Soil

The physical and morphological characteristics of the soil are very important for plant growth. These characteristics determine the fertility status of the soil. The soils of the experimental site are ideal for horticultural crops. The soils are red sandy loams on the surface and tend to be sandy clay towards depth. The soils had subangular blocky structure with fine pores and had good drainage and moisture holding capacity. They are deep and more congenial for root growth. They had ustic moisture regime and argillic horizon in the deeper layers which provide sufficient moisture and available nutrients. No free calcium carbonate was observed in the profile as such it is favourable for citrus plantation. On study of the morphological characters like colour, texture, structure, clay distribution in the profile, they are light soils which are highly responsive for fertilizer application. According to the study of all physical and morphological characteristics as described under results, the soil of the experimental plot is classified under Haplustalf.

5.1.2 Physico-chemical characteristics of the soil

5.1.2.1 Soil reaction. The pH values in the soil varied from 7.0 to 7.4 which was neutral in reaction. Before fertilizer application, the soils showed no significant differences in the pH values whereas after fertilizer application, significant differences were observed only at 15-30 cm depth and showed a slight increase in the soil reaction but fell under the range of neutral. It cannot be attributed to only fertilizer application but may be due to slight differences in sample collection and variations in clay content to some extent which could not be avoided as the soil properties are location specific. However, it suggested that the soils were homogenous in nature. Chapman (1960) considered the pH range of 5.5 to 7.5 to be ideal for optimum citrus growth and the availability of micronutrients was also high in these soils.

5.1.2.2 Electrical conductivity. The salt content of the soils also did not differ significantly and ranged from 0.1 to 0.275 dS m^{-1} and was normal as reported by Chauhan *et al* (1984) and Vijaysankar Reddy (1989). These results further indicated the homogeneity of the soils with respect to soluble salts.

5.1.3 Available Macro-nutrient Status of Soils

5.1.3.1 Nitrogen. The available nitrogen content in the surface soils varied from 205.15 to 286.16 kg ha^{-1} and was low to medium. Significant differences were not exhibited by the soils in their N status before and after fertilizer application. However, the available N status of the soils slightly increased with the fertilizer application and it was just sufficient for the maintenance and productivity of citrus fruits. This revealed the homogeneity of soils in their N content. High leaf Mg was associated with high soil N after 45 days of fertilizer application, high leaf Ca, Mg and Zn were reported with high soil N. It can be attributed to the more synthesis of chlorophyll and absorption of more nutrients associated with the growth of vegetative parts. After 45 days of fertilizer application, leaf N was not associated with soil N which might be due to the differential absorption of N by the rootstock and the utilization of absorbed nutrient for the fruit development. Whereas, after 90 days period, non-significant positive relationship was obtained between soil N and leaf N as reported by Anderson and Albrigo (1977).

5.1.3.2 Phosphorus. Before and after fertilizer application, the differences in the P status of soils were significant and the soil P ranged from 15.1 to 41.9kg ha^{-1}. Of all the basins, it was noted that P status was high in Sathgudi basins and least in Jambheri basins. It was also observed that the available P status in these soils gradually decreased after fertilizer application. It might be due to the partial fixation of applied phosphorus by the kaolinite and illitic clay minerals and adsorption of P after fertilizer application and further utilization of P by rootstocks for their growth and development which further resulted in the differences of soil phosphorus status.

On the other hand, P had non-significant positive correlation with the leaf P before fertilizer application. But after fertilizer application, it had a negative relationship. High soil P resulted in comparatively high leaf Zn content which could be attributed to more absorption of zinc due to increased requirements at the stage of fruit development and low Cu and this may be due to antagonistic effect after 45 and 90 days of fertilizer application.

5.1.3.3 Potassium. Before and after fertilizer application, differences were not significant in the available K status of soils revealing its homogeneity and it ranged from 279.3 to 488.4 kg K ha^{-1} and was high. Further, the soils did not show immediate response to the applied K and resulted in an irregular trend in the available K status in the soils, even after fertilizer application. But Rangpur lime showed high leaf K concentration compared to Trifoliate orange which showed less K concentration in their leaves. This differential concentration of K in the above two rootstocks could be related to the differential behaviour of rootstocks in absorption of K.

5.1.4 Available Secondary Nutrient Status of Soils

5.1.4.1 Calcium. The soils did not differ significantly in their Ca status before after fertilizer application and ranged from 2.53 to 4.38 me 100^{-1}g soil in the subsoil and was sufficient. However, Jambheri basins had numerically high Ca status before fertilizer application as the Jambheri plants probably had less capacity to absorb the soil Ca because of decline resulting in the high soil Ca.

But after fertilizer application, Trifoliate orange basins had the highest soil available Ca while the least was in Sathgudi. After 45 days of fertilizer application, soil Ca showed negative correlation with leaf Ca because, the absorbed Ca was utilized for the fruit formation and development for which the nutrients moved from leaves to the fruits but after 90 days, the soil Ca had positive correlation with leaf Ca as the nutrients were less utilized for the fruit development leading to its accumulation in the leaves.

5.1.4.2 Magnesium. Similar to Ca, soils did not differ significantly in their available Mg status which ranged from 2.09 to 3.18 me 100^{-1}g soil and was sufficient. the absence of the difference in the available Mg status of soils revealed the homogeneity of soils with respect to Mg. Further, the soil Mg content showed nonsignificant negative correlation with the leaf Mg content which was contrary to the findings of Anderson and Albrigo (1977).

5.1.4.3 Sulphur. Unlike Ca and Mg, soil showed significant differences in their available S status which ranged from 17.2 to 26.8 ppm which was sufficient. Highest S content was in Sathgudi basins while the least was in Troyer citrange basins. The available S showed significantly positive correlation with the leaf S content after 45 days of fertilizer application which could be attributed to more absorption. Even after 90 days, though the correlation was non-significantly positive, it agreed with the above result. The highest S content in the soils of Sathgudi basins might be due to their low salt content whereas it was the least in Troyer citrange basins within the sufficient range because of comparatively high soluble salt content in the soils.

5.1.5 Available Micronutrient Status of Soils

5.1.5.1 Zinc, copper and boron. Significant differences in soils were not observed regarding the available zinc, copper and boron status which ranged from 1.9 to 6.8, 1.1 to 2.2 and 0.96 to 1.1 respectively. Boron was found to be normal whereas Zn and Cu were high. The availability of all these nutrients in the soils after 90 days of fertilizer application was found to decrease because of their utilization during the plant growth. The relationship of soil available Zn, Cu and B was non-significant with their respective leaf nutrient contents.

5.1.5.2 Iron and manganese. The differences were highly significant in the available Fe and Mn status of the soils of different rootstock basins and ranged from 6.8 to 11 and 13.3 to 20.5 ppm respectively and were sufficient. The differences in availability of nutrients in the soil might be due to the differential ability of absorption of micronutrients by different rootstocks from the soil leading to the increase or decrease of the available nutrients in the particular basins. Soil Fe showed a significant negative correlation with the leaf Fe content. The leaf iron content was observed to be above optimum and it could not maintain the further increase in leaf though it was high in soil. Whereas, Mn showed nonsignificant positive relationship with the leaf Mn concentration.

5.2 FOLIAR ANALYSIS

5.2.1 Micronutrient Concentration in Sathgudi Sweet Orange Leaves

5.2.1.1 Nitrogen. No significant differences were found in leaf N content of Sweet orange budded on different rootstocks except at 45 days after fertilizer application. This might be due to the application of N to soil which increased the N content of orange leaves. This was in agreement with the findings of Glonti (1970), Rees and Koo (1975) and Desai *et al* (1986). The non-significant differences in the leaf N status of sweet orange on different rootstocks was in consonance with the findings of Smith *et al* (1949) and Suryanarayana Reddy and Swamy (1986). But the gradual decrease in N content at 90 days after fertilizer application might be due to the reason that growing organs essentially require N for protein synthesis as reported by Deidda and Viridis (1969) Millella *et al* (1968) and Zhuang *et al* (1985).

5.2.1.2 Phosphorus. The absence of significant differences between the mean P content of leaves from the different rootstocks was in agreement with many workers (Castle and Krezdorn (1975), Iyengar *et al* (1982), Mehrotra *et al* (1982), Mehrotra *et al* (1983), Anjaneyalu and Ravishankar (1984) and Misra and Ranvir Singh (1993). However, the mean leaf P content has gradually increased from the early stage to 45 days after fertilizer application and thereafter showed a gradual decrease. the increase might be due to the increase in absorption of P at the early stages of fertilizer application which might have increased the P content of orange leaves. The fall in concentration of P in leaves of sweet orange as the crop reaches maturity could be attributed to the dilution and utilization of P for the development of fruits. The same was reported by Ortuno *et al* (1970) and Intrigliolo (1985). The leaf P content was found to be in the high range which might be due to high soil available P content.

5.2.1.3 Potassium. The effect of different rootstocks on the content of potassium was found to be significant in the sweet orange leaves. It was in agreement with the findings of Iyengar *et al* (1982), Iyengar *et al* (1984) and Anjaneyalu and Ravishankar (1984). The increase in K content after 45 days might be due to the fertilizer application where the applied K increased the leaf K (Kiely *et al* (1972), Murthy *et al* (1983) and Desai *et al* (1986). The leaf K concentration was high which agreed with the findings of Mehrotra *et al* (1982). Low K content was recorded on Trifoliate orange which agreed with the findings of Castle and Krezdorn (1975) while the same on Rangpur lime was found to be high compared to Cleopatra mandarin and agreed with findings of Gaffar (1967). The significant differences in the leaf K concentration of sweet orange on different rootstocks indicated that various rootstocks influenced the translocation of potassium differently (Misra and Ranvir Singh 1993).

5.2.2 Secondary Nutrient Concentration in Sathgudi Sweet Orange Leaves

5.2.2.1 Calcium. The calcium content of leaves after 45 days of fertilizer application increased in Sathgudi and Rangpurlime whereas in others it decreased and there onwards, after 90 days of fertilizer application, it showed a reverse trend. This might be due to the immobile nature of the element in the plant body and could be suggested that flowers and fruits acquired their Ca requirements only from roots through xylem. Similar results were reported by Reuther 1950, Ortuno *et al* (1970), Liu *et al* (1985) and Sharples and Hilgeman (1972). Before fertilizer application, Cleopatra mandarin had high Ca which might be due to the lower amount of P and K where K exhibited antagonism toward Ca uptake (Desai *et al* 1986).

5.2.2.2 Magnesium. The high leaf Mg status in Sweet Orange leaves on Cleopatra mandarin which was observed in this study was also reported by Jones *et al* (1957), Iyengar *et al* (1982) and Iyengar *et al* (1984). But after fertilizer application, Trifoliate orange maintained significantly high leaf Mg content and least was in Rangpur lime. These results were in agreement with the findings of Anjaneyalu and Ravishankar (1984). In general, all the rootstocks exhibited significant positive increase in the Mg content of sweet orange leaves as the levels of N increased after 45 days of fertilizer application. This could be attributed to the fact that higher N content lead to the formation of chlorophyll leading to the higher utilization of Mg. Similar findings were made by Mehrotra *et al* (1982) and Mehrotra *et al* (1983).

But later after 90 days of fertilization ie., at the fruit development stage, the differences in leaf Mg content were not significant due to different rootstocks on Sathgudi sweet orange and these findings were similar to that of Sharples and Hilgeman (1972), Labanauskas and Bitters (1974), Misra *et al* (1989) and Misra and Ranvir Singh (1993).

5.2.2.3 Sulphur

The effect of rootstocks on Sathgudi sweet orange did not result in any significant differences in the S content of leaves and was in agreement with the findings of Iyengar *et al* (1984). It was also observed that the S concentration of leaves increased gradually with increase in plant growth. However, numerically, Troyer citrange had the least but sufficient S content in its leaves as compared to Sathgudi and Cleopatra mandarin after 45 and 90 days of fertilizer application.

5.2.3 Micronutrient Concentration of Sathgudi Sweet Orange Leaves

5.2.3.1 Zinc. After 90 days of fertilizer application, Zn content did not vary significantly under the influence of different rootstocks in the leaves of sweet orange and it was also reported by Chundawat *et al* (1981) whereas before and after 45 days of fertilizer application, Cleopatra mandarin had significantly exhibited the least Zn content which might be due to the antagonistic effect of Cu as it was observed to be highly significant. While Trifoliate orange recorded the high Zn content which had lower Cu content. These findings were in accordance with that of Mehrotra *et al* (1982) and Mehrotra *et al* (1984).

5.2.3.2 Iron. The results indicated that the rootstocks showed no significant differences in the Fe uptake. It was also reported by Chundawat *et al* (1981), Mehrotra *et al* (1982), Anjaneyalu and Ravishankar (1984) and Misra and Ranvir Singh (1993). Rangpur lime rootstock exhibited optimum Fe concentration in its leaves which was also reported by Nache Gowda *et al* (1982). However, the leaf Fe status showed no definite trend in their accumulation at different periods but was relatively high at the initial period before fertilizer application.

5.2.3.3 Copper. The copper concentration in the leaves of Sathgudi sweet orange was found to be optimum to high and showed significant differences in Cu content due to the rootstocks, Sathgudi recorded the least Cu content in its leaves at all the periods from fertilizer application while Rangpur lime recorded the highest. The minimum Cu content in the leaves of plants on Sathgudi might be due to the minimum content of Mn in its leaves as both the elements had antagonism as reported by Misra *et al* (1989). The antagonistic effect between Cu and Mn was revealed by the non-significant negative correlation. However, the Cu concentration in the leaves had slightly increased and thereafter showed a decrease after 90 days of fertilizer application.

5.2.3.4 Manganese. Manganese level in the Sweet orange leaves was found to be optimum in all the rootstock combinations which was also reported by Mehrotra *et al* (1982). During all the stages i.e. before and after 45 and 90 days of fertilizer application, Trifoliate orange had the highest leaf Mn content and least in Troyer citrange. The highest content of Mn in the leaves of Trifoliate orange rootstocks were reported by Nache Gowda *et al* (1982), Iyengar *et al* (1984). Similarly the lower Mn content of the scion leaves on Troyer citrange rootstocks was in agreement with the findings of Mehrotra *et al* (1982), Nache Gowda *et al* (1982), Iyengar *et al* (1982), Mehrotra *et al* (1983), Iyengar *et al* (1984), Misra *et al* (1989) and Esmaeil Fallahi *et al* (1990), and contrary to the findings of Labanauskas and Bitters (1975), Anjaneyalu and Ravishankar (1984) and Misra and Ranvir Singh (1993). The Mn status of leaves showed no change before and after fertilizer application but thereafter showed a slight decrease. It might be due to the reason that this element was not applied through fertilizers and hence showed no change whereas the decrease in its concentration might be due to the dilution effect of the element during its vegetative as well as fruit development phases.

5.2.3.5 Boron. Highly significant differences were observed in the concentration of boron in the scion leaves on different rootstocks and the boron concentration was in the optimum range. The concentration of B in the sweet orange leaves was more before fertilizer application but showed a decrease after 45 days of fertilizer application and thereafter increased. This may be due to the reason that B was also not supplied through fertilizers and the available B in the leaves was utilized during the fruit development and the nutrients move to the fruits from the leaves thereby showing a decrease in the leaf B content. This was in agreement with the findings of Diedda and Viridis (1969), Ortuno *et al* (1970), Gallo *et al* (1977), Patange and Patil (1981), Raciti (1981), Intrigliolo (1985) and Zhuang *et al* (1985), Trifoliate orange had the high B concentration in their leaves which might be due to the least N, P,K which showed a negative correlation with B.

5.2.4 Effect of Different Rootstocks on the Absorption and Translocation of Nutrients to Sathgudi Sweet Orange Leaves

Sathgudi

Sathgudi sweet orange leaves on Sathgudi rootstock showed optimum levels of K, Mg, Fe and Mn at all the periods from fertilizer application. Eventhough the nutrients were in the optimum level, K concentration increased after 45 days of fertilizer application and thereafter showed a decreasing trend where as Mg concentration also increased after fertilizer application but resulted in an increasing trend in its uptake. The increased K and Mg concentration might be attributed to the application of fertilizers, which was also recorded by Glonti (1970), Kiely *et al* (1972), Murthy *et al* (1983). But the decrease in the K content may be attributed to its lesser absorption and increased utilization during the fruit development. Eventhough Mg is not supplied through fertilizers, it increased in its concentration following the application of N fertilizer which was also reported by Rees and Koo (1975). This is also evident by the positive correlation between the soil K in sathgudi rootstock basin and the leaf Mg. Mg concentration in the leaves was maintained due to the continuous production of chlorophyll in the leaves. Eventhough the soils had Fe content above their critical limits, it decreased after 45 days of fertilizer application which might be due to the application of P fertilizer to the soil which might have inhibited the uptake of Fe by the rootstocks to as revealed by the non significant negative correlation between the soil P and leaf Fe. The concentration of Mn in the leaves was maintained in the same level upto 45 days of fertilizer application but later showed a decreasing trend because of the decrease in the availability of this nutrient as it was not applied through fertilizers.

The concentration of N and Cu in the leaves were optimum before fertilizer application but increased to higher levels after 45 days of fertilizer application and thereafter decreased to optimum level after 90 days of fertilizer application. The increased availability of N following the application of fertilizers resulted in rapid absorption of nutrient by the rootstock leading to its higher concentration in its leaves. The Cu concentration in the leaves increased which might be due to K application as reported by Kiely *et al* (1972). The decrease in the concentration after 90 days may be due to the movement of these nutrients from the leaves for utilization during fruit development as was reported by Millela *et al* (1968) and Zhuang *et al* (1985).

Sulphur and boron concentration in the leaves showed a reverse trend i.e. before fertilizer application. Sulphur concentration was optimum and B concentration was higher. Whereas after fertilizer application, the S concentration was changed to high and B concentration to optimum showing an increasing trend. This antagonistic behaviour was also revealed by their non significant negative correlation.

The concentration of Zn was optimum before and after 90 days of fertilizer application. But after 45 days of fertilizer application, Zn concentration was low. This might be due to the high levels of Cu in its leaves and Zn and Cu exhibited antagonism towards each other which was also reported by Mehrotra et al (1982) and Mehrotra *et al* (1984).

Eventhough Ca was in sufficient levels in the soils, the leaves showed deficiency in their Ca content which might be due to the reduced uptake of Ca by the rootstock and might also be due to the K application. This was reported by Kiely *et al* (1972). But after 45 days of fertilizer application, a slight increase in the Ca content was observed which might be due to P application which was synergistic to Ca uptake and was in consonance with the findings of Desai *et al* (1986).

Phosphorus concentration was high in the leaves before fertilizer application but reached to excess level after 45 days of fertilizer application and thereafter dropped to high level. The excess level of P in the leaves might be contributed by the addition of P fertilizer (Desai *et al* 1986) and also due to the presence of S, Zn, Cu and Mn in soils which might have increased the uptake of P by the rootstocks as revealed by the positive correlations obtained between them.

Rangpur lime

After 45 days of fertilizer application, the concentration of N was high which might be attributed to the increased absorption of N by the rootstocks following the N application and also might be due to higher content of N and P in the soils which might have contributed to more leaf N. This was revealed by their significant positive correlation. Higher levels of Zn and Cu in the soils might have also contributed to the high levels of N in the leaves. But after 90 days of fertilizer application, N concentration in the leaves decreased because of its utilization during the fruit development process.

The P concentration in the scion leaves on this rootstock also was in excess after fertilizer application because of its addition to the soil through fertilizers and may also be due to the presence of high copper and boron content in the soils resulting in increased absorption and translocation of P to the leaves as the soil Cu and B showed significant positive correlations with the leaf P.

The concentration of Mg and S in the leaves increased from optimum to high level after 90 days of fertilizer application which might be due to their decreased utilization during the fruit development period and also due to higher amounts of chlorophyll in the leaves.

Zinc, eventhough it was low at all the three periods of sampling, it showed a slight decrease and thereafter resulted in an increasing trend. This increase might be due to higher amounts of P and K concentration in the leaves as revealed by their positive correlation. Whereas Fe which was in the optimum range at all the periods showed a slight decrease and thereafter increased which might be due to the decreased levels of Ca and Mg in soils which were negatively correlated with the leaf Fe content.

After fertilizer application, copper showed an increasing trend and thereafter decreased but was in high levels. This high concentration of Cu in its leaves might be due to low levels of Zn as they were negatively correlated with the leaf Fe content.

The concentration of Mn in the leaves was maintained in the optimum level at all the periods but showed a slight increase after fertilizer application which might be due to the increase in the Mn level in the soil as both had positive relationship. The Ca content in the soils also increased the concentration of Mn in the leaves as revealed by their positive correlation.

The leaf B concentration was decreased after fertilizer application and thereafter showed a slight increase which might be due to its negative association with the leaf K concentration after 90 days period as revealed by its negative correlation.

Cleopatra mandarin

After fertilizer application, the concentration of N in leaves increased and continued thereafter in the same trend, which might be due to the higher amounts of K and Mn in the soils as recorded by its positive correlation. P and K concentration as leaves showed an increasing trend and thereafter showed a slight decrease which may be due to the decrease in the P content of the soils.

The leaf K was low before fertilizer application but reached optimum level after fertilizer application which may be due to the addition of K fertilizer. Even though, the soils had high amount of K, the leaves had low concentration of K because of the high amounts of P in the soil which inhibit the uptake of K by the rootstocks as revealed by its negative correlation. Desai et al (1986) also reported that P was antagonistic to K and N uptake, and hence the scion leaves on this rootstock had low levels of K and N.

Sulphur, manganese and boron were maintained at optimum levels in their leaves at all the periods of sampling. But S showed a continuous increasing trend reaching a higher level after 90 days of fertilizer application, Mn content was in decreasing trend whereas B showed a slight decrease after 45 days of fertilizer application and again increased within 90 days.

The increase in the S concentration in the leaves might be attributed to its accumulation in its leaves due to its decreased utilization. Manganese exhibited decreasing trend in its concentration in the leaves because of the high amounts of Fe in the soils which might have suppressed the uptake of Mn by rootstocks. But after 90 days period, it showed a slight increase which might be due to its lesser concentration of K in its leaves as revealed by its negative correlation.

Calcium, zinc and copper were maintained at deficient low and high levels respectively in all the periods of sampling upto 90 days from fertilizer application. Eventhough Ca was present in sufficient amounts in the soils, addition of K might have exhibited antagonism towards Ca uptake which was also reported by Desai et al (1986) hence it was present in deficient levels. After fertilizer application, it showed a slight decrease and thereafter increased in its concentration in the scion leaves. As leaf N had positive association with the leaf Ca, a slight decrease in the leaf N content after 45 days also resulted in a slight decrease in the Ca content and thereafter showed an increase.

Eventhough Zn and Cu were in low and high levels respectively in the scion leaves, Zn showed a decreasing and increasing trend whereas Cu showed increasing and decreasing trends respectively in their accumulation in the leaves clearly revealing their antagonistic behaviour which was also indicated by their negative association with each other.

Magnesium and iron were in the same track i.e., their concentration was higher before fertilizer application and thereafter decreased to optimum levels after fertilizer application which might be due to the reduced uptake by the rootstocks.

Troyer citrange

Nitrogen and sulphur concentration in the leaves of sweet orange on Troyer citrange rootstocks were maintained at optimum level at all the periods of sampling and showed an increasing trend in their accumulation in the leaves after fertilizer application. This rootstock resulted in the uniform absorption of nutrients from the soil thereby maintaining optimum levels at all the periods of sampling.

Calcium, zinc, manganese, and boron were found in deficient, low and high levels respectively in the leaves at all the periods of sampling. The higher concentration of B in the leaves might be due to the lower concentration of Mn in the leaves as revealed by their non significant negative correlation. After 45 days period of fertilizer application, Zn showed a slight decrease whereas Mn showed a slight increase. This antagonistic behaviour was revealed by their non significant association between them.

Phosphorus in the leaves was in excess levels before and after 45 days of fertilizer application but decreased to high levels after 90 days period. This decrease of the P concentration in leaves might be due to the increase in the N state of soil. The high N content in soils might have suppressed the absorption of P by the plants as revealed by their negative correlation. Also due to increased utilization of P by the rootstock during fruit development the P concentration might have decreased in the leaves. The decreased P concentration in leaves might also be due to high Cu content in the soils as revealed by their positive correlation.

Troyer citrange rootstock resulted in the higher absorption of K thus increasing the concentration of K in the leaves after fertilizer application. This increase in K concentration of leaves after 45 days of fertilizer application might be due to the application of N fertilizer which also increased the K content of the leaves (Glonti, 1970). It may also be due to the addition of K fertilizers to the soil.

Magnesium was optimum before fertilizer application and reached high levels after fertilizer application. But Fe concentration was high before fertilizer application but decreased to optimum levels after fertilizer application. The increase in the concentration of Mg in the leaves might be due to the increase in the N content in the soil after fertilizer application which was also revealed by its positive correlation leaf Fe showed negative relationship with the soil. Mg which indicated that increase in the soil Mg content will result in decreased uptake of Fe by the rootstock.

Copper concentration was high in the scion leaves before and after 90 days of fertilizer application but it was excess after 45 days of fertilizer application. The increase in the concentration of Cu in the scion leaves might be due to the increase in the Fe content of the soils as revealed by their significant positive correlation.

Trifoliate orange

Nitrogen, magnesium and manganese maintained optimum levels of nutrients in their leaves at all the periods of sampling. Nitrogen and manganese showed a slight increase and then a decrease whereas Mg showed a gradual

Troyer citrange rootstock resulted in the higher absorption of K thus increasing the concentration of K in the leaves after fertilizer application. This increase in K concentration of leaves after 45 days of fertilizer application might be due to the application of N fertilizer which also increased the K content of the leaves (Glonti, 1970). It may also be due to the addition of K fertilizers to the soil.

Magnesium was optimum before fertilizer application and reached high levels after fertilizer application. But Fe concentration was high before fertilizer application but decreased to optimum levels after fertilizer application. The increase in the concentration of Mg in the leaves might be due to the increase in the N content in the soil after fertilizer application which was also revealed by its positive correlation leaf Fe showed negative relationship with the soil. Mg which indicated that increase in the soil Mg content will result in decreased uptake of Fe by the rootstock.

Copper concentration was high in the scion leaves before and after 90 days of fertilizer application but it was excess after 45 days of fertilizer application. The increase in the concentration of Cu in the scion leaves might be due to the increase in the Fe content of the soils as revealed by their significant positive correlation.

Trifoliate orange

Nitrogen, magnesium and manganese maintained optimum levels of nutrients in their leaves at all the periods of sampling. Nitrogen and manganese showed a slight increase and then a decrease whereas Mg showed a gradual increase in its concentration in the scion leaves. The decreased absorption of the Mn by the scion leaves might be due to the higher content of K, Ca and Mg in the soils as revealed by their negative correlation.

5.3 FRUIT ANALYSIS

5.3.1 Physical Characteristics of the Fruits

5.3.1.1 Fruit Weight. The results showed significant differences in the fruit weight of sweet orange on different rootstocks which was contrary to the findings of Chohan (1986) but in agreement with Bal and Chohan (1987), Mustafa and Reddy (1990) and Ghosh and Narayan Chattopadhyay (1993). Significantly high fruit weight recorded on Rangpur lime rootstock in the present study was also reported by Ghosh and Narayan Chattopadhyaya (1993). This might be due to high levels of N concentration in their leaves which was directly related to the fruit weight whereas Trifoliate orange showed less fruit weight due to its lower content of N in its leaves. This was in agreement with the findings of Marchal (1984), Vijaysankar Reddy (1989) and Venkataramanaiah (1993).

5.3.1.2 Fruit size. Rangpur lime recorded the highest fruit length and diameter whereas Trifoliate recorded the least. The increase in fruit size might be related to the N,P,K application and their uptake, by the rootstocks. While, P concentration was not significant among different scion leaves of the rootstocks, the N and K contents were highest on Rangpur lime rootstock whereas in Trifoliate orange, they were less and resulted in increased fruit size in Rangpur lime.

5.3.1.3 Rind. The results showed no significant differences in the rind thickness of fruits on different rootstocks which was in agreement with findings of Bal and Chohan (1987). But non-significant maximum rind thickness was observed in Troyer citrange which could be attributed to its higher N content as reported by Dhillon *et al* (1961) and Peel percentage was also less in Troyer citrange and was contrary to the findings of Chohan *et al* (1988) and Harish Kumar *et al* (1993).

5.3.2 Fruit Quality Characters

5.3.2.1 Fruit segment and seed numbers. Even though the rootstocks did not differ significantly in their segment and seed numbers, numerically highest seed and segment number was recorded on Trifoliate orange and least on Sathgudi.

5.3.2.2 Seed weight. Seed weight was significantly high in Cleopatra mandarin while it was the lowest in Trifoliate orange. The difference in seed weight might be due to the inherent genetic characters of the species producing different sized seeds.

5.3.2.3 Juice content of the fruits. Sweet orange fruits on Rangpur lime had significantly high juice volume, juice weight and Trifoliate orange had the least which was at par with Troyer citrange. The maximum juice content in Rangpur lime was in agreement with Mustafa and Reddy (1990) but contrary to the findings of Thornton and Dimsey (1987) whereas the minimum juice content of sweet orange on Trifoliate rootstock was also contrary to Bhullar and Nauriyal (1975). The N content in the leaf was directly related to juice content as reported by Marchal (1984), Vijaysankar Reddy (1989) and Venkataramanaiah (1993). The highest N content in Rangpur lime might be the reason for its high juice content. Moss in 1972 stated that high leaf P was associated with high juice content. In the present study, eventhough, the difference in the leaf P content were not significant, Rangpur lime showed high leaf P after 90 days after fertilizer application which might have resulted in high juice content.

5.3.2.4 Rag. Differences in rag content of sweet orange fruits on different rootstocks were not significant but the rag percentage was the lowest in Rangpurlime and highest in Trifoliate orange. Similar findings were reported by Bal and Chohan (1987).

5.3.3 Chemical Characteristics of the Fruits

5.3.3.1 Total soluble solids. There were significant differences among the total soluble solid content of the sweet orange fruit juice on different rootstocks. Maximum total soluble solids was noted in Sathgudi sweet orange on Troyer citrange and Trifoliate orange which was in agreement with the findings of Mehrotra *et al* (1984), Chohan *et al* (1988) and Bhullar and Nauriyal (1975). The high TSS content of juice might be due to the N, K application and their efficient uptake by the rootstock as reported by Suryanarayana Reddy and Swamy (1986), Desai *et al* (1986) whereas P had no significant effect. The increase in TSS was associated with low nitrogen (Calvert 1970) and phosphorus (Smith 1966) in the leaves was also reported.

5.3.3.2 Acidity. The percent acidity of the fruit juice was found to be high because the acid content was estimated prior to the full maturity of the fruit. Anyhow, the differences in acidity among the rootstocks were not significant which was in consonance with Chohan *et al* (1986). But numerically maximum acidity of fruits was noted on Trifoliate orange rootstocks (Bhullar and Nauriyal 1975) and minimum on Rangpur lime (Ghosh and Narayan Chattopadhyay 1993). It was earlier reported by Embleton *et al* (1973) that increase in K content of leaves was associated with increase in acidity of the orange juice. But the present findings were contrary to the above showing a reverse trend which may be because of the differences in maturity.

5.3.3.3 Ascorbic acid. Significant differences were observed in the ascorbic acid content of sweet orange fruits produced on different rootstocks. Highest ascorbic acid content was recorded by Cleopatra mandarin while the lowest was on Troyer citrange and it agreed with the findings of Vijay Kumar *et al* (1989). Earlier reports were evident that the ascorbic acid content of the fruit juice increased with decreased N application (Embleton *et al* 1967), increased K content of leaves (Embleton *et al* 1973) increased K application (Desai *et al* 1986) and it decreased consistently with P application (Smith *et al* 1963, Bar-Akiva *et al* 1968). But the present findings were contrary to those made by Embleton *et al* (1973) wherein the rootstocks containing lower leaf K concentration resulted in high ascorbic acid content compared to the other rootstocks.

5.3.3.4 Sugars. Sweet orange fruits on different rootstocks showed highly significant differences in the non-reducing and total sugar content of the fruit juice while the reducing sugar content was not affected. The trend of the sugars was almost similar to that of TSS as sugars constituted a major component of TSS. Similar to TSS, Rangpur lime had highest and Cleopatra mandarin had the least non-reducing and total sugars in this fruit juice. The availability of more photosynthates to fruits ultimately increased the sugar percent in the juice. The acidity and sugar content were found to have negative effect on each other which was obvious in the present study. Rangpur lime which recorded the highest sugar content had the least acidity.

5.3.3.5 Yield. The results indicated that yield of sweet orange on different rootstocks had not differed significantly in number. However, highest fruit number was recorded in Troyer citrange followed by Rangpur lime and least on Cleopatra mandarin. These findings were in agreement with that of Mehrotra *et al* (1982) and Ghosh and Narayan Chattopadhyay (1993). However, Rangpur lime proved to be the highest vigorous yielder as reported by Mustafa and Reddy (1990), Vijayakumar *et al* (1990), Ghosh and Narayan Chattopadhyay (1993). The probable reason for Rangpur lime to give the highest yield might be due to the high content of N, P and K in its leaves resulting in good yield which was revealed by many workers (Smith 1969, Jones *et al* (1970), Liu *et al* (1985) Dhillon and Datt (1988) Vijaysankar Reddy (1989) and Venkataramanaiah (1993).

When the fruit yield in Kg per tree was considered, Rangpur time rootstock significantly gave highest yield followed by Troyer citrange, Sathgudi, Cleopatra mandarin and the least being in Trifoliate orange.

5.4 CORRELATION ANALYSIS

5.4.1 Interrelationships Within the Soil Properties

Significant positive correlation was observed between soil pH and Mn which indicated that with the increase in the soil pH where the soil pH was 7.0 to 7.8 the Mn availability increased and vice versa. Soil EC also had significant positive correlation with K and Ca which showed that with the increase in the salt content of the soil, the K and Ca contents of the soil also increased, while decrease in the available Fe content of the soil could be attributed to its oxidation state as revealed by the negative correlation.

5.4.2 Influence of Soil Physico-chemical Properties on Leaf Nutrients

Soluble salt content of the sol has shown a negative relationship with the leaf S content on scion in general irrespective of the rootstocks. In general, the soluble SO_4^{-2} ion concentration is very low at the existing low EC levels under low organic carbon status which might have supported the negative correlation with soluble salt content of these soils.

5.4.3 Influence of Soil Nutrients on Leaf Nutrients

Among the macro nutrients in general irrespective of the rootstocks and it was observed that soil nitrogen had significant positive correlation with leaf Mg, and soil avail P with leaf Zn. This indicated that the increased contents of N and P had a positive effect on the absorption of Mg and Zn respectively while soil P showed a negative effect on the leaf Cu content. It clearly indicated that Zn and Cu had antagonistic effect on each other in the presence of P.

Of the secondary nutrients, soil Ca content showed negative effects on leaf S after 45 days of fertilizer application. Later, after 90 days of fertilizer application, it was not observed. The presence of Ca in the soil to some extent hindered the absorption of S by the plants. Soil S had significant positive and negative relationship with leaf S and Cu respectively which indicated that the presence of sufficient amount of S in soils might have influenced the leaf S content and Cu might have got antagonistic effect with sulphur. Soil S also had significant positive relationship with leaf K and Ca and resulted in increased leaf K and Ca with the increase in soil S content. Fe in the soil had significant negative relationship with leaf Mn which might be due to antagonistic effect.

After 90 days of fertilizer application, soil N had significant positive relationship with leaf Ca, Mg and Zn while P had negative association with Cu in leaf. It might be due to the influence of higher utilization of nitrogen from soil and inturn increased the absorption of the nutrients Ca, Mg and Zn, while P might have got antagonistic effect with Cu.

After 45 days of fertilizer application, Ca had negative relationship with K while S had positive association with leaf K and negative association with Cu. So Cu and K might have got antagonistic effect among each other in the presence of soil S.

5.4.4 Interrelationship Among the Leaf Nutrients

After 45 days of fertilizer application in general irrespective of the rootstocks and on Sathgudi sweet orange it was observed that leaf nitrogen content showed positive correlation with P and K which might be due to the increased absorption of nitrogen which further influenced the absorption of other two major nutrients P and K. Further, the increased absorption of P influenced the increased absorption of S and Zn as evident by the positive correlation existed between these nutrients. Further the increase in the absorption of K also influenced the absorption of Mg, S and Zn as evidenced by their positive resulted in the high concentration of P in the leaves. The high P of the soils resulted in high Ca in the Scion leaves

Rangpur lime

Significant positive relationships existed between soil N and leaf N, soil Mn and leaf Mn. The positive association between soil N, P, Zn and Cu with leaf N indicated that the high levels of these nutrients in the soils resulted in the high concentration of nitrogen in the foliage. High levels of Ca in the soil has enhanced the concentration of Mn in the leaves but depressed the Fe concentration as indicated by its negative correlation. Higher concentration of Mg in the soil also depressed the concentration of Fe in the leaves. Copper in the soils had positive association with the leaf P.

Cleopatra mandarin

The K and Mn of the soils in Cleopatra mandarin basin had positive relationship with leaf N content. But the soil P and soil Ca exhibited antagonism towards the concentration of K and Mg respectively in the scion leaves.

Troyer citrange

Significant negative relationships were observed between Soil N and leaf P, soil P and leaf Fe, soil K and leaf S, whereas, positive associations were observed between soil N and leaf Zn, soil Fe and leaf Cu and soil Cu and leaf P which revealed that the higher concentration of N, Fe and Cu had direct relationship with Zn, Cu and P respectively resulting in their higher concentration in their scion leaves. The relationship between N is soils and concentration of P in leaves is in reverse with that observed in Rangpurlime.

Trifoliate orange

The negative association between soil N and leaf N revealed that at high concentration of N in the soil, depressed the level of N in the leaves. But high concentration of K in the soils had enhanced the zinc levels in leaves and depressed the Cu and Mn concentration in the leaves. Both the Ca and Mg in the soils had negative association with both Cu and Mn of leaves while both Fe and Cu of soils had direct association with both N, and P concentration of the scion leaves. High level of S in soils depressed the Zn in the leaves but increased the Mn concentration. This revealed the antagonistic behaviour of Zn and Mn in the scion leaves. The calcium concentration in the leaves is depressed in the presence of high amounts of Fe and Cu in the soils as indicated by its negative association. The higher accumulation of P in the scion leaves in the presence of high Cu in soils is also revealed in the scion leaves on other rootstocks except on Cleopatra mandarin.

Summary and Conclusions

SUMMARY AND CONCLUSIONS

The entire investigation carried out on different aspects of Sathgudi sweet orange budded on different rootstocks to know their relative efficiency on the leaf nutrient content, fruit quality and yield is presented in nutshell in this chapter.

Primarily, citrus is a highly potential commercial fruit crop grown throughout the world. As it is a rich source of vitamins and nutrients, it occupies a prime place even in the nutrition of man. So many investigations were carried out on citrus to improve its productivity and yield in different climatic and soil conditions.

Among different kinds of investigations carried out, growing of citrus plants on rootstocks is one because the studies indicated that rootstocks exert profound influence on vigour, productivity, fruit quality, disease resistance, drought endurance, nutrition and longevity of scions budded on them.

But the performance of rootstocks depends on climatic and soil conditions and it is not easier to suggest such a particular rootstock is suitable for that particular scion because the combination of which, may be satisfied under one set of climatic and soil conditions but may fail entirely in other situation.

Keeping these factors in view, the present investigation is carried out on a rootstock trial. Sathgudi which is a commercial variety of sweet orange in AP. was grown on different rootstocks in Alfisols of Citrus Improvement Project at Tirupati. The rootstocks employed were Sathgudi, Rangpur lime, Cleopatra mandarin, Troyer citrange, Trifoliate orange and Jambheri. The efficiency of these rootstocks on the leaf nutrient content, fruit quality and yield of Sathgudi sweet orange was studied with the following objectives.

1. To study the effect of different rootstocks on the yield and leaf nutrient contents of N, P, K, Ca, Mg, S, Zn, Cu, Fe, Mn and B.
2. To correlate the physical, physico-chemical and chemical characters of soil with the leaf nutrient content.
3. To study the effect of different rootstocks on quality characters of fruits like size, rind thickness, rag, juice, seed, TSS, brix, reducing and non-reducing sugars, ascorbic acid and titrable acidity.

Earlier, Jambheri which was proved to be one of the efficient rootstocks, has now become susceptible to decline due to pathological factors as evident during the conduct of present investigation.

The soils of the experimental site was red sandy loams to sandy clay loams and were proved to be more congineal for the plant growth. The surface soils were neutral and non saline and showed no significant differences in their N, K, Ca, Mg, Zn, Cu and B contents, except for P, S, Fe and Mn. On observation of these nutritional status of the experimental field, it was concluded that the field was almost statistically homogenous but for few differences in P, S, Fe and Mn. These statistically significant differences might be due to some differences in clay content and genetic characters and continuous absorption of nutrients over a period of 13 years. However, these differences may not affect the major nutritional variation in horticultural plants as they are perennial.

The available N in soils ranged from 205-290 kg ha^{-1} and was in medium range and available P (kg ha^{-1}) fluctuated between 15.1 to 41.9 which was low to medium while available K (kg ha^{-1}) was high in soil and varied from 279.3 to 488.4. Available Ca, Mg and S varied between 2.53 to 4.38 and 2.09 to 3.18 me 100^{-1} g soil and 17.2 to 26.8 ppm respectively and were found to be sufficient.

Among the soil available micronutrients, Zn, Fe, Cu and Mn varied between 1.93 to 6.85, 6.8 to 11.0, 1.1 to 2.2 and 13.25 to 20.5 respectively and were all above the critical limits, and were sufficient Boron status in soils fluctuated between 0.96 to 1.1 ppm and was found to be normal.

Soil pH and EC showed significant positive correlation with soil Mn and K, Ca respectively while EC had significant negative correlation with soil Cu.

The leaf nutrient content in sweet orange on different rootstocks before and after fertilizer application as revealed by the present study are as follows. The experimental field received a general recommended does of organic manures like FYM, castor cake and inorganic fertilizer like urea, SSP and MOP but no micro nutrients.

The nitrogen content was optimum in all the rootstocks at all the periods except in Sathgudi and Rangpur lime where it reached high levels after 45 days of fertilizer application. Before and after fertilizer application, P content was high except in Troyer citrange where it maintained excess level before fertilizer application. But after 45 days of fertilizer application, all the rootstocks had excess levels. At all the periods, the concentration of K was optimum except in Cleopatra mandarin, Troyer citrange and Trifoliate orange which maintained low levels of K in their leaves.

Calcium in Sathgudi leaves was found to be deficient on all rootstocks at all periods from fertilizer application. Magnesium and sulphur ranged from optimum to high at different periods in different rootstocks.

All the rootstocks maintained low levels of Zn in their leaves before and after fertilization except Sathgudi and Trifoliate orange which maintained optimum levels before fertilizer application and later after 90 days of fertilization in Sathgudi rootstock. Iron was found in optimum levels at all periods from fertilizer application, except in Cleopatra mandarin, Troyer citrange and Trifoliate orange rootstocks which maintained high levels before fertilizer application. The copper concentration was high in all the rootstock combinations but Sathgudi had optimum copper content before and after 90 days of fertilizer application, while excess levels were maintained in Rangpur lime and Troyer citrange after 45 days of fertilizer application. Except Troyer citrange, which maintained low levels of Mn, all the other rootstocks had optimum Mn content before and after fertilizer application. Optimum B content in cleopatra mandarin and high B level in Rangpur lime, Troyer citrange and Trifoliate orange rootstocks maintained at all the periods but Sathgudi had high and optimum levels of B before and after fertilizer application.

In general the effect of different rootstocks on Sathgudi sweet orange with respect to the absorption and status of nutrient was observed as follows.

Sathgudi

Before fertilizer application, it recorded the highest leaf K, Zn and least P, Mg, Cu and B. After 45 days of fertilizer application, it maintained highest leaf P, K, Ca, S and Zn and least but sufficient Cu and B. While after 90 days, it had highest K, Zn and least but sufficient P, Cu and B.

Rangpur lime

Before fertilizer application, it showed highest leaf S, Cu and least but sufficient Ca and Fe. After 45 days of fertilizer application, it had high leaf N, Cu and least Fe but after 90 days, it had high leaf P followed by Cu and least Ca and Fe.

Cleopatra mandarin

Initially, it had highest leaf Ca, Mg followed by Mn and least but sufficient N,P and Zn. But after 45 days from fertilizer application, it maintained less Ca, Mg and Zn whereas after 90 days, it recorded high leaf S followed by Cu and leaf Mg.

Troyer citrange

Before fertilizer application, higher content of leaf N, P and Fe followed by Ca, Mg and Cu were recorded while S and Mn were least but sufficient. But after 90 days, it recorded high N, Mg and Cu followed by B, least K, S, Zn and Mn.

Trifoliate orange

Before fertilizer application, it had high leaf Zn, Mn, B and least K. After 45 days of fertilizer application, it recorded high leaf Fe, Mn, B and least K and S while after 90 days it maintained highest leaf Ca, Fe, Mn and B and least N, P, K.

Mn with leaf Mn, soil B with leaf P, soil Ca and leaf Mn. While significant negative correlations were seen between soil Ca and Mg with leaf Fe.

Cleopatra mandarin

Soil K and Mn with leaf N, and soil Fe with leaf Cu had significant positive correlation while soil P and Ca had negative relationship between leaf K and Mg respectively.

Troyer citrange

Significant positive correlations were obtained for soil N, Fe with leaf Mg, soil Cu, Zn with leaf P, and soil Fe with leaf Mg and Cu. While negative associations were between soil N,P,K with leaf P, Fe and S respectively.

Trifoliate orange

Significant positive correlations were obtained for soil K and leaf Zn, soil S with leaf Mn, while negative for soil N, K, S with leaf Fe, Cu and Zn respectively and between soil Ca, Mg with leaf Mn. Soil Fe and Cu were significantly correlated with leaf N and P positively but negatively with Ca in leaves.

Among the five rootstocks with reference to the maintenance of nutrients in Sathgudi scion leaves, (apart from Jambheri which has declined), Troyer citrange maintained the higher concentration of Fe, Cu and Mg and B followed by Trifoliate orange which had high leaf concentration of Mn, B and Ca followed by S, Zn and Fe while the least concentration of Fe, Cu, B, Ca, Mg & S were observed in Sathgudi. But sathgudi had higher concentration of K and Zn. So of all these rootstocks, Troyer citrange was found to have an efficient absorption of micronutrients followed by Trifoliate orange and the least being Sathgudi.

In general, with reference to the micro nutrient absorption the by the root stocks, Troyer citrange was more efficient followed by, Trifoliate orange, Rangpur lime, Cleopatra mandarin and the least efficient being Sathgudi.

The following were the fruit quality characters of sweet orange exhibited on different rootstocks.

Sathgudi

If recorded more fruit length, rind weight and juice weight and less seed and segment number.

Rangpur lime

It recorded higher fruit weight, fruit length, diameter, juice volume, juice percentage, rag weight, reducing, non-reducing and total sugars and yield by weight while rind thickness and percentage, rag percentage, acidity, and ascorbic acid content were the least.

Cleopatra mandarin

It recorded high seed weight and ascorbic acid content and least TSS, reducing, non reducing and total sugars and yield (number).

Troyer citrange

It recorded more rind percentage, TSS and yield (number)

Trifoliate orange

It recorded more rind thickness, segment and seed numbers, acidity while fruit weight, length, diameter, rind weight, seed weight, juice volume, juice weight, juice percentage, rag weight and yield (weight) were less.

Based on the above observations Rangpur lime proved to be the most efficient with reference to almost all positive yield and other quality characters, followed by Sathgudi, Troyer citrange, Cleopatra mandarin and least efficient being Trifoliate orange.

Future line of Research

As observed from the investigation of this present study, the yield potential in the more efficient rootstocks like Rangpur lime, Troyer citrange and Sathgudi could be exploited by efficient fertilizer management (both organic and inorganic) by conducting full proof fertilizer trials with efficient irrigation management.

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