

**EFFECT OF MACRO AND MICRO NUTRIENTS ON GROWTH,
YIELD AND FRUIT QUALITY OF MANDARIN ORANGE
(*Citrus reticulata* Blanco) IN DARJEELING DISTRICT**

**A Thesis
Submitted to the
Bidhan Chandra Krishi Viswavidyalaya
for the Award of the Degree of
Doctor of Philosophy
in
HORTICULTURE**

BY

Ram Awadh Ram

DEPARTMENT OF HORTICULTURE
FACULTY OF AGRICULTURE
BIDHAN CHANDRA KRISHI VISWAVIDYALAYA
KALYANI, NADIA, WEST BENGAL
AUGUST, 1987

Dedicated
to my parents

Bidhan Chandra Krishi Viswavidyalaya

DEPARTMENT OF HORTICULTURE

From : Dr. T.K. Bose
Professor



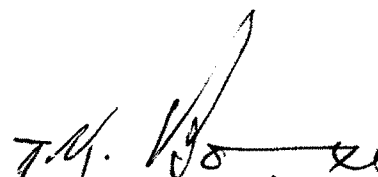
P.O. Kalyani, Dist. Nadia,
West Bengal.
Pin-741 235

Ref. No.....

Date... 31.9.....1987.

CERTIFICATE

This is to certify that the work recorded in the thesis entitled "Effect of macro and micronutrients on growth, yield and fruit quality of mandarin orange (Citrus reticulata Blanco) in Darjeeling district" submitted by Sri Ram Awadh Ram for the award of the Degree of Doctor of Philosophy in Horticulture of the Bidhan Chandra Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received during the course of investigation have been duly acknowledged.


(T. K. Bose)

ACKNOWLEDGEMENT

I have the greatest pleasure in expressing and acknowledging my deepest and heartiest gratitude to Dr. T.K. Bose, Professor, Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya for his guidance, valuable suggestions, constant supervision and painstaking efforts during the course of investigation.

I am acknowledging my deepest gratitude to Dr. P.K. Chattopadhyay, Reader, Dr. S.K. Mitra, Reader, Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya for their guidance and valuable suggestions during the period of investigation and thesis work.

I am very grateful to Dr. T.K. Chattopadhyay, Head of the Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya for providing the facilities for carrying out the experiments.

My indebtedness to Dr. L.P. Yadav, Reader, Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya for his valuable suggestions.

I am extending my gratitude to Sri Rinchen Dorji for providing his orchards and other facilities for carrying out the experiments.

It will be great omission if I fail to put on record my sense of gratitude to Dr. A.Roy, Dr. R.S. Dhua, R. Chatterjee, D.Sengupta, Dr. T.K.Maity, B. Ghosh and S.K. Mallik, teachers and research

scholar, Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya for their cooperation during the period of thesis work.

The typist, Sri Satyen Bhowmick, laboured even in to the wee hours. I appreciate his capacity for hand work with great speed and great finesse.

Dated, Kalyani

The 3rd August, 1987.

Ram Awadh Ram
(RAM AWADH RAM)

CONTENTS

<u>CHAPTER</u>	<u>PAGE</u>
INTRODUCTION	1
REVIEW OF LITERATURE	6
MATERIALS AND METHODS	29
RESULTS AND DISCUSSION	
Experiment 1. Effect of different levels of N, P and K on growth, yield and fruit quality.	40
Experiment 2. Effect of irrigation and different levels of N on growth, yield and fruit quality.	87
Experiment 3. Effect of application of urea and Zn as foliar spray on growth and yield of mandarin orange.	104
Experiment 4. Effect of Mg, Cu, Zn, Fe and B on growth, yield and fruit quality.	120
Experiment 5. Effect of pruning and nutrients applica- tion on rejuvenation of decline orange trees.	136
SUMMARY AND CONCLUSION	154
BIBLIOGRAPHY	(i-xxiv)

LIST OF TABLES

<u>TABLE NO.</u>	<u>CONTENT</u>	<u>PAGE NO.</u>
1.	Meteorological data (mean) pertaining to the period of experimentation (1984 and 1985).	30
2.	Effect of different levels of N, P, K and their interactions on increases in plant height (cm).	41
3.	Effect of different levels of N, P, K and their interactions on increase in stem girth (cm).	44
4.	Effect of different levels of N, P, K and their interactions on increase (cm) in plant spread (East-West).	46
5.	Effect of different levels of N, P, K and their interactions on increase (cm) in plant spread (North-South).	49
6.	Effect of different levels of N, P, K and their interactions on number of fruits per plant.	52
7.	Effect of different levels of N, P, K and their interactions on weight (g) of each fruit.	54
8.	Effect of different levels of N, P, K and their interactions of fruit yield (kg/plant).	56
9.	Effect of different levels of N, P, K and their interactions on yield (Q/ha) of mandarin orange.	59
10.	Effect of different levels of N, P, K and their interactions on diameter of fruit (cm).	61
11.	Effect of different levels of N, P, K and their interactions on peel weight (g) of fruit.	64
12.	Effect of different levels of N, P, K and their interactions on pulp weight (g) of fruit.	66
13.	Effect of different levels of N, P, K and their interactions on juice content of fruits(percent)	69

Contd...

<u>TABLE NO.</u>	<u>CONTENT</u>	<u>PAGE NO.</u>
14.	Effect of different levels of N, P, K and their interactions on total soluble solids ($^{\circ}$ Brix) content of fruits.	71
15.	Effect of different levels of N, P, K and their interactions on total sugar (per cent fresh weight) content of fruits	73
16.	Effect of different levels of N, P, K and their interactions on reducing sugar content (per cent fresh weight) of the fruits.	76
17.	Effect of different levels of N, P, K and their interactions on fruit acidity (per cent).	79
18.	Leaf nitrogen content as influenced by treatment with different levels of N, P and K (expressed as per cent dry weight).	80
19.	Leaf phosphorus content as influenced by treatment with different levels of N, P and K (expressed as per cent dry weight).	82
20.	Leaf potassium content as influenced by treatment with different levels of N, P and K (expressed as per cent dry weight).	83
21.	Vegetative growth of mandarin orange as influenced by different levels of nitrogen and irrigation.	89
22.	Number of fruits and fruit yield of mandarin orange influenced by different levels of nitrogen and irrigation.	92
23.	Physical characteristics of mandarin orange fruits as influenced by different levels of nitrogen and irrigation.	94
24.	Fruit quality of mandarin orange as influenced by different levels of nitrogen and irrigation.	96
25.	Leaf nitrogen content as influenced by different levels of nitrogen and irrigation (expressed as per cent dry weight).	97

contd...

<u>TABLE NO.</u>	<u>CONTENT</u>	<u>PAGE NO.</u>
26.	Leaf phosphorus content as influenced by different levels of nitrogen and irrigation (expressed as per cent dry weight).	99
27.	Leaf potassium content as influenced by different levels of nitrogen and irrigation (expressed as per cent dry weight).	100
28.	Vegetative growth of mandarin orange as influenced by application of urea and zinc.	106
29.	Number of fruits and fruit yield of mandarin orange as influenced by application of urea and zinc.	109
30.	Physical characteristics of mandarin orange fruits as influenced by application of urea and zinc.	110
31.	Fruit quality of mandarin orange as influenced by application of urea and zinc.	113
32.	Leaf nitrogen content as influenced by application of urea and zinc.	114
33.	Leaf phosphorus content as influenced by application of urea and zinc.	115
34.	Leaf potassium content as influenced by application of urea and zinc.	116
35.	Effect of foliar application of Mg, Cu, Zn, Fe and B on vegetative growth of mandarin orange.	121
36.	Effect of foliar application of Mg, Cu, Zn, Fe and B on number of fruits and fruit yield of mandarin orange.	124
37.	Effect of foliar application of Mg, Cu, Zn and B on physical characteristic of mandarin orange fruit.	126
38.	Effect of foliar application of Mg, Cu, Zn, Fe and B on fruit quality of mandarin orange.	128
39.	Effect of foliar application of Mg, Cu, Zn, Fe and B on leaf nitrogen content (expressed as per cent dry weight).	130

Contd...

<u>TABLE NO.</u>	<u>CONTENT</u>	<u>PAGE NO.</u>
40.	Effect of foliar application of Mg, Cu, Zn, Fe and B on leaf phosphorus content (expressed as per cent dry weight).	131
41.	Effect of foliar application of Mg, Cu, Zn, Fe and B on leaf potassium content (expressed as per cent dry weight).	132
42.	Effect of pruning and nutrients on vegetative growth of declined mandarin orange.	138
43.	Effect of pruning and nutrients on number of fruits and fruit yield of declined mandarin orange.	140
44.	Physical characteristics of declined mandarin orange fruit as influenced by pruning and nutrients.	142
45.	Fruit quality of mandarin orange as influenced by pruning and nutrients.	144
46.	Leaf nitrogen content as influenced by pruning and nutrients (expressed as per cent dry weight)	146
47.	Leaf phosphorus content as influenced by pruning and nutrients (expressed as per cent dry weight).	147
48.	Leaf potassium content as influenced by pruning and nutrients (expressed as per cent dry weight).	148

CHAPTER I

INTRODUCTION

INTRODUCTION

The citrus fruits represent the third largest fruit industry of India, next to the mango and the banana. The estimates show that an area about 1.48 lakh hectares is covered by its various species with an annual fruit production of 17 lakhs tonnes (Ghosh, 1985). The climatic conditions in many parts of this country being highly suitable for their culture, these fruits occupy a place of considerable importance in the development of country's fruit industry. It is, however, discouraging to find that there is a wide-spread decline of citrus plants in many parts of India. The trees do well in first few years, bearing heavy crop and then begin to deteriorate in vigour and bearing.

The most important commercial citrus in the country is the mandarin orange which is grown in certain areas of Karnataka, Nagpur, Darjeeling, Sikkim and North Eastern States of India.

It is popular for its rich juice containing sugars, acids, minerals and vitamins. Mandarin orange (Citrus reticulata Blanco.) commonly known as Darjeeling mandarin which occupies nearly 1500 hectares in Darjeeling, Kurseong and Kalimpong sub-divisions, is one of the best in the world but due to absence of any scientific cultivation practices, the orchards are fast declining both in tree health and productivity, and the average productivity of about 5 to 6 tonnes of fruits per hectare is considered to be very low.

The decline in production is a serious malady in citrus cultivation arising out of different causes of complex nature. The declined tree shows sparse, yellow and variously symptomatic foliage, stunted growth, sickly appearance with a dried up top growth. The shoots of the trees begin to die from the top downward, and produce fruits of inferior quality (with rough surface, thick skin and less juice); and some times immature fruit drop also occurs

Among the factors responsible for citrus decline, plant nutrition occupies an important place. Malnutrition, among many other factors, often results in a chlorotic condition of the leaves. Major elements play an important role in the physiological functioning of the plant. The essentiality of maintaining proper nutrient balance in the citrus orchard to ensure tree health and productivity has been reported by Chapman et al. (1945). In 7 to 8-year old sweet orange tree, application of 600 g of N per tree, 50 per cent N from farm yard manure and 50 per cent from ammonium sulphate, resulted in maximum fruit yield and the increased yield due to this treatment was about 60 per cent more in comparison to the unfertilized control trees (Bajwa and Kaura, 1952). According to Randhawa (1970), the poor nutrient status of the soil was the greatest single factor responsible for the decline of orange trees in Kerala. From a trial conducted in a 15-year old Khasi mandarin orchard, Ghosh et al. (1981) reported that a fertilizer dose of 300 g N, 250 g P_2O_5 and 300 g K_2O per tree per year was found to be optimum for an economic yield. Increased

yields were also obtained at different locations in Darjeeling District with the annual application of 400 g nitrogen, 200 g phosphorus and 400 g potassium per plant by Mitra et al. (1985).

There is considerable evidence of the existence of micronutrient deficiencies in different parts of India which is considered to be one of the major factors associated with citrus decline. The chlorotic condition and dieback in citrus could effectively be corrected by spraying with micronutrients such as Zn, Fe, B (Chakdhury, 1954), Zn and Cu (Dikshit, 1958), Zn and B (Singh and Mishra, 1980). Ghosh et al. (1981) obtained significantly higher yield of Khasi mandarin orange through foliar application of spring flush. Chapman (1960) and Calvert (1970) have reported about the significant role of Zn, Cu and B on growth, yield and quality of citrus fruits. Mann et al. (1985) also observed increased fruit yield, fruit weight, juice content and acidity when Zn alone or in combination with Fe, Mn and Cu were applied as foliar spray.

Efficient orchard management programme should provide, besides nutrients, ^{and} other inputs at the right season, particularly at the critical stage of growth. To ensure a healthy and productive orchard, it is also necessary to supply moisture to the trees according to their requirement. Improper moisture management lead to abnormal water relation in the plant and it is also an important factor responsible for citrus decline.

Trees irrigated in field capacity produced fruits with a better storage life, whereas, those irrigated at 80% of field capacity

produced fruits with thinner peel with poor storage life (Akhmedov, 1983). Kuriyama et al. (1983) recorded few puffy fruits and also few fruits with rind disorder in Satsuma mandarin when the soil was kept moist from July to September and dry during October and November. They noticed quick fruit colouration and improvement in the fruit quality.

The diseases like powdery mildew, gummosis, scab, root rot, canker etc. are prevalent in the mandarin orchards of Darjeeling district. The vitality of the trees ^{is} are reduced due to the diseases infection. A number of major and minor insect pest^s like stem borer, citrus leaf miner, scale insects, mealy bugs, citrus butterfly, fruit sucking bugs, aphids etc. also give a set-back to the normal growth of the trees and also contribute to citrus decline.

From the results of the investigations mentioned above it is evident that the citrus decline can be reduced by adapt^oing improved cultural practices such as nutrient management, water management, plant protection measures etc.

In order to improve the conditions of the existing mandarin orchards in Darjeeling district for increasing the yield of better quality fruits the following experiments were carried out during 1984-85.

1. Effect of different levels of N, P and K on growth, yield and fruit quality.

2. Effect of irrigation and different levels of N on growth, yield and fruit quality.

3. Effect of application of urea and Zn as foliar spray on growth and yield of mandarin orange.

4. Effect of Mg, Cu, Zn, Fe and B on growth, yield and fruit quality.

5. Effect of pruning and nutrients application on rejuvenation of declined orange trees.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Citrus require a fairly good amount of nutrients for better growth and yield. The estimate made on the removal of nutrients by the citrus fruits (18 tonnes), were in the order of 21 kg N, 5 kg P, 41 kg K, 19 kg Ca, 3.6 kg Mg, 2.3 kg S, 45 g B, 50 g Fe, 13 g Mn, 13 g Cu and it amply demonstrates the necessity of nutrient application to the plants (Chapman et al., 1945). The ^{Source} results of the investigations on the effect of both macro and micronutrients on growth, yield and quality and nutrient uptake have been summarized hereunder.

Effect of nitrogen on growth, yield and fruit quality :

The plants of Valencia orange receiving higher N were relatively dwarf with greener foliage in comparison to optimum level of N. Such a suppression of growth may be attributed to the fact that excessive N reduced the root population which ultimately affected the plant vigour (Cameron and Appleman, 1934). A marked reduction of feeder roots in Valencia orange on Florida soil receiving high nitrogen was also noted by Ford et al. (1957).

Klein and Monselise (1962) reported that Shamouti orange on sweet lime rootstock showed an increase in internode length, leaf number and leaf area by the application of nitrogenous fertilizers.

Smith et al. (1968-69) also observed that application of nitrogen significantly influenced tree height of Valencia orange and

there was distinct effect of nitrogen placement on root development. The most prominent symptom of inadequate nitrogen on Valencia was thinness of foliage and premature leaf abscission (Smith, 1970). Nokrashy et al. (1977) reported marked increase in yield on young Balady orange tree by the application of N at 350-380 g/tree in equal dose plus an additional 50 g/tree for each year of tree age. In 10 to 11-year old trees, the yield rose with N rates, whereas in 12-year old trees it rose with rates upto 650 g/tree and then declined. Deidda et al. (1980-81) obtained higher yield (218-241 q/ha) by treatment with nitrogen 60 kg N/ha along with P_2O_5 and K_2O , compared to unfertilized control (142 q/ha). In a 3-year trials with 13-year old tree of Valencia orange on sour orange rootstocks, N was applied at 600-1200 g/tree per year in split doses in February, May, July and August (Alla et al., 1985). The yield rose from 40.80 to 57 kg/tree with 600 kg N and from 60.1 to 68.6 kg/tree at 120 g N but the treatments had no appreciable effect on physical and chemical properties of fruit. Franciosi et al. (1985) reported that supplementary foliar application of N, P, K to Washington Navel orange trees affected by tristeza gave the highest yield of 37.9 kg/tree when treated with $N:P_2O_5:K_2O$ (6000:6000:4000 ppm) plus normal NPK fertilization.

Sato and Ishihara (1964) reported that plants of mandarin orange treated with the higher rates of nitrogen showed stronger growth than those treated with the lowest rate. Tomita (1971) reported that in Satsuma orange plants nitrogen treatment (18 g/tree in pot) improved new shoot growth even in dry condition. Singh and Singh

(1977) reported that the lowest nitrogen rate (454 g CAN/tree/year) gave the best result in term of tree vigour, yield and fruit quality of Nagpur mandarin.

In an experiment carried out in a Satsuma orchard on volcanic ash soil over 5 years, Hong and Chung (1979) reported that higher level of nitrogen than the normal combination (125 g N, 175 g P and 100 g K/tree) increased trunk circumference but the shoot growth was not appreciably affected. Hirobe (1981) found increased trunk growth in Satsuma (cv. Fujinaka) tree with 300 kg N/ha, while the crown volume was greatest with 400 kg N/ha. He also noted increased non-flowering shoots with increasing N rate.

In an experiment, Bopalah et al. (1983) noted the effect of NPK application on growth parameters of Coorg mandarin on different rootstocks and found no significant effect in this respect. However, the chlorosis level varied in the tree due to rootstocks.

In another experiment, 5 doses each of N, P and K were applied on mandarin orange trees (N - 0, 159, 400, 646 and 800 g; P_2O_5 - 0, 39, 100, 161 and 200 g and K_2O - 0, 77, 200, 323 and 400 g/tree) and medium level of P and K and increasing levels of N resulted in increased number of fruits per tree. Juice content and TSS decreased with increasing levels of N. The medium level of N and K and increasing levels of P resulted in increased number of fruits and fruit size. At the medium levels of K, the fruit yield increased and decreased the juice content (Anon. 1982-84).

Nadareishvili (1984) found that the recommended fertilizer application produced good vegetative growth on young mandarin trees. He also found that the older trees needed higher application rates, namely 150 g N/tree annually, and 420 g P_2O_5 + 200 g K_2O /tree once in four years.

Improvement in growth was recorded with application of N, P and K (Anon, 1985). The number of fruits, fruit size and also the yield increased with progressive increase in each nutrient. The juice percentage was found to be improved with the increase in the dose of each nutrient. An increase in N and P decreased TSS, while K application exerted beneficial influence. Acidity was increased significantly by N application, while it decreased by K application. Higher levels of N and P were found to reduce vitamin C, while K application increased it.

It was concluded by Kacharava (1985) from a long-term fertilizer trials, where P_2O_5 and K_2O were applied at constant rates of 0 or 100 kg/ha and N in split doses at 0, 250, 500 or 750 kg/ha that application of N: P_2O_5 : K_2O at 500:100:100 kg/ha produced the highest yield.

In a fertilizer trial on Baianinha orange tree, in which each plant received annually 0, 250 or 500 g N, 0, 200 or 400 g P_2O_5 and 0, 150 or 300 g K_2O , Hiroce et al. (1985) found that N fertilization increased leaf N, Ca, S and Mn contents and decreased K, B and

Cl contents, while P fertilization led to higher contents of P, Ca, Mg and reduced B, Cl and Cu contents. K fertilization increased K content and reduced Ca, Mg and B contents.

Fruit production and initial fruit set were usually highest with the increased levels of nitrogen in sweet orange as reported by Singh (1961). In a two-year nitrogen fertilization trial on Navel orange, Azzony *et al.* (1970) found that the yield enhanced in the first year, though not significantly in all the treatments, specially with urea. In the second year, yields of all trees including the controls were much higher. They obtained 46% yield increase over control with CaNO_3 at 0.75 and 1.0 kg N/tree and foliar application of urea. Size of fruit and juice content were greatly enhanced by application of nitrogen either in the form of $\text{Ca(NO}_3)_2$ or urea. However, vitamin C and soluble solids contents were not affected, but acidity and rind thickness were increased by all treatments, especially by urea. From a 6-year trial on sweet orange cvs. Hamlin, Pineapple and Valencia, Reese and Koo (1975) found that increase in N rate increased the juice content, acidity percentage and produced more green fruit of smaller size.

In a 7-year trial with young Nagpur mandarin trees on Karna Khatta rootstock the effects of N (454, 908 and 1362 g/tree/year) were compared and it was noted that the lowest application rate gave the best result in terms of tree vigour, yield, and controlling of fruit drop and the fruit quality (Singh and Singh, 1977). Kodama

et al. (1977) obtained higher fruit weight and juice percentage with increased application of nitrogen in Satsuma mandarin orange. Suzuki et al. (1977) obtained the highest fruit yield from young Satsuma trees receiving the 2 highest N rates and lowest fruit yield from tree receiving no N. The juice content, soluble solids and citric acid were highest in fruit from no N and low N trees. Koo et al. (1977) reported that higher rates of N and K fertilizers resulted in higher juice and acid content in Temple orange.

In an experiment on Satsuma mandarin with N at the rate of 40, 80 or 120 g/tree along with basal dressing of FYM + PK, Lomtadze (1979) obtained a yield of 5016 kg/ha from trees receiving 80 g N/tree compared with 2409 kg/ha in the control.

In Kinnow mandarin, with urea at the rate of 1 or 2 lb N/tree, Lodhi and Rashid (1980) found that the size of fruits increased with urea treatment and the fruits also showed lower acidity, higher T.S.S. and higher total sugar content than the control.

According to Hirobe (1981) the yield of Satsuma (cv. Fuzi-Naka) orange was increased by different levels of nitrogen (100-400 kg/ha). Rind thickness was affected by N level, while the shape of fruit did not vary due to different levels of N.

Bopaiah and Srivastava (1982) reported that 5-year old mandarin trees receiving 500 g/tree showed lower incidence of chlorosis and the highest yield per tree compared to other treatments. Fruit quality (TSS and vitamin C) was also better.

Effect of phosphorus on growth, yield and fruit quality :

Many workers have failed to notice any significant effect of P, despite its application at various rates (Van der Plank and Turner, 1936; Anderson, 1937; Morris, 1937; Parker and Butcheler, 1942; Finch and McGeorge, 1945; Jones, 1946; Reuther et al., 1948; Hayman-Hershberg, 1956; Bouma, 1959; Smith et al., 1963; Sakamoto et al., 1964; Hernandez, 1979).

In contrast, significant response to phosphorus application has also been reported from various citrus growing areas of the world. The increase in fruit size due to P application was reported by Crous (1937), All-wright (1938) and Anderson (1966) in Valencia oranges. Innes (1946) in grape fruit; Jones and Parker (1949) and Devilliers (1969) in Washington Navel orange; Rosselet et al. (1962) in Valencia orange; Suzuki et al. (1972, 1977) in Satsuma mandarin and Leyden (1978) in Rubi Red grape fruit.

Gold-webber et al. (1956) obtained positive effect of P fertilization in respect of trunk growth and relative tree size in Persian lime but number of fruits per tree, total yield and fruit quality remained unaffected.

Mouma and McIntyre (1963) noted that application of superphosphate markedly improved the yield and quality of Valencia Late and Washington Navel orange in non-tilled plots.

In a long-term trial, Pineapple orange trees were grown in a virgin sandy soil for 20 years with different rates of applied

superphosphate. Neither tree growth nor yield was appreciably affected by P levels. Fruit quality in the first 10 or 12 crops was not greatly affected by P treatment, but thereafter, the fruits on high P was poorly coloured and had low soluble solids, acid and vitamin C content than fruits grown without added P (Smith et al., 1963).

Anderson (1966) found that added P increased the yield of Valencia orange, but lowered the fruit quality. In another study, Anderson and Calvert (1967) found that application of P fertilizers improved tree growth on different types of soil except on calcareous soils, although the added fertilizers were effective in increasing P content of the leaves.

In general, P fertilization reduced peel thickness (Smith, 1966; Bar-Akiva et al., 1968; Moss, 1972). Most observations indicated that additional application of P increased the percentage of juice in the orange fruit (Chapman and Rayner, 1951; Smith et al., 1963; Rosselet et al., 1962; Bar-Akiva et al., 1968; Chapman, 1968; Moss, 1972).

Effect of potassium on growth, yield and fruit quality :

Reed and Hass (1923) noted reduction in leaf size and found less chlorophyll in the leaves due to K deficiency in the young orange tree. According to Krishnamurthy and Randhawa (1953) the early potassium deficiency symptoms were stunted growth, sparse foliage and somewhat bronzed and lusterless appearance.

Sato and Ishihara (1964) reported that the effect of potassium

application on growth of mandarin orange tree was not apparent. Hash and Ishihara (1972) found that leaf number, dry weight of most organs of Satsuma mandarin were higher at lower potassium level. According to them, the higher level of K reduced trunk diameter and fruit size. The application of potassium fertilizer in mandarin orange resulted in increasing the crown diameter (Tsotsonava and Marshaniya, 1973).

A fertilizer trial was conducted with the mandarin at the Punjab Agricultural University, Ludhiana with 5 levels each of N (0, 159, 400, 646, 800 g/tree), P (0, 39, 100, 161 and 200 g/tree) and K (0, 77, 200, 323 and 400 g/tree) (Anon. 1982). It was noted that at the medium level of P and K and with the increasing level of P the number of fruits increased appreciably. The number of fruit as also the size of the fruit increased at the medium level of N and K with the increasing level of P. However, the juice content and TSS decreased with the increase in the level of N.

Effect of magnesium on growth, yield and fruit quality :

As summarised by Camp (1947), Mg deficiency caused severe chlorosis of leaves (bronzing), premature defoliation, extreme susceptibility to cold damage, die-back of branches, poor root growth, alternate bearing, reduction in yields and poor fruit quality. Apparently, the detrimental effect of Mg deficiency was associated with photosynthetic capacity of the leaves and defoliation. Therefore application of Mg to deficient plants removed chlorosis and restored health and vigour of plants. However, there are many reports that

application to prevent visible deficiency symptoms had no effect on vegetative growth, yield and fruit quality (Reuther and Smith, 1952; Spencer and Wander, 1960; Smith et al., 1954; Smith, 1954; Calvert, 1970). In fact, mild cases of deficiency did not show any adverse effect. On the other hand, there are reports showing the beneficial effect of Mg application. Calvert and Reitz (1966) in a long-term experiment found that higher dose of $MgSO_4$ significantly increased the yield of grape-fruit for a period of 16 years but the tree condition and fruit quality remained unaffected by Mg application. Kuznestov and Koridge (1977) obtained the best result with regard to yield per tree and fruit quality in Satsuma tree receiving 200 g magnesium. Kuznestov and Treshchov (1979) reported that higher rates (above 200 g/tree) of $MgSO_4$ increased the fruit dry matter and decreased the pulp ratio in young mandarin. Plessis and Smart (1982), however, found no marked effect on yield and fruit size.

Effect of zinc on growth, yield and fruit quality :

It appears that zinc is indispensable for normal growth, flowering and fruiting of citrus. Dwarf and mottle-leaved plants recovered quickly after application of zinc. Reed and Parker (1937) recorded development of healthy leaves of normal size in the first growth flush following foliar spray of zinc sulphate. They also observed improvement in shoot growth and flowering. Internally, there was no significant difference between the thickness of phloem in twig from zinc sprayed and unsprayed trees, but the xylem cylinder was found to

be distinctly thicker in the treated trees, particularly when the older twigs were compared. Increased cambial activity resulted in greater increase of chlorophyll bearing area. Marked increase in yield after corrective treatments was also reported by Parker (1936, 1937).

In an experiment, Golan (1963) mentioned that low volume spray, which was 80 per cent cheaper than high volume spray, with a mixture of 0.5 kg zinc oxide and 0.5 kg zineb per dunam (1000 sq.m.) in 30 lb of water completely corrected deficiency of Valencia and Washington Navel orange.

Soil and foliar application of zinc increased Zn content of leaves of treated plants. Several other workers also demonstrated the effectiveness of $ZnSO_4$ in combating die-back and leaf mottle in citrus (Aiyappa and Subramaniam, 1958; Mani et al., 1959; Singh and Agarwal, 1961).

Labanauskas et al. (1963) found that zinc as foliar sprays on moderately Zn-deficient trees increased the amount of ascorbic acid per unit volume in the juice, but decreased the percentage of juice by weight.

Samoladas (1964) reported that applied zinc stimulated photosynthetic activity, increased yield and controlled irregular bearing of citrus. Zinc added to Bordeaux spray and applied to mandarin trees on alluvial soil brought about an increase in yield by 20 per cent over control (Samoladas, 1965). Chanturiya (1974) obtained 7.3 per cent fruit set in lemons receiving NPK basal dressing plus Zn at 3 g

per tree as compared to 4-8 per cent fruit set in trees receiving only basal dressing of NPK.

Chanturiya (1974) reported 25.8 per cent yield increase in young mandarin trees and Chanturiya and Mikaberidge (1976) obtained 30 per cent yield increment in Satsuma orange tree receiving Zn @ 3 g per tree.

The effect of Zn on the quality of citrus has also been reported by several workers. Bacha (1977) recorded increase in total soluble solid content of Succary orange in the second year following zinc application and improvement in storage of Satsuma fruits. Spraying on Kinnow mandarin with zinc sulphate or ferrous sulphate (0.5-1%) resulted in better sized fruits with increased juice percentage, Total soluble solids, total sugar and ascorbic acid concentration (Dikshit et al., 1977). From a 2-year old trial on Hamlin sweet orange tree, Sahota et al., 1981 found that spraying of zinc at the rate of 0.6% in February and in April did not affect tree girth, height or spread.

Effect of copper on growth, yield and fruit quality :

Bayers and Jonbert (1952) found that soil application of CuSO_4 + compost greatly improved juice content of Tangerine, whereas, foliar sprays gave unsatisfactory response. Majorana (1960) obtained positive response of sweet orange and mandarin trees to injection of 0.012 per cent Cu and spraying with Bordeaux mixture containing 2 per cent Cu, in respect of improvement in fruit size and yield. More

vigorous growth and increased fruit production in Satsuma mandarin were recorded following treatments of Cu containing fungicide; sugar content and sugar acid ratio of the fruit also increased (Ishihara et al., 1974). Bacha (1977) showed that vitamin C content of Balady orange fruit increased following sprays with CuSO_4 at 250 ppm. Mann et al. (1983) noted higher Cu content in leaves when Cu was applied at the rate of 0.2 per cent as a foliar spray in spring, summer and autumn.

Effect of iron on growth, yield and quality of fruits :

Lisanti and Catalano (1956) found that neither vitamin C nor total sugar content in orange, was influenced significantly by ferrous sulphate treatment. Ford et al. (1957) noticed a significant increase in feeder roots, primarily to the zone below 25 cm following soil application of Fe-EDTA. Jones and Smith (1964) pointed out that with increasing Fe deficiency the tree decreased in size and the yield was reduced. In severe stage, the tree became almost fruitless. In this case, the fruit became small, hard, coarse, dry, misshapen and very pale in colour. Wallihan and Garber (1966) noted a close relationship between yield of Navel orange trees and Fe concentration in the leaves. When the concentration of Fe in the spring cycle (September) leaves was below 30 ppm (based on dry weight of leaves), the production of fruit was less than when Fe concentration exceeded 30 ppm. As the Fe content decreased below this value, fruit production declined progressively. Fruit quality at harvest was not seriously affected

except for some loss in colour. The Fe concentration of the juice was almost proportional to that in the leaves. The decrease in yield was due to fewer fruits being matured, while fruit size was same or slightly longer in Fe deficient trees.

Effect of boron on growth, yield and fruit quality :

Smith and Reuther (1951) found no difference in tree size of Valencia as a result of treatment with different levels of boron ranging from deficiency to toxicity. They, however, noted the only concentration of ascorbic acid in low B culture. A field study conducted for several years with different cultivars of orange and grape fruit failed to express any beneficial effect of B at levels above deficiency state (Smith, 1955).

Ishihara and others (1965) showed that boron application increased fruit and seed weights, improved seed development and lowered the total sugar content and sugar acid ratio of fruit.

Kodua (1980) reported beneficial effect of boron on mandarin in increasing the yield by 15-20 per cent when applied with lime and NPK. Boron treatment also increased the ascorbic acid content in fruits.

From a micronutrient trial on mandarin orange tree, in which micronutrients were sprayed @ Zn (0.5%), Mn (0.5%), Cu (0.25%), Fe (0.25%) and B (0.1%), it was observed that all treatments were superior to control. The fruit weight increased in all the treatments

compared to control and the increase was more with Zn+Mg+Mn+Cu+Fe+B and Zn+Mg+Mn+Cu+Fe. Juice percentage also increased in all the treatments and it was more with Zn+Mg, Zn alone and Zn+Mg+Mn+Cu. T.S.S. content also improved by the application of micronutrients (Anon. 1982.).

Plant analysis

Sweet orange (C. sinensis Osbeck) :

There are a number of evidences that application of nitrogenous fertilizers to sweet orange tree cultivars Hamlin, Washington Navel, Valencia, Shamouti etc. resulted in increased leaf nitrogen content (Thombesi et al., 1962; Leyden, 1963; Chhonkar and Tiwari, 1966; Jones and Embleton, 1967; Smith et al., 1969; Feungchan and Sharma, 1974; Reese and Koo, 1975), and consequent decrease in leaf phosphorus and potassium content (Thombesi et al., 1962; Leyden, 1963; Reese and Koo, 1975).

Labanauskas et al. (1962) observed that in Washington Navel orange trees when treated with organic manure increased the foliar concentration of K and decreased N and Fe as compared with leaves treated with similar quantities of N, P and K from chemical sources. The optimum level of leaf nitrogen content of normal orange trees varied according to the cultivar; for Shamouti orange it was 2.2% (Pat and Zafrir, 1963) and for Valencia and Navel orange, it varied from 2.4-2.6% (Jones and Embleton, 1968).

From an investigation on mineral nutrition status of sweet

orange trees in healthy and declining condition, Nijjar and Singh (1971) noted that leaf Mn, Fe and Zn were insufficient at most sites and foliar N was adequate only in the healthy plants.

Leaf $\text{NO}_3\text{-N}$ (often not more than 0.25% of total N) varied directly with applied N in Valencia and Shamouti orange, Eureka lemon and Marsh grape fruit trees (Bar-Akiva, 1972). Hernandez (1979) reported that in Valencia orange the difference in foliar N content was not very pronounced to reflect the different rates of N (160, 320, 480 kg/N/ha) application.

Mann et al. (1979) reported that healthy sweet orange tree cv. Blood Red usually contained higher leaf N, Ca and Zn contents than those showing symptoms of chlorosis and dieback.

Mandarin orange :

Sinha and Randhawa (1961) observed in sweet orange a marked reduction of N content in the leaves of autumn flush and an increase in early spring. Calabrese (1965) reported that in Avana and Tardi-vodi Ciaculli mandarins, foliar N (in fruiting shoots) increased from early June till late July or early August, remained fairly constant for several weeks and did not increase again in the late autumn.

Randhawa and Kar (1967) reported that in mandarin, the total N content decreased with leaf age. In Valencia orange foliar N of fruiting branches was influenced by the rate of N applied and showed a sharp fall at the spring flush, followed by summer and fairly gradual decline until the end of winter (Aso and Dantur, 1969).

Deidda and Virdis (1969) working with various types of citrus viz., Washington Navel, Torocco sweet orange, Avana Mandarin, Comune Clementine and Teresa lemons found that leaf N and P contents fell between January and May of spring flush, rose during summer and autumn until December. Plessis and Smart (1970) reported that N content was highest (3.8%) in young leaves, in September but during the following two months it declined rapidly to 2.3%. The variation in leaf content of different elements was least from April to June i.e. when the leaves were 7-9 months old.

Reese and Koo (1976-77) found that in Temple mandarin, leaf N and Mg were increased by N application but foliar P, K and Ca tended to decrease as N rate increased. However, Suzuki et al. (1977) reported that leaf N was inversely related to foliar Ca, Mg and K. Leaf age, season of growth and type of shoots (bearing/non-bearing), also influenced nutrient content of leaf.

Suzuki et al. (1977) also recorded that leaf nitrogen content in the leaf changed within 10-15 days of application of fertilizers in proportion of the amount applied and the difference persisted until harvest. In Navel orange, the N content of spring growth on the non-fruiting terminals increased gradually as the rate of N fertilizer increased (Shawky et al., 1979).

Lodhi and Rashid (1980) found increased leaf N and better shoot growth with urea at 1 or 2 lb N/tree in Kinnow mandarin.

Prasad and his associates (1981) observed that the leaves

(64% of the samples) from non-fruiting shoots contained low N (1.96 to 2.66%), while 38% of the samples contained low Zn (10-13 ppm) in the mandarin trees of the North-Eastern hill region.

With an annual application of 0.4 kg N/tree, average leaf N content of Imperial was 2.8% in non-fruiting terminal and 2.32% in fruiting terminals while, with an application of 0.7 kg N/tree both these figures were increased by 0.11% (Chapman, 1982).

Effect of P and K nutrient on foliar nutrient content :

A comprehensive study of citrus leaf analysis as a diagnostic tool with special reference to K was made by Chapman and Brown (1950).

Sinha and Randhawa (1961) reported that in sweet orange leaves, K decreased in November. Marked variation in the composition of twig of different growth flushes were observed. In autumn flush P and K were highest. Labanauskas et al. (1962) reported that in Washington Navel orange application of K and urea increased the K and Cl content of leaves as compared with leaves of trees treated with urea alone. Millella (1968) reported that in Washington Navel and Torocco orange, K values of leaves rose gradually from April to July, sharply from July to August and fell comparatively steadily from August until the following March. In orange trees, the chief effects of application of potassic fertilizer were observed as a marked reduction in leaf N and Ca and an increase in P and K. Neither P nor K showed significant correlation between the amounts applied and the percentage

present in the leaves (Thombesi et al., 1962).

Aso and Dantur (1969) reported that except for a slight rise in mid-summer, followed by a very sharp fall, the K content of the leaves fell fairly steadily with age. Both N and P, especially the former depressed K values.

Deidda and Virdis (1969) working on a number of citrus like Washington Navel, Torocco sweet orange, Avana mandarin, Comune Clementine and lemon reported that Leaf P contents fell between January and May during spring flush. Total foliar P rose until October-November and then again decreased sharply.

Hasse and Ishihara (1972) claimed that the optimum level of K in leaf of mandarin should be between 1.2 and 1.6% for high fruit quality and yield. However, in the normal healthy tree it was 1.0-1.3% and when the K value fell beyond 0.5%, it was found to show potash deficiency. Whereas, Magnitsi and Takidze (1972) reported that critical foliar K level was 1.6%. They observed a positive correlation between leaf P and K contents and yield of mandarin tree.

In a study Mann et al. (1979) found leaf P, Ca and Mg contents, low to optimum and leaf K, B, Cu, Fe and Mn contents, optimum to high in most orchards of sweet oranges, irrespective of the tree conditions (healthy and decline).

Intrigliolo et al. (1981) reported that leaf P and K declined with leaf age. Chapman (1982) found that K contents resulting from treatment with 0, 0.5 and 0.6 kg K/tree were 0.85, 0.93 and 1.35%

respectively, in non-fruiting terminals and 0.40, 0.44 and 0.77% in fruiting terminals.

Basso et al. (1983) found that leaf N and Cu were high and P and Zn were low in the leaves of Valencia orange trees receiving N, P_2O_5 and/or K_2O at 75-150; 75-150; 75-225 kg/ha. They also found a positive correlation between leaf P and K contents. High K rates decreased leaf Mg and Ca. Leaf-age, season of growth and type of shoots also influenced foliar P and K content.

From a long-term NPK fertilizer trial on Baianinha orange tree in which each plant received annually 0, 250 or 500 g N, 0, 200 or 400 g P_2O_5 and 0, 150 or 300 g K_2O , it was observed that, N fertilization increased leaf N, Ca, S and Mn contents and decreased K, B and Cl contents. P fertilization led to higher contents of P, Ca, Mg and reduced B, Cl and Cu contents while, K fertilization increased K content and reduced Ca, Mg and B contents (Hiroce, 1985).

Effect of irrigation on growth, yield and quality of fruit :

Koo et al. (1965, 1966) reported that fruit production was increased by irrigation in Dancy tangerines. Irrigation resulted in lower total soluble solids and acid contents but higher juice as compared with no irrigation. Maturity date was advanced in certain years by irrigation and supplemental irrigation had no effect on decay of the fruit.

Koo et al. (1976) further reported that increase in N and K fertilizer resulted in higher juice content of fruit. Fruit from the

split irrigation treatment had higher total soluble solids than autumn irrigation. Treatment with N decreased and K increased the fruit size and weight while no consistent trend was found with irrigation treatments. More intense orange colour in the rind was produced by high N and spring irrigation treatments. More later-fruit was found in plot treated with high N and autumn-irrigation.

In a trial with orange cv. Natal, it was found that application of irrigation increased number of fruits by 56% and fruit weight by 70% (Vieira, 1985).

The size of the tree was increased with supplemental irrigation. Fruit production increased with N, K and irrigation treatment. Yield and total soluble solids content of fruit increased with N rates and decreased with increased K and irrigation rates. Higher fruit production from irrigation treatment was due to larger tree size and increased production efficiency of canopy surface area. N was more efficiently used with irrigation than without irrigation (Koo, 1979). Goel et al. (1983) reported that sub-optimally irrigated or partially stressed trees did not grow to the same size compared to those receiving optimum water. A short period of moisture stress during the irrigation season was very effective in initiating and promoting vegetative growth flushes.

Kuriyama et al. (1983) carried out experiments in pots and in framed boxes in the field from 1965 to 1973. When the soil was kept moist from July to September (the period during which the fruit develops) and dry from October to November (the period during which

fruit matures) the fruits developed colour rapidly. There were few puffy fruits or those affected with rind disorder. The juice was concentrated and quality was markedly improved. Akhmedov (1983) reported that lemon trees irrigated at field capacity produced fruits with a thick peel, low juice and sugar contents but with good storability, while those irrigated at 80% of field capacity produced fruits with a thinner peel and poorer storability.

Plessis et al. (1983) reported that in Valencia orange orchard moisture conservation during 3 stages; during full bloom to the end of December (about 10 weeks); end of December to early May (about 18 weeks); and early May to end of August (16 weeks); growth enhanced rapidly during the second stage.

In an experiment with 2-water regimes on different citrus crops, Yusufi and Gulov (1985) noted that all types (lemons cv. Meyer, Mandarins cv. Kovanovase and oranges cv. Hamlin) had a high leaf water content and water retaining capacity was highest in mandarin. Chilembewe (1985) found that application of irrigation to Marsh Seedless' grape fruit from flowering stage to fruit maturity stage was more effective than frequent irrigation throughout the year.

Koo and Smajstrla (1985) studied the effect of trickle irrigation and fertilization on fruit production and juice quality of Valencia orange. They recorded increased fruit production by 39.649% over control and the increase being directly related to the increase in ground coverage due to irrigation and fertilizer treatment.

Irrigation and partial fertilizer reduced both TSS and acid concentration in juice.

Effect of pruning on growth, yield and fruit quality :

Bziava and Kvirkveliya (1980) noted longest tree height, average yield and greatest productivity by pruning young lime trees. Sanikidze (1981) recommended semi-hard pruning as most economic method to obtain higher yield of aged mandarin tree. Whereas, Zargoza and Alansocabo (1981) found that mean yields for the first 4 years, were highest in unpruned trees (127.56 kg/tree). They further noted that pruning had no effect on fruit weight, fruit diameter, rind thickness or percentage of juice. Tavadze (1983) pruned mandarin trees, to open the canopy and found yield reduction in the first year but economic production was reported from pruned trees afterwards.

Raciti et al. (1982) in an experiment with 3 orange cvs., Femminello Commune, Lemons and Avana mandarins concluded that mechanical pruning had no detrimental effect on total yield over 3 years and had little effect on fruit quality. Borrell et al. (1983) found that pruning stimulated growth and improved yield and fruit quality of Valencia late orange. In a pruning and fertilizer trial Iwagaki et al. (1985) observed that canopy growth was suppressed by pruning and yields were decreased. However, the fruit size was longer and biennial bearing was slightly reduced by pruning. Fruit quality was slightly lower in the pruned and high fertilised plants.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiments were carried out at two locations Sakyong and Pedong in Kalimpong sub-division of Darjeeling district, West Bengal in two successive years 1984 and 1985.

The orchards are situated between 900-1050 metres above sea level. The meteorological data during the period of investigation have been presented in Table 1. The soil of the orchards is sandy loam in texture with pH between 5.6-5.8. A composite soil sample was taken before laying out the experiments and the chemical analysis indicates the fertility status of the soil as follows.

Location	Nitrogen (per cent)	Available phosphorus (kg/ha)	Available potash (kg/ha)
Sakyong	0.181	10.01	79.00
Pedong	0.158	11.50	75.00

In order to improve the yield and fruit quality of the mandarin orange in Darjeeling district the following experiments were taken up.

Experiment 1. Effect of different levels of N, P and K on growth, yield and fruit quality.

The trial was carried out on 15 years old bearing mandarin orange plants of uniform vigour. The details of the treatments employed

TABLE 1. Meteorological data (mean) pertaining to the period of experimentation (1984 and 1985).

Months	Temperature (°C)		Rainfall (mm)	Humidity (percent)
	Maximum	Minimum		
January	17.77	7.18	37.00	85.50
February	19.88	8.26	39.89	89.75
March	24.09	13.98	70.93	88.50
April	27.18	14.86	87.02	89.50
May	25.69	16.86	180.20	92.50
June	27.60	19.31	326.15	91.00
July	25.78	20.02	222.48	92.50
August	27.61	19.47	217.73	91.00
September	24.62	19.73	174.98	91.50
October	26.20	18.85	174.48	94.00
November	23.08	13.18	51.10	91.00
December	19.67	8.63	46.36	85.50

in this experiment are given below.

Design of the experiment	- 3^3 confounding
Number of replications	- 3
Number of treatments	- 27
Spacing	- 6 m x 6 m

Treatments : Levels of N, P and K

Nitrogen	N_1	N_2	N_3
	400	600	800 g/plant
Phosphorus	P_1	P_2	P_3
	200	400	600 g/plant
Potassium	K_1	K_2	K_3
	400	600	800 g/plant

The treatment combinations are as follows :

$N_1P_1K_1$	$N_2P_1K_1$	$N_3P_1K_1$
$N_1P_1K_2$	$N_2P_1K_2$	$N_3P_1K_2$
$N_1P_1K_3$	$N_2P_1K_3$	$N_3P_1K_3$
$N_1P_2K_1$	$N_2P_2K_1$	$N_3P_2K_1$
$N_1P_2K_2$	$N_2P_2K_2$	$N_3P_2K_2$
$N_1P_2K_3$	$N_2P_2K_3$	$N_3P_2K_3$
$N_1P_3K_1$	$N_2P_3K_1$	$N_3P_3K_1$
$N_1P_3K_2$	$N_2P_3K_2$	$N_3P_3K_2$
$N_1P_3K_3$	$N_2P_3K_3$	$N_3P_3K_3$

The land of the experimental field was kept clean throughout the period of investigation by timely intercultural operations. Nitrogen, phosphorus and potassium were applied in the form of urea (46% N),

single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. In order to prevent flow of leaching the fertilizers from one plot to another, channels were provided around each plot. Nitrogen fertilizer was given in two split doses once in June and another in September, while the phosphorus and potassium were applied along with the first dose of nitrogen.

Irrigation was given following fertilization as well as during the winter months to provide uniform moisture content beneficial for plant growth. Thimet 10-G @ 10 g per plant was applied at the base of the plant during manuring to control the trunk borer. The plants were sprayed with Bavistin (0.1%) followed by Cythion (1 ml/litre) at an interval of 15 days from May to October to control powdery mildew, mites and shoot borer and spraying of Rogor (1 ml/litre) was made to minimise the incidence of fruit borer.

Experiment 2. Effect of different levels of nitrogen and irrigation on growth, yield and fruit quality.

Studies were made on 8 years old mandarin orange plants of uniform growth.

Design of the experiment	- Randomized Block Design
Number of replications	- 3
Number of treatments	- 16
Spacing	- 6 m x 6 m

The treatments consisted of three levels of nitrogen at the rate of 200 g (N_1), 400 g (N_2) and 600 g (N_3) per plant per year and

three levels of irrigation at an interval of 10 days (I_1), 20 days (I_2) and 30 days (I_3) alone and in combinations. The irrigation was started from the month of February and continued till the beginning of monsoon.

The treatments are as follows :

1. Control	5. I_1	9. N_2+I_1	13. N_3+I_2
2. N_1	6. I_2	10. N_3+I_1	14. N_1+I_3
3. N_2	7. I_3	11. N_1+I_2	15. N_2+I_3
4. N_3	8. N_1+I_1	12. N_2+I_2	16. N_3+I_3

The intercultural operations were the same as done in experiment 1. The source of nitrogen fertilizer was urea and time of application was the same as in experiment 1.

Experiment 3. Effect of application of urea and Zn as foliar spray on growth and yield of mandarin orange.

The experiment was conducted on 8 years old mandarin orange plants.

Design of the experiment - Randomised Block Design

Replications - 4

Number of treatments - 10

Spacing - 6m x 6m

The details of the treatments employed in this experiment are given below :

1. Control
2. Urea - 400 g N/tree (soil)

3. Zinc - 0.5% (foliar spray)
4. Urea (soil) + urea 0.5% (foliar spray)
5. Urea (soil) + urea 1% (foliar spray)
6. Urea (soil) + urea 1.5% (foliar spray)
7. Urea (soil) + Zn
8. Urea (soil) + urea 0.5% + Zn
9. Urea (soil) + urea 1.0% + Zn
10. Urea (soil) + urea 1.5% + Zn

The intercultural operations were the same as done in experiment 1. The source of zinc was zinc sulphate.

In case of foliar application of nutrients, the required amount of fertilizer was dissolved in water separately, the pH of the $ZnSO_4$ solution was adjusted by lime and sprayed twice in the month of May and September with a foot sprayer. Soil application of urea was done twice i.e. June and September.

Experiment 4. Effect of Mn, Cu, Zn, Fe and B on growth, yield and fruit quality.

About 18 years old mandarin orange plants were selected for the study.

Design - Randomised Block Design

Number of replication - 4

Number of treatments - 10

Spacing - 6m x 6m

The treatments consisted of one level each of magnesium

sulphate (2.0%) copper sulphate (0.4%), zinc sulphate (0.5%), boric acid (0.1%) and ferrous sulphate (0.25%). The nutrient were sprayed either singly or in various combinations. The details of the treatments are as follows.

- | | |
|------------|---------------------------|
| 1. Control | 6. B |
| 2. Mg | 7. Cu + Zn |
| 3. Cu | 8. Mg + Cu + Zn |
| 4. Zn | 9. Mg + Cu + Zn + B |
| 5. Fe | 10. Mg + Cu + Zn + Fe + B |

The required amount of nutrients were dissolved in water separately and sprayed twice in the month of May and September.

The intercultural operations were the same as done in experiment 1.

Experiment 5. Effect of pruning and nutrients application on rejuvenation of declined orange trees.

The investigation was carried out on more than fifty years old mandarin orange plants.

Design of the experiment - Randomised Block Design

Number of replications - 3

Number of treatments - 17

The treatments consisted of four levels of nitrogen at the rate of 400 g (N_1), 600 g (N_2), 800 g (N_3) and 1000 g (N_4)/plant and one level each of phosphorus 400 g (P), potassium 600 g (K), zinc

(0.5%) and magnesium (2.0%). Pruning was done along with the treatment. Nitrogen, phosphorus and potash were applied in the soil in the form of urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively, while zinc and magnesium were sprayed as sulphates.

The details of the treatments are as follows.

1. Control (pruning)
2. Control (without pruning)
3. $N_1 + P + K$
4. $N_2 + P + K$
5. $N_3 + P + K$
6. $N_4 + P + K$
7. $Mg + Zn$
8. $N_2 + P + K + Zn$
9. $N_2 + P + K + Mg$
10. $N_1 + P + K + \text{pruning}$
11. $N_2 + P + K + \text{pruning}$
12. $N_3 + P + K + \text{pruning}$
13. $N_4 + P + K + \text{pruning}$
14. $N_3 + P + K + Zn + \text{pruning}$
15. $N_3 + P + K + Mg + \text{pruning}$
16. $N_2 + P + K + Mg + Zn + \text{pruning}$
17. $N_3 + P + K + Mg + Zn + \text{pruning}$

The intercultural operations were the same as done in experiment 1.

The plants were old and in a declining state. As such removal of branches was necessary and all diseased and declined shoots were pruned. Nutrients were also applied after thorough pruning for

rejuvenation. After pruning the cut surfaces were painted with Elitox. Time of application of the nutrients was same as done in previous experiments. Pruning was done in the first week of January, 1984.

Observations recorded :

Plant height :

The plant height was recorded before starting the experiment and also after a period of one year. The data were pooled and the increase in growth was expressed in centimeter.

Plant spread :

The spread of tree in both East-West and North-South directions was measured at maximum width once at the beginning and again after a period of one year. The data were pooled ^{and} on the increase in spread was expressed in centimeter.

Girth :

Stem girth (5 cm above ground level) of plant was measured before starting the experiment and two years after the treatment and the increase was expressed in centimeter.

Total number of fruits :

The number of fruits per tree was recorded at harvest and individual fruit weight was recorded.

Yield :

The total yield per tree was recorded in kilogramme at harvest and yield/ha was calculated in quintal.

Fruit quality :

Uniformly ripened fruits of marketable appearance were analysed for physical parameters and chemical constituents. Each sample consisting of 10 fruits, from each replication per treatment was taken at random.

Diameter of fruit :

The diameter was measured after harvest with slide caliper. Ten fruits under each treatments were taken and the average was determined.

Pulp weight :

The weight of pulp excluding peel and seeds was measured.

Peel weight :

The peel of fruits was separated by hand and weighed and average was calculated.

Juice content :

After peeling, the pulp of the fruit was crushed to extract the juice. The juice was strained through fine strainer. The quantity of the juice was measured in a measuring cylinder and expressed in percentage with respect to the fruit weight.

Total soluble solids :

The total soluble solid was recorded with the help of a hand refractometer calibrated in °Brix.

Sugar :

The different sugar fractions of fruit were determined by copper reduction method (A.O.A.C., 1970).

Total titratable acidity :

Total titratable acidity was determined with N/10 NaOH using phenolphthalein as an indicator.

Leaf analysis :

Leaf samples were collected four times in a year i.e. *define ?* January, April, July, October. Leaves of same physiological age were taken from plants under each replication and the composite samples were prepared for estimation. Leaf nitrogen was estimated by the micro-kjeldahl apparatus (Humphries, 1950).

The phosphorus content of leaf was determined by phosphomolybdo-vanadate yellow colour method and was read at 670 m μ in a colorimeter (Jackson, 1967).

The potassium content in leaf was determined by flame photometer (Piper, 1944). The constituents of leaf nutrients was expressed as percentage dry matter.

Statistical analysis :

The experimental data were analysed statistically following the analysis of variance method given by Panse and Sukhatme (1978).

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Experiment 1. Effect of different levels of N, P and K on growth, yield and fruit quality.

The different levels of nutrients used in this experiment, were nitrogen (N_1 - 400, N_2 - 600, N_3 - 800 g N/plant/year), phosphorus (P_1 - 200, P_2 - 400, P_3 - 600 g P_2O_5 /plant/year) and potassium (K_1 - 400, K_2 - 600, K_3 - 800 g K_2O /plant/year).

Plant height :

The data on increase in height during a period of two years due to the treatment with different levels of N, P and K presented in Table 2 revealed that an increase in the rates of N and K considerably increased the plant height, while the effect of P was not consistent. The highest level of nitrogen (N_3) was found more effective compared to phosphorus and potassium. An increase in the level of nitrogen from 400 to 800 g per plant increased the total height by more than 15.05 cm, while the differences between the highest and lowest level of P and K were 0.86 and 4.84 cm, respectively.

The interaction effects of N x P, P x K and N x P x K were also significant. The highest level of N and K (N_3K_3) resulted in more (43.99 cm) increase in height compared to (42.30 cm) with highest level of N and (N_3P_3) and 37.20 cm with highest level of P and K (P_2K_3). The treatment $N_3P_3K_3$ caused maximum increase (44.21 cm)

TABLE 2. Effect of different levels of N, P, K and their interactions on increase in plant height (cm)

N levels		P levels			K levels		
N ₁	26.37	P ₁	33.06	K ₁	31.70		
N ₂	33.88	P ₂	34.70	K ₂	33.43		
N ₃	41.42	P ₃	33.92	K ₃	36.54		
S. Em ±	0.39		0.39		0.39		
C.D.at 5%	1.10		1.10		1.10		
<u>N x P</u>		P ₁	P ₂	P ₃			
N ₁	27.54		29.19		P ₃		
N ₂	31.29		33.26				27.60
N ₃	40.33		41.62				31.86
S. Em ±	0.68						42.30
C.D.at 5%	1.92						
<u>N x K</u>		K ₁	K ₂	K ₃			
N ₁	25.34		31.17				27.82
N ₂	25.95		32.64				37.81
N ₃	38.60		41.67				43.99
S. Em ±	0.68						
C.D.at 5%	1.92						

Contd....

Contd.... Table 2.

<u>P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
P ₁	29.56	34.29	35.32
P ₂	29.87	37.00	37.20
P ₃	30.46	34.20	37.10
S. Em ±	0.68		
C. D. at 5%	1.92		
<u>N x P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
N ₁	24.25	31.76	26.63
	25.76	33.00	28.82
	26.02	28.76	28.03
N ₂	27.19	30.98	35.70
	25.31	35.81	38.66
	25.37	31.15	39.08
N ₃	37.25	40.13	43.63
	38.55	42.20	44.13
	40.01	42.70	44.21
S. Em ±	1.17		
C.D. at 5%	3.30		

in plant, while the increase was minimum (24.25 cm) with the lowest level of the nutrient ($N_1P_1K_1$). Better results were also obtained with $N_3P_2K_2$ (42.20 cm), $N_3P_3K_2$ (42.70 cm), $N_3P_1K_3$ (43.63 cm) and $N_3P_2K_3$ (44.13 cm) treatments.

Stem girth :

Like the increase in height of the plant, the stem girth also increased considerably due to different levels of N, P and K and the variation was significant (Table 3). Increase in the level of nitrogen, phosphorus and potassium from 400 to 800 g, 200 to 600 g and 400 to 800 g respectively, increased the basal girth of the stem. Among the interaction of N x P, N x K and P x K, the increase was maximum (4.80 cm) with N_3K_3 treatment. The highest level of nitrogen (N_3) along with different levels of phosphorus and potassium nutrients resulted better girth growth in the present investigation. However the stem girth was found to be maximum (4.91 cm) with $N_3P_2K_3$.

Spread of the plant.

East-West :

The spread growth presented in Table 4 showed that an increase in the level of nitrogen increased the spread of the plant during the period of two years. An increase in the level of P and K did not improve markedly the spread of the plants. Among the different interaction treatments, interaction between N x P and N x K and P x K was found significant and N_3K_3 showed 48.30 cm increase in spread compared to 46.62 cm with N_3P_3 and 39.36 cm with P_3K_2 in

TABLE 3. Effect of different levels of N, P, K and their interactions on increase in ste girth (cm).

N levels		P levels		K levels	
N ₁	2.68	K ₁	3.50	K ₁	3.43
N ₂	3.34	K ₂	3.58	K ₂	3.59
N ₃	4.66	K ₃	3.60	K ₃	3.67
S. Em ±	0.01		0.01		0.01
C.D.at 5%	0.02		0.02		0.02
<u>N x P</u>	P ₁		P ₂		P ₃
N ₁	2.81		2.89		2.97
N ₂	3.06		2.14		3.19
N ₃	4.49		4.71		4.64
S. Em ±	0.03				
C.D.at 5%	0.08				
<u>N x K</u>	K ₁		K ₂		K ₃
N ₁	2.53		3.32		3.56
N ₂	2.68		3.35		2.83
N ₃	4.44		4.73		4.80
S. Em ±	0.03				
C.D.at 5%	0.08				

Contd....

Contd...Table 3.

<u>P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
P ₁	3.09	3.75	3.36
P ₂	3.22	3.82	3.70
P ₃	3.34	3.82	3.64
S. Em ±	0.03		
C.D.at 5%	0.08		
<u>N x P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
N ₁	2.35	3.28	2.81
	2.52	3.33	2.84
	2.72	3.35	2.86
N ₂	2.50	3.33	3.36
	2.71	3.35	3.37
	2.83	3.37	3.38
N ₃	4.42	4.66	4.81
	4.44	4.78	4.91
	4.48	4.76	4.69
S. Em ±	0.05		
C.D. at 5%	0.14		

TABLE 4. Effect of different levels of N, P, K and their interactions on increase (cm) in plant spread (East-West).

N levels		P levels			K levels		
N ₁	23.54	P ₁	34.47	K ₁	33.33		
N ₂	36.04	P ₂	34.84	K ₂	34.40		
N ₃	45.61	P ₃	35.88	K ₃	37.45		
S.Em ±	0.28		0.28		0.28		
C.D.at 5%	0.79		0.79		0.79		
<u>N x P</u>		P ₁	P ₂	P ₃			
N ₁	26.69		27.46			P ₃	27.63
N ₂	31.75		31.80				32.72
N ₃	44.95		45.25				46.62
S.Em ±	0.49						
C.D.at 5%	1.38						
<u>N x K</u>		K ₁	K ₂	K ₃			
N ₁	22.05		34.11				25.61
N ₂	22.96		35.55				38.42
N ₃	43.83		44.69				48.30
S.Em ±	0.49						
C.D.at 5%	1.38						

Contd....

Contd... Table 4.

<u>P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
P ₁	22.80	37.40	36.84
P ₂	29.20	37.58	37.70
P ₃	30.46	39.36	37.80
S. Em ±	0.49		
C.D. at 5%	1.38		
<u>N x P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
N ₁	P ₁	21.09	24.65
	P ₂	22.03	26.66
	P ₃	23.05	25.54
N ₂	P ₁	22.71	38.16
	P ₂	21.35	38.44
	P ₃	24.82	38.68
N ₃	P ₁	43.66	47.72
	P ₂	44.30	48.01
	P ₃	43.53	49.19
S. Em ±	0.85		
C.D. at 5%	2.40		

the East-West direction. The maximum increase in spread growth in the East-West direction was recorded (49.19 cm) with $N_3P_3K_3$, followed by $N_3P_2K_3$ (48.01 cm), $N_3P_1K_3$ (47.72 cm) and $N_3P_3K_2$ (47.14 cm) and the spread was minimum (21.09 cm) with the lowest rates of the nutrients ($N_1P_1K_1$).

North-South :

A marked increase in spread growth was also noted with the highest level of nitrogen application. The increase in the spread of the canopy in North-South direction in two years was 43.56 cm in plant receiving 800 g N compared to 23.42 cm in the plant treated with 400 g N per year (Table 5). The highest level of N and K (N_3K_3) showed 45.59 cm increase in spread in North-South direction compared to 36.73 cm with the highest level of P and K (P_3K_3) and 44.34 cm with N_3P_3 . The treatment $N_3P_3K_3$ resulted in the maximum (46.83 cm) spread in North-South direction. ^{Good} Better response was also obtained with $N_3P_1K_3$ (46.63 cm), $N_3P_2K_2$ (45.36 cm) and $N_3P_3K_2$ (45.16 cm).

Number of fruit per plant :

Data presented in Table 6 revealed that an increase in the level of nitrogen, phosphorus and potassium markedly increased the fruit production. The increase in fruit number was more pronounced due to higher rates of nitrogen. The plants treated with 800 g nitrogen produced, on an average 778 fruits per plant compared to 538 with 400 g nitrogen. It was interesting to note that the production during the second year was much higher compared to that in the

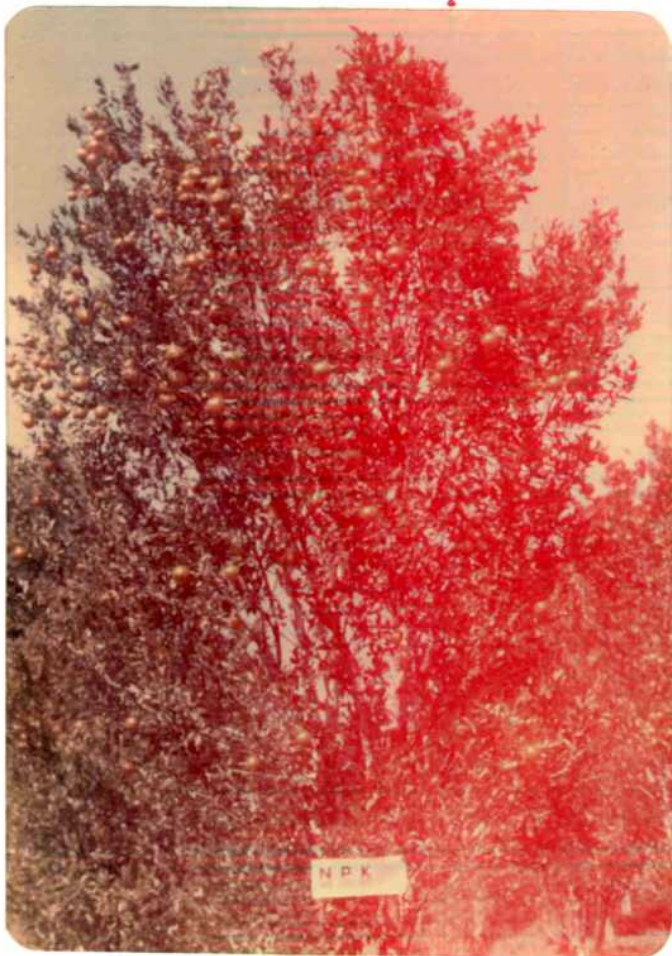
TABLE 5. Effect of different levels of N, P, K and their interactions on increase (cm) in plant spread (North-South).

N levels		P levels			K levels		
N ₁	23.42	P ₁	33.35	K ₁	32.25		
N ₂	35.99	P ₂	33.93	K ₂	34.13		
N ₃	43.56	P ₃	34.80	K ₃	35.69		
S. Em ±	0.25		0.25		0.25		
C.D. at 5%	0.70		0.70		0.70		
<u>N x P</u>		P ₁	P ₂	P ₃			P ₃
N ₁	26.77		26.87		27.31		
N ₂	29.81		31.76		32.74		
N ₃	43.26		43.08		44.34		
S. Em ±	0.43						
C.D. at 5%	1.21						
<u>N x K</u>		K ₁	K ₂	K ₃			
N ₁	22.20		33.94		24.80		
N ₂	23.24		34.40		36.67		
N ₃	40.60		44.48		45.59		
S. Em ±	0.43						
C.D. at 5%	1.21						

Contd....

Contd... Table 5.

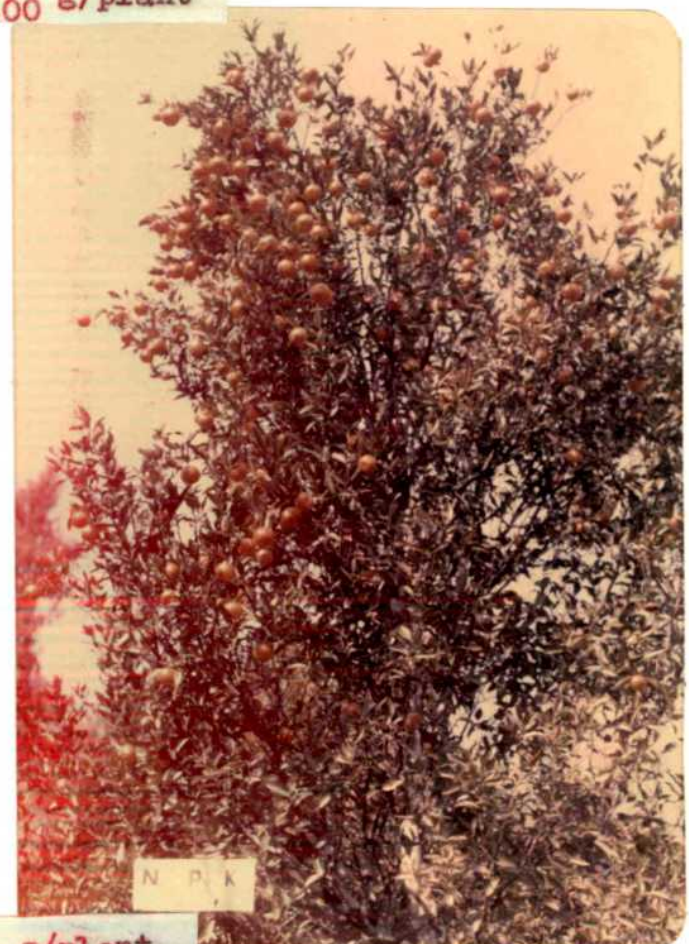
<u>P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
P ₁	28.23	36.05	35.56
P ₂	28.68	38.25	34.77
P ₃	29.13	38.52	36.73
S. Em ±	0.43		
C.D. at 5%	1.21		
<u>N x P x K</u>	<u>K₁</u>	<u>K₂</u>	<u>K₃</u>
N ₁			
	22.02	33.20	25.10
	22.37	34.20	23.96
	22.23	34.35	25.35
N ₂			
	22.46	32.03	34.96
	23.13	35.13	37.03
	24.15	36.06	38.03
N ₃			
	40.23	42.92	46.63
	40.56	45.36	43.33
	41.03	45.16	46.83
S. Em ±	0.75		
C.D. at 5%	2.12		



Photographs showing the plants treated with-

1. $N_{400}P_{200}K_{800}$ g/plant

2. $N_{800}P_{200}K_{400}$ g/plant



3. $N_{800}P_{600}K_{400}$ g/plant

4. $N_{800}P_{600}K_{400}$ g/plant

Photograph 5. Plant treated with $N_{800}P_{600}K_{800}$ g/plant



Photograph 6. Plant treated with $N_{400}P_{600}K_{400}$ g/plant

first year with nitrogen nutrition only, while application of phosphorus and potassium ^{were increased} showed a ^{marked} increase in fruit production. + ?

The interaction effect of N x K was, however, more pronounced compared to NxP and P x K. The plant receiving 800 g nitrogen and 800 g potassium per year showed an average of 845 fruit per plant compared to 498 with 400 g nitrogen and 200 g phosphorus. The highest levels of the nutrients ($N_3P_3K_3$) produced the largest number of fruits per plant i.e. 933 and 857 in 1984 and 1985, respectively, while the lowest level of the nutrients ($N_1P_1K_1$) used in this experiment produced an average of 514 fruits only. Higher production was also obtained with $N_3P_3K_2$ (824), $N_3P_1K_3$ (823), $N_3P_2K_3$ (816) and $N_3P_3K_1$ (803) treatments (Table 6).

Weight of each fruit :

It is clear from the data presented in Table 7 that application of nitrogen caused marked improvement in the individual fruit weight and N_3 level produced fruits weighing 80.09 g each compared to 72.47 g with N_1 level. The maximum fruit weight of 93.93 and 87.48 g was produced by $N_3P_3K_1$ in 1984 and 1985, respectively. The variation in weight due to various levels of phosphorus and potassium was not so pronounced as recorded in the case of nitrogen.

Yield per plant :

The data presented in Table 8 revealed that the yield of fruit increased with the application of nitrogen. It was found to

TABLE 6. Effect of different levels of N, P, K and their interactions on number of fruits per plant.

N Levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	483	594	538	P ₁	678	556	617	K ₁	711	654	682
N ₂	523	752	637	P ₂	737	571	654	K ₂	722	556	639
N ₃	710	846	778	P ₃	777	589	638	K ₃	759	605	682
S. Em ±	9.96	16.59			9.96	16.59			9.96	16.59	
C.D. at 5%	28.29	47.12			28.29	N.S.			28.29	N.S.	
<u>N x P</u>				P ₁		P ₂				P ₃	
N ₁	508	488	498		610	473	541		666	487	576
N ₂	727	555	641		766	512	639		763	520	642
N ₃	801	624	712		835	728	782		901	779	840
S. Em ±	17.25	28.73									
C.D. at 5%	49.00	81.63									
<u>N x K</u>				K ₁		K ₂				K ₃	
N ₁	575	504	539		573	429	501		634	464	549
N ₂	740	509	622		747	528	638		769	536	652
N ₃	818	654	736		845	661	753		873	816	845
S. Em ±	17.25	28.73									
C.D. at 5%	49.00	81.63									

Contd....

Contd...Table 6.

<u>P x K</u>	1984		1985		Mean	1984		1985		Mean	1984		1985		Mean			
	K ₁	K ₂	K ₃	K ₁		K ₂	K ₃	K ₁	K ₂		K ₃	K ₁	K ₂	K ₃		K ₁	K ₂	K ₃
P ₁	657	538	598	669	514	591	708	515	612									
P ₂	706	561	633	740	575	657	764	577	671									
P ₃	770	564	667	756	580	668	804	624	714									
S.E.m ±	17.25	28.73																
C.D. at 5%	49.00	81.63																
<u>N x P x K</u>	K ₁		K ₂		K ₃		K ₁		K ₂		K ₃		K ₁		K ₂		K ₃	
N ₁	469	560	514	487	461	474	561	444	502									
	571	479	525	619	492	555	639	448	544									
	683	474	578	611	485	548	703	501	602									
N ₂	725	535	630	714	554	634	742	576	659									
	739	498	618	769	520	644	789	518	653									
	757	482	619	758	511	635	775	514	644									
N ₃	777	521	649	804	527	666	822	825	823									
	807	705	756	832	712	772	865	766	816									
	871	735	803	900	748	824	933	857	895									
S.E.m ±	29.88	49.77																
C.D. at 5%	84.88	141.38																

N.S. = Not significant.

Table 7. Effect of different levels of N, P, K and their interactions on weight (g) of each fruit.

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	74.82	70.12	72.47	P ₁	73.46	72.57	73.01	K ₁	75.98	72.93	74.45
N ₂	73.91	73.40	73.65	P ₂	77.29	75.31	76.30	K ₂	76.53	76.07	76.30
N ₃	80.59	79.60	80.09	P ₃	78.57	75.25	76.91	K ₃	76.81	74.13	75.47
S. Em ±	1.25	0.98			1.25	0.98			1.25	0.98	
C.D. at 5%	3.53	2.77			3.53	2.77			N.S.	2.77	
<u>N x P</u>											
				P ₂							
N ₁	72.71	69.24	70.97		74.02	70.37	72.19		72.14	68.65	70.39
N ₂	74.73	70.71	72.72		76.69	73.79	75.24		76.34	75.61	75.97
N ₃	74.06	76.21	75.13		81.64	82.11	81.87		87.19	81.78	84.48
S. Em ±	2.16	1.71									
C.D. at 5%	6.10	4.83									
<u>N x K</u>											
				K ₂							
N ₁	73.65	69.09	71.37		70.25	70.97	70.61		74.97	70.39	72.68
N ₂	75.83	70.87	73.35		75.63	76.62	76.12		72.82	72.62	72.72
N ₃	84.03	81.37	82.70		78.12	79.41	78.76		79.62	79.37	79.49
S. Em ±	2.16	1.71									
C.D. at 5%	6.10	4.83									

Contd...

TABLE 8. Effect of different levels of N, P, K and their interactions on fruit yield (kg/plant).

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	45.35	35.19	40.27	P ₁	49.68	40.42	45.05	K ₁	53.38	38.68	46.03
N ₂	57.52	39.83	48.67	P ₂	56.93	42.97	49.95	K ₂	53.44	40.65	47.04
N ₃	65.39	52.54	58.96	P ₃	61.64	44.18	52.91	K ₃	61.40	48.24	54.82
S. Em ±	1.22	1.30			1.22	1.30			1.22	1.30	
C.D. at 5%	3.45	3.67			3.45	3.67			3.45	3.67	
<u>N x P</u>											
N ₁	37.25	35.42	36.33	P ₁	46.33	33.89	40.11		52.26	36.26	44.26
N ₂	52.98	40.91	46.94		61.18	40.47	50.82		58.30	38.12	48.21
N ₃	58.82	44.93	51.87		63.09	54.55	58.82		74.25	58.16	66.20
S. Em ±	2.26	2.12									
C.D. at 5%	6.39	5.99									
<u>N x K</u>											
N ₁	42.41	34.96	38.68	K ₁	40.01	33.94	36.97		53.62	36.67	45.14
N ₂	56.30	35.74	46.02		56.46	40.50	48.48		59.69	43.26	51.47
N ₃	61.42	45.33	53.37		63.86	47.51	55.68		70.88	64.80	67.84
S. Em ±	2.26	2.12									
C.D. at 5%	6.39	5.99									

Contd...

Contd....Table 8.

	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
<u>P x K</u>									
		<u>K₁</u>			<u>K₂</u>			<u>K₃</u>	
P ₁	48.19	36.89	42.54	49.37	36.60	42.98	51.49	47.77	49.63
P ₂	54.16	41.01	47.58	54.44	40.57	47.50	62.19	47.32	54.75
P ₃	57.79	38.13	47.96	56.53	47.32	51.92	70.50	49.63	60.06
S.Em ±	2.26	2.12							
C.D.at 5%	6.39	5.19							
<u>N x P x K</u>		<u>K₁</u>			<u>K₂</u>			<u>K₃</u>	
N ₁									
	32.21	38.82	35.51	37.30	32.84	35.07	42.23	34.60	38.41
P ₁	44.02	33.04	38.53	42.70	33.94	38.32	52.87	32.70	42.78
P ₂	51.07	33.04	42.05	40.03	35.03	37.53	65.75	40.71	53.23
P ₃	55.34	37.14	46.24	57.72	39.82	48.77	50.88	45.77	48.32
N ₂									
	57.67	37.99	47.83	60.27	38.67	49.47	65.59	44.75	55.17
P ₁	55.89	32.09	53.99	56.40	43.01	49.70	62.60	39.25	50.92
P ₂									
P ₃	57.03	34.70	45.86	58.08	37.15	47.61	61.38	62.93	62.15
N ₃									
	60.78	52.01	56.39	60.36	49.11	54.73	68.12	62.52	65.32
P ₁	66.46	49.28	57.87	73.16	56.27	64.71	83.15	68.94	76.04
P ₂									
P ₃									
S.Em ±	3.67	3.92							
C.D.at 5%	10.37	11.08							

increase from 45.35 to 65.39 kg per plant in 1984 and from 35.19 kg to 52.54 kg in 1985 by increasing the level of nitrogen from 400 to 800 g per plant. An increase in the level of phosphorus and potassium also resulted in higher yield in both the years. The interactions between N x P and N x K appreciably increased the yield when used at higher levels and treatment with N_3K_3 produced an yield of 67.84 kg per plant. The highest average yield of 76.04 kg per plant was obtained with $N_3P_3K_3$.

Yield per hectare :

Like the yield per plant the yield per hectare was also found to increase with the increase in the levels of nitrogen, phosphorus and potassium (Table 9). The average yield of fruit was found to increase by about 53.15 and 22.78 quintals by increasing the levels of nitrogen and potassium from 400 to 800 g per plant. The yield per hectare was considerably increased in the year 1984 compared to that recorded in 1985. Among the N x P, N x K and P x K interactions the highest (188.75 q) average yield was recorded with N_3K_3 treatment and N_3P_3 combination produced 184.80 q of fruits. The combination of P and K ^{movement} has effected in this respect. The average yield of two year^s was, however, maximum (211.23 q/ha) by treatment with highest level of the nutrients ($N_3P_3K_3$)(Table 9).

Diameter of fruit :

The data in Table 10 showed that an increase in the level of potassium and nitrogen from 400 to 800 g increased the average

Table 9. Effect of different levels of N, P, K and their interactions on yield (Q/ha) of mandarin orange.

N Levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	125.96	98.14	112.05	P ₁	138.01	112.27	125.14	K ₁	148.27	107.82	128.04
N ₂	159.68	107.71	133.69	P ₂	158.34	115.95	137.14	K ₂	149.07	113.86	131.46
N ₃	184.46	145.94	165.20	P ₃	171.74	123.56	147.65	K ₃	170.75	130.90	150.82
S. Em ±	3.53	3.48			3.53	3.48			3.53	3.48	
C.D. at 5%	9.98	9.84			9.98	9.84			9.98	9.84	
<u>N x P</u>				P ₁				P ₂			
N ₁	103.46	98.38	100.92		129.25	92.72	110.48		145.17	103.31	124.24
N ₂	147.16	113.64	130.40		169.93	103.61	136.77		161.94	105.88	133.91
N ₃	163.40	124.80	144.10		175.86	151.81	163.83		208.11	161.50	184.80
S. Em ±	6.13	6.04									
C.D. at 5%	17.33	17.05									
<u>N x K</u>				K ₁				K ₂			
N ₁	117.82	98.28	108.05		111.73	94.27	103.00		148.93	101.86	125.39
N ₂	156.38	99.28	127.83		156.84	115.42	136.13		165.80	108.43	137.11
N ₃	170.61	125.91	148.26		179.25	131.91	155.58		197.51	179.99	188.75
S. Em ±	6.13	6.04									
C.D. at 5%	17.33	17.05									

Contd....

Contd...Table 9.

P x K	1984		1985		1984		1985		Mean	1984		1985		Mean
	K ₁	K ₂	K ₃	K ₃	K ₁	K ₂	K ₃	K ₃						
P ₁	133.87	102.46	118.16	137.12	101.67	119.39	143.04	132.68	122.86					
P ₂	150.43	112.50	131.46	151.23	119.73	135.48	173.38	115.62	144.50					
P ₃	160.52	108.51	134.51	158.87	124.31	141.59	195.83	137.87	166.85					
S. Em ±	6.13	6.04												
C.D.at 5%	17.33	N.S.												
N x P x K	K ₁		K ₂		K ₃		K ₃			K ₁		K ₂		
N ₁	89.47	107.83	98.65	103.60	91.22	97.41	117.31	96.10	106.70					
	122.28	87.41	104.84	118.61	94.28	106.44	146.86	96.39	121.62					
	141.71	99.53	120.62	111.81	97.31	104.56	182.63	110.08	146.35					
N ₂	153.73	103.17	128.45	146.45	110.60	128.52	141.32	127.14	134.23					
	160.18	105.53	132.85	167.41	116.17	141.79	182.20	89.14	135.67					
	155.25	89.14	122.19	156.67	119.48	138.07	173.89	109.03	141.46					
N ₃	158.40	96.39	127.39	161.32	103.19	132.25	170.49	174.81	172.65					
	168.84	144.48	156.66	167.66	136.40	152.03	191.88	173.66	182.77					
	184.60	136.88	160.74	208.76	156.13	182.44	230.97	191.50	211.23					
S. Em ±	10.61	10.46												
C.D. at 5%	30.00	29.58												

N.S. = Not significant.

Table 10. Effect of N, P, K and their interactions on diameter of fruit (cm).

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	5.48	5.10	5.29	P ₁	5.36	5.14	5.25	K ₁	5.25	5.07	5.16
N ₂	5.23	5.14	5.18	P ₂	5.46	5.12	5.29	K ₂	5.27	5.07	5.17
N ₃	5.45	5.23	5.34	P ₃	5.46	5.21	5.33	K ₃	5.75	5.33	5.54
S. Em ±	0.06	0.03			0.06	0.03			0.06	0.03	
C.D.at 5%	0.16	0.08			N.S.	0.08			0.16	0.08	
<u>N x P</u>											
		P ₁				P ₂				P ₃	
N ₁	5.41	5.10	5.25		5.64	5.07	5.35		5.40	5.13	5.26
N ₂	5.37	5.11	5.24		5.27	5.18	5.22		5.36	5.13	5.24
N ₃	5.28	5.20	5.24		5.45	5.13	5.29		5.61	5.37	5.49
S. Em ±	0.11	0.05									
C.D.at 5%	0.31	0.14									
<u>N x K</u>											
		K ₁				K ₂				K ₃	
N ₁	5.53	5.02	5.27		5.16	5.08	5.12		5.77	5.20	5.48
N ₂	4.99	5.08	5.03		5.34	5.07	5.20		5.68	5.27	5.47
N ₃	5.23	5.12	5.17		5.33	5.07	5.20		5.80	5.51	5.65
S. Em ±	0.11	0.05									
C.D.at 5%	0.31	0.14									

Contd....

Contd...Table 10.

P x K	1984		1985		1984		1985		1984		1985		Mean
	Mean	K ₁	Mean	K ₁	Mean	K ₂	Mean	K ₂	Mean	K ₃	Mean	K ₃	
P ₁	5.21	5.03	5.12	5.09	5.09	5.10	5.09	5.09	5.77	5.28	5.52		
P ₂	5.23	5.09	5.16	5.48	5.48	5.04	5.26	5.26	5.66	5.24	5.45		
P ₃	5.30	5.10	5.20	5.25	5.25	5.06	5.15	5.15	5.81	5.76	5.78		
S.Em ±	0.11	0.05											
C.D.at 5%	0.31	0.14											
<u>N x P x K</u>													
		K ₁				K ₂				K ₃			
N ₁	5.34	4.99	5.16	5.23	5.23	5.10	5.16	5.16	5.67	5.23	5.45		
	5.76	4.95	5.35	5.42	5.42	5.04	5.23	5.23	5.74	5.22	5.48		
	5.48	5.14	5.31	4.83	4.83	5.09	4.96	4.96	5.90	5.17	5.53		
N ₂	5.26	5.03	5.14	4.87	4.87	5.04	4.95	4.95	5.98	5.27	5.62		
	4.62	5.21	4.91	5.63	5.63	5.12	5.37	5.37	5.58	5.20	5.39		
	5.09	5.00	5.04	5.51	5.51	5.04	5.27	5.27	5.48	5.34	5.41		
N ₃	5.03	5.08	5.05	5.16	5.16	5.17	5.16	5.16	5.66	5.36	5.51		
	5.30	5.12	5.21	5.40	5.40	4.97	5.18	5.18	5.67	5.30	5.48		
	5.35	5.18	5.26	5.42	5.42	5.06	5.24	5.24	6.07	5.86	5.96		
S.Em ±	0.19	0.10											
C.D.at 5%	0.53	0.28											

fruit diameter from 5.16 cm to 5.54 cm and 5.29 cm to 5.34 cm, respectively. The interaction of N x P, N x K, P x K and N x P x K were significant. The average fruit diameter was found maximum (5.96 cm) in plants receiving 800 g N, 600 g P₂O₅ and 800 g K₂O per year compared to 5.16 cm recorded under N₁P₁K₁ and N₁P₁K₂.

Peel weight :

The data presented in Table 11 revealed that the peel weight of fruits did not show marked variation with the different levels of the nutrients. The interactions effect of N x K, N x P, P x K and N x P x K were not statistically significant. The peel weight was found maximum (21.81 g) under N₁P₃K₃ and minimum (16.10 g) under N₁P₂K₂ (Table 11).

Pulp weight :

An increase in the level of nitrogen and phosphorus could not improve the pulp weight of fruit. However, application of K appreciably increased the pulp weight (Table 12). Among the interactions of N x P, N x K and P x K the highest average pulp weight was recorded with N₃K₃ (60.67 g). Application of different levels of N, P and K showed more pulp weight (65.43 g) with N₁P₃K₃ and minimum (51.25 g) with N₁P₁K₁ treatment.

Juice content :

The juice content of the fruit was found to increase with the increase in the levels of nitrogen, phosphorus and potassium

Table 11. Effect of different levels of N, P, K and their interactions on peel weight(g) of fruit.

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	17.68	18.44	18.06	P ₁	18.02	18.13	18.07	K ₁	19.60	17.78	18.69
N ₂	19.95	18.59	19.27	P ₂	18.10	19.16	18.63	K ₂	18.47	19.28	18.87
N ₃	19.59	19.07	19.33	P ₃	21.10	18.80	19.95	K ₃	19.15	18.39	18.77
S.Em ±	0.72	0.36			0.72	0.36			0.72	0.36	
C.D.at 5%	2.03	1.01			2.03	1.01			N.S.	1.01	
N x P											
N ₁		P ₁				P ₂					
N ₂	18.07	18.94	18.50		16.03	17.98	17.00		18.96	18.38	18.67
N ₃	17.81	17.82	17.81		21.01	19.87	20.44		21.03	18.07	19.55
S.Em ±	1.24	0.62			17.25	19.62	18.43		23.32	19.95	21.63
C.D.at 5%	N.S.	N.S.									
N x K											
N ₁		K ₁				K ₂					
N ₂	17.24	17.55	17.39		16.64	18.10	17.37		19.18	19.66	19.42
N ₃	20.28	17.93	19.10		19.75	18.55	19.15		19.82	19.28	19.55
S.Em ±	21.29	18.06	19.67		19.02	20.30	19.66		18.46	18.85	18.65
C.D. at 5%	1.24	0.62									
	N.S.	N.S.									

Contd....

Contd....Table 11.

	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
<u>P x K</u>												
					<u>K₁</u>						<u>K₂</u>	
P ₁	17.89	17.38	17.63	19.16	18.98	19.07	17.02	18.04	17.53			
P ₂	20.00	17.38	18.69	16.27	18.31	17.29	18.02	18.45	18.23			
P ₃	20.92	17.87	19.39	19.98	19.50	19.74	22.41	20.21	21.31			
S.Em ±	1.24	0.62										
C.D.at 5%	N.S.	N.S.										
<u>N x P x K</u>												
					<u>K₁</u>						<u>K₂</u>	
N ₁	17.40	18.20	17.80	18.93	19.80	19.36	17.87	18.83	18.35			
	16.39	16.93	16.66	15.00	17.20	16.10	16.69	19.83	18.62			
	17.94	17.53	17.73	15.97	17.30	16.63	23.30	20.33	21.81			
N ₂	15.99	17.60	16.79	19.28	16.80	18.04	18.16	19.06	18.61			
	24.32	19.26	21.79	18.29	18.46	18.37	20.42	21.90	21.16			
	20.54	16.93	18.73	21.68	20.40	21.04	20.87	16.90	18.88			
N ₃	20.29	16.30	18.29	19.62	20.40	19.83	15.02	16.23	15.62			
	19.30	18.73	19.01	15.51	19.70	17.60	16.95	20.43	18.69			
	24.28	19.16	21.72	22.29	20.80	21.54	23.40	19.90	21.65			
S.Em ±	4.68	1.09										
C.D.at 5%	N.S.	N.S.										

N.S. - Not significant.

TABLE 12. Effect of different levels of N, P, K and their interactions on pulp weight (g) of fruit.

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	57.77	54.44	56.10	P ₁	55.10	54.44	54.82	K ₁	55.00	52.39	53.69
N ₂	56.36	57.56	56.96	P ₂	58.79	56.13	57.46	K ₂	55.03	54.42	54.72
N ₃	56.81	55.06	55.93	P ₃	57.06	56.39	56.72	K ₃	60.92	60.25	60.58
S.Em ±	0.87	0.96			0.87	0.96			0.87	0.96	
C.D. at 5%	N.S.	N.S.			2.31	N.S.			2.31	2.71	
<u>N x P</u>											
				P ₂							
N ₁	54.98	53.93	54.45		59.57	53.61	56.59		58.77	55.80	57.28
N ₂	56.16	56.18	56.17		58.77	58.85	58.81		54.16	57.66	55.91
N ₃	54.17	53.52	53.84		58.02	55.92	56.97		58.25	55.73	56.99
S.Em ±	1.42	1.67									
C.D. at 5%	N.S.	N.S.									
<u>N x K</u>											
				K ₂							
N ₁	56.07	51.56	53.81		53.28	52.87	53.07		63.96	58.90	61.43
N ₂	55.57	53.27	54.42		55.54	58.87	57.20		57.97	61.35	59.66
N ₃	53.35	82.33	52.84		56.27	52.32	54.29		60.82	60.52	60.67
S.Em ±	1.42	1.67									
C.D. at 5%	N.S.	N.S.									

Contd...

Contd....Table 12.

P x K	1984		1985		Mean		1984		1985		Mean		1984		1985		Mean	
	K ₁																	
P ₁	54.55	51.56	53.05	55.17	52.35	53.76	55.59	59.72	57.65									
P ₂	56.89	54.48	55.64	56.74	52.93	54.83	62.72	60.97	61.84									
P ₃	53.55	51.14	52.34	53.18	57.98	55.58	64.44	60.07	62.25									
S. Em ±	1.42	1.67																
C.D. at 5%	4.01	4.72																
	K ₂																	
	K ₃																	
	K ₁																	
N ₁	51.28	51.23	51.25	56.53	51.83	54.18	57.12	58.73	57.92									
	60.64	51.23	55.93	53.92	51.80	52.86	64.15	57.73	60.94									
	56.30	52.16	54.23	49.39	55.00	52.19	70.63	60.23	65.43									
	59.67	53.10	56.38	54.62	55.13	54.87	54.18	60.33	57.25									
	54.21	56.96	55.58	59.64	55.33	57.48	62.46	64.26	63.36									
	52.83	49.76	51.29	52.37	63.75	58.06	57.28	59.46	58.37									
	52.70	50.36	51.53	54.35	80.10	52.22	55.48	60.10	57.79									
	55.83	55.17	55.50	56.66	51.66	54.16	61.56	60.93	61.24									
	51.53	51.46	51.49	57.80	55.20	56.50	65.43	60.53	62.98									
S. Em ±	2.47	2.90																
C.D. at 5%	N.S.	N.S.																

N.S. = Not significant.

(Table 13). It showed a decrease with the higher levels of nitrogen in 1984 but in the second year, it increased considerably. The plants treated with higher level of potassium (800 g/plant) produced 42.68 per cent juice (maximum) compared to 38.74 per cent (minimum) under 400 g N in 1985. The interaction effects of N x P, N x K, P x K and N x P x K were not statistically significant. The highest level of nitrogen, phosphorus and potassium ($N_3P_3K_3$) caused 42.20 per cent juice in the present investigation (Table 13).

Total soluble solids :

In general, an increase in the level of the nutrients decreased the T.S.S. content in the fruit (Table 14). The interaction effect of N x K, P x K and N x P was significant, while the variation due to different levels of N x P x K was not significant.

Total sugar :

The variation in total sugar of fruits due to increase in the level of nitrogen, phosphorus and potassium was not consistent (Table 15). In the interaction between N x P and N x K, the highest level of nitrogen (800 g/plant) showed a decrease in sugar content compared to higher (600 g/plant) dose of the nutrient, the P x K interaction at the highest level of P showed a similar trend. Treatment combination with $N_2P_3K_2$ resulted in highest average (7.15%) total sugar content followed by 7.08 per cent under $N_3P_1K_2$ treatment.

Reducing sugar :

It is apparent from the data in Table 16 that different

Table 13. Effect of different levels of N, P, K and their interactions on juice content of fruits (per cent).

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	39.89	38.74	39.31	P ₁	39.82	39.06	39.44	K ₁	39.68	40.05	39.86
N ₂	39.85	39.49	39.67	P ₂	39.95	40.02	39.98	K ₂	39.68	39.72	39.70
N ₃	39.73	41.97	40.85	P ₃	39.70	41.13	40.41	K ₃	40.11	42.68	41.39
S.Em ±	0.24	0.49			0.24	0.49			0.24	0.49	
C.D.at 5%	N.S.	N.S.			N.S.	N.S.			N.S.	N.S.	
<u>N x P</u>											
N ₁	40.17	38.89	39.53	P ₂	39.84	37.81	38.82		39.65	39.53	39.59
N ₂	39.53	38.93	39.23		40.08	44.10	42.09		39.94	39.88	39.91
N ₃	39.77	39.35	39.56		39.92	42.60	41.26		39.51	43.97	41.74
S.Em ±	0.41	0.86									
C.D.at 5%	N.S.	N.S.									
<u>N x K</u>											
N ₁	39.71	38.84	39.27	K ₂	39.53	38.73	39.13	K ₃	40.43	38.65	39.54
N ₂	39.43	39.75	39.59		39.81	38.73	39.27		40.32	39.98	40.15
N ₃	39.90	41.55	40.72		39.71	41.68	40.69		39.60	42.68	41.14
S.Em ±	0.41	0.86									
C.D.at 5%	N.S.	N.S.									

Contd....

Contd...Table 13.

		1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
<u>P x K</u>										
			<u>K₁</u>							<u>K₃</u>
P ₁		39.37	38.78	39.07	39.85	39.20	39.52	40.25	39.20	39.72
P ₂		40.14	39.96	40.05	39.67	42.62	41.14	40.03	40.81	40.42
P ₃		39.52	41.40	40.46	39.52	40.62	40.07	40.06	41.32	40.69
S.Em ±		0.41	0.86							
C.D. at 5%		N.S.	N.S.							
<u>N x P x K</u>										
			<u>K₁</u>							<u>K₃</u>
N ₁	P ₁	40.33	39.54	39.93	39.53	38.03	38.78	40.66	39.10	38.88
	P ₂	39.56	36.90	38.23	39.76	38.13	38.94	40.20	38.40	39.30
	P ₃	39.23	40.10	39.66	39.30	40.05	39.67	40.43	38.46	39.44
N ₂	P ₁	37.93	38.13	38.03	40.10	39.11	39.60	40.56	39.56	40.06
	P ₂	40.46	40.53	40.49	39.76	38.53	39.14	40.03	39.90	39.96
	P ₃	39.90	40.60	40.25	39.56	38.56	39.06	40.36	40.50	40.43
N ₃	P ₁	39.86	38.66	39.26	39.93	40.46	40.19	39.53	38.93	39.23
	P ₂	40.40	42.96	41.68	39.50	41.20	40.35	39.86	44.13	41.99
	P ₃	39.43	43.52	41.47	39.70	43.40	41.55	39.40	45.00	42.20
S.Em ±		1.49	0.72							
C.D. at 5%		N.S.	N.S.							

N.S. = Not significant.

14. Effect of different levels of N, P, K and their interactions on total soluble solids ($^{\circ}$ Brix) of the fruits.

	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
S.Em \pm	0.07	11.15	P ₁	10.97	11.23	11.10	K ₁	10.93	11.06	10.99
C.D. at 5%	0.20	11.01	P ₂	10.77	11.13	10.95	K ₂	10.83	11.27	11.05
	0.60	10.83	P ₃	10.77	11.92	10.94	K ₃	10.76	11.15	10.95
	0.07	0.06		0.07	0.06			0.07	0.06	
	0.20	0.17		N.S.	N.S.			N.S.	N.S.	
<u>N x P</u>			P ₁		P ₂				P ₃	
N ₁	11.23	11.34	11.28	10.95	11.13	11.04		11.02	11.20	11.11
N ₂	10.89	11.18	11.03	10.78	11.25	11.01		10.84	11.12	10.98
N ₃	10.79	10.70	10.74	10.58	11.01	10.79		10.45	11.04	10.74
S.Em \pm	0.12	0.12			K ₂				K ₃	
C.D. at 5%	0.34	0.34			K ₂				K ₃	
<u>N x K</u>			K ₁		K ₂				K ₃	
N ₁	10.96	11.14	11.45	11.14	11.38	11.26		11.11	11.15	11.13
N ₂	11.05	11.11	11.08	10.77	11.19	10.98		10.59	11.25	10.97
N ₃	10.79	10.94	10.86	10.54	11.24	10.89		10.48	11.04	10.76
S.Em \pm	0.12	0.12								
C.D. at 5%	0.34	0.34								

Contd....

Contd... Table 14.

	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
<u>P x K</u>									
		<u>K₁</u>			<u>K₂</u>			<u>K₃</u>	
P ₁	11.10	11.18	11.14	11.00	11.30	11.15	10.81	11.15	10.98
P ₂	10.74	10.96	10.85	10.82	11.26	11.04	10.75	11.21	10.98
P ₃	10.96	11.06	11.01	10.63	11.25	10.94	10.72	11.18	10.95
S.E.m ±	0.12	0.12							
C.D.at 5%	0.34	0.34							
<u>N x P x K</u>		<u>K₁</u>			<u>K₂</u>			<u>K₃</u>	
N ₁									
	10.99	11.16	11.07	11.63	11.66	11.64	11.09	11.21	11.15
P ₁	10.70	11.98	11.34	10.99	11.21	11.10	11.15	11.21	11.18
P ₂	11.17	11.30	11.23	10.80	11.28	11.04	11.09	11.03	11.06
P ₃									
N ₂									
	11.22	11.17	11.19	10.78	11.14	10.96	10.67	11.22	10.94
P ₁	10.81	11.10	10.99	10.83	11.30	11.06	10.83	11.37	11.10
P ₂	11.05	11.06	11.05	10.70	11.15	10.92	10.78	11.15	10.96
P ₃									
N ₃									
	11.09	11.21	11.15	10.59	11.10	10.84	10.67	11.21	10.94
P ₁	10.64	10.80	10.72	10.65	11.28	10.96	10.47	10.96	10.71
P ₂	10.66	10.82	10.74	10.38	11.33	10.85	10.31	10.96	10.63
P ₃									
S.E.m ±	0.21	0.20							
C.D.at 5%	N.S.	N.S.							

N.S. = Not significant.

TABLE 15. Effect of different levels of N, P, K and their interactions on total sugar (per cent fresh weight) content of fruits.

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	7.00	6.74	6.87	P ₁	6.91	6.79	6.85	K ₁	6.96	6.92	6.94
N ₂	7.08	7.02	7.05	P ₂	6.98	6.82	6.90	K ₂	6.95	6.73	6.84
N ₃	6.78	6.69	6.73	P ₃	6.91	6.83	6.87	K ₃	6.94	6.81	6.87
S. Em ±	0.01	0.03			0.01	0.03			0.01	0.03	
C.D. at 5%	0.02	0.08			0.02	N.S.			N.S.	0.08	
<u>N x P</u>											
		P ₁				P ₂				P ₃	
N ₁	6.93	6.77	6.85		7.08	6.69	6.88		6.99	6.77	6.88
N ₂	6.99	6.93	6.96		7.06	7.06	7.06		7.19	7.06	7.12
N ₃	6.99	6.68	6.83		6.79	6.72	6.75		6.56	6.66	6.61
S. Em ±	0.03	0.06									
C.D. at 5%	0.08	0.16									
<u>N x K</u>											
		K ₁				K ₂				K ₃	
N ₁	6.98	6.83	6.90		7.02	6.63	6.82		7.00	6.77	6.88
N ₂	7.09	7.10	7.09		7.07	6.87	6.97		7.08	7.07	7.07
N ₃	6.81	6.85	6.83		6.77	6.69	6.73		6.76	6.60	6.68
S. Em ±	0.03	0.06									
C.D. at 5%	0.08	0.16									

Contd....

Contd....Table 15.

		1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
<u>P x K</u>		K ₁			K ₂			K ₃		
P ₁		6.95	6.87	6.91	6.98	6.69	6.83	6.97	6.82	6.89
P ₂		7.02	6.92	6.97	6.95	6.70	6.82	6.96	6.85	6.90
P ₃		6.91	6.98	6.94	6.93	6.73	6.83	6.90	6.77	6.83
S. Em ±		0.03	0.06							
C.D.at 5%		N.S.	N.S.							
<u>N x P x K</u>		K ₁			K ₂			K ₃		
N ₁	P ₁	6.88	6.82	6.85	6.92	7.02	6.97	6.91	6.77	6.84
	P ₂	7.07	6.70	6.83	7.05	6.92	6.98	7.12	6.59	6.85
	P ₃	6.99	6.79	6.89	7.09	7.03	7.06	6.88	6.69	6.78
N ₂	P ₁	7.04	6.82	6.93	7.03	7.07	7.03	6.90	6.84	6.87
	P ₂	7.06	6.49	6.77	7.01	6.99	7.00	7.13	6.63	6.88
	P ₃	7.18	6.46	6.82	7.17	7.13	7.15	7.22	6.71	6.96
N ₃	P ₁	6.94	6.85	6.89	7.00	7.08	7.04	7.03	6.68	6.85
	P ₂	6.94	6.69	6.81	6.79	6.82	6.80	6.64	6.63	6.63
	P ₃	6.58	6.77	6.67	6.53	6.84	6.68	6.60	6.41	6.50
S. Em ±		0.05	0.11							
C.D.at 5%		0.14	0.31							

N.S. = Not significant.

levels of N, P and K and their interactions showed no significant variation on the reducing sugar content of fruits. The treatment $N_1P_3K_2$ exhibited the highest percentage of reducing sugar (3.18) during 1985. In general, reducing sugar was found to be higher in 1985 compared to 1984.

Acidity :

The data on percentage of acidity presented in Table 17 indicated that application of the highest dose of nitrogen increased the acidity while, the variation due to phosphorus and potassium was not consistent. The interaction effects of N x P, N x K, P x K and N x P x K was also not significant. The highest fruit acidity (0.97 per cent) was noted with highest rate of N, P and K ($N_3P_3K_3$), in 1985.

Leaf analysis :

Nitrogen :

The nitrogen content in leaf was found to increase gradually and reached the maximum in the month of July, which declined in the month of October i.e. when the fruit began to mature. In general, an increase in the level of nitrogen from 400 to 800 g per plant considerably increased the leaf nitrogen content at all the stages of sampling but the effect of different levels of phosphorus and potassium was less pronounced. The leaf nitrogen during January was found to vary between 2.28 to 3.00 per cent, while it showed maximum value (2.40 to 3.46 per cent) during July (Table 18).

TABLE 16. Effect of different levels of N, P, K and their interactions on reducing sugar content (per cent fresh weight) of fruits.

N levels	1984	1985	Mean	P levels	1984	1985	Mean	K levels	1984	1985	Mean
N ₁	2.81	2.91	2.86	P ₁	2.81	2.94	2.87	K ₁	2.81	2.92	2.86
N ₂	2.82	2.94	2.88	P ₂	2.81	2.94	2.87	K ₂	2.81	2.98	2.89
N ₃	2.81	2.92	2.86	P ₃	2.82	2.90	2.86	K ₃	2.81	2.92	2.86
S.E.m ±	0.005	0.02			0.005	0.02			0.005	0.02	
C.D. at 5%	N.S.	N.S.			N.S.	N.S.			N.S.	N.S.	
<u>N x P</u>											
		P ₁				P ₂				P ₃	
N ₁	2.80	2.94	2.87		2.81	2.84	2.82		2.82	2.95	2.88
N ₂	2.83	2.99	2.91		2.81	3.00	2.90		2.82	2.83	2.82
N ₃	2.81	2.90	2.85		2.81	2.96	2.88		2.81	2.91	2.86
S.E.m ±	0.01	0.04									
C.D. at 5%	N.S.	N.S.									
<u>N x K</u>											
		K ₁				K ₂				K ₃	
N ₁	2.80	2.90	2.85		2.82	2.97	2.89		2.81	2.86	2.87
N ₂	2.82	2.95	2.88		2.81	2.91	2.86		2.82	2.96	2.89
N ₃	2.81	2.90	2.85		2.81	2.94	2.83		2.81	2.93	2.87
S.E.m ±	0.01	0.04									
C.D. at 5%	N.S.	N.S.									

Contd...Table 16.

		1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
<u>P x K</u>										
P ₁		2.81	2.91	2.86	2.82	2.93	2.87	2.82	2.98	2.90
P ₂		2.81	2.94	2.87	2.81	2.95	2.88	2.82	2.93	2.87
P ₃		2.83	2.91	2.87	2.82	2.94	2.88	2.81	2.84	2.82
S.Em ±		0.01	0.04							
C.D.at 5%		N.S.	N.S.							
<u>N x P x K</u>										
N ₁										
	P ₁	2.78	2.86	2.82	2.80	2.90	2.85	2.82	3.07	2.94
	P ₂	2.79	2.92	2.85	2.83	2.84	2.83	2.82	2.78	2.80
	P ₃	2.84	2.93	2.88	2.83	3.18	3.00	2.80	2.74	2.77
N ₂										
	P ₁	2.83	3.01	2.92	2.84	3.04	2.94	2.82	2.91	2.86
	P ₂	2.82	2.96	2.89	2.81	2.97	2.81	2.79	3.08	2.93
	P ₃	2.82	2.88	2.85	2.79	2.73	2.76	2.85	2.88	2.86
N ₃										
	P ₁	2.81	2.85	2.83	2.82	2.87	2.84	2.81	2.97	2.89
	P ₂	2.81	2.94	2.87	2.78	3.04	2.91	2.84	2.92	2.88
	P ₃	2.82	2.91	2.86	2.82	2.91	2.86	2.80	2.91	2.85
S.Em ±		0.017	0.08							
C.D. at 5%		N.S.	N.S.							

N.S. = Not significant.

TABLE 17. Effect of different levels of N, P, K and their interactions on fruit acidity (per cent).

N levels	1984	1985	Mean P Levels	1984	1985	Mean K Levels	1984	1985	Mean
N ₁	0.84	0.84	P ₁	0.82	0.83	K ₁	0.82	0.86	0.84
N ₂	0.82	0.83	P ₂	0.82	0.92	K ₂	0.82	0.83	0.82
N ₃	0.82	0.89	P ₃	0.82	0.88	K ₃	0.82	0.86	0.84
S. Em ±	0.002	0.013		0.002	0.013		0.002	0.013	
C.D.at 5%	N.S.	N.S.		N.S.	N.S.		N.S.	N.S.	
<u>N x P</u>									
		P ₁			P ₂			P ₃	
N ₁	0.82	0.84	0.83	0.83	0.83	0.83	0.82	0.86	0.84
N ₂	0.82	0.81	0.81	0.82	0.82	0.82	0.82	0.85	0.83
N ₃	0.82	0.84	0.83	0.82	0.88	0.85	0.81	0.94	0.87
S. Em ±	0.004	0.023							
C.D.at 5%	N.S.	N.S.							
<u>N x K</u>									
		K ₁			K ₂			K ₃	
N ₁	0.82	0.84	0.83	0.82	0.81	0.81	0.82	0.87	0.84
N ₂	0.82	0.85	0.83	0.82	0.81	0.81	0.82	0.83	0.82
N ₃	0.81	0.89	0.85	0.82	0.87	0.84	0.82	0.90	0.86
S. Em ±	0.004	0.023							
C.D.at 5%	N.S.	N.S.							

Contd...Table 17.

	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
<u>P x K</u>									
P ₁	0.82	0.87	0.84	0.82	0.81	0.81	0.82	0.81	0.81
P ₂	0.87	0.83	0.85	0.82	0.85	0.83	0.82	0.86	0.84
P ₃	0.81	0.88	0.84	0.81	0.83	0.82	0.82	0.83	0.82
S.Em ±	0.004	0.023							
C.D.at 5%	N.S.	N.S.							
<u>N x P x K</u>									
N ₁	0.81	0.88	0.84	0.83	0.83	0.82	0.82	0.82	0.82
	0.83	0.80	0.81	0.83	0.82	0.82	0.83	0.86	0.84
	0.82	0.85	0.83	0.82	0.80	0.81	0.82	0.92	0.87
N ₂	0.83	0.87	0.85	0.82	0.79	0.80	0.83	0.78	0.80
	0.81	0.82	0.81	0.82	0.86	0.84	0.82	0.79	0.80
	0.82	0.87	0.84	0.82	0.78	0.85	0.82	0.91	0.86
N ₃	0.81	0.87	0.84	0.82	0.83	0.82	0.82	0.83	0.82
	0.82	0.87	0.84	0.81	0.87	0.84	0.83	0.91	0.87
	0.81	0.93	0.87	0.81	0.92	0.87	0.82	0.97	0.89
S.Em ±	0.008	0.04							
C.D.at 5%	N.S.	N.S.							

N.S. = Not significant.

TABLE 18. Leaf nitrogen content as influenced by treatment with different levels of N, P and K (expressed as per cent dry weight).

Treatments	January	April	July	October
N ₁ P ₁ K ₁	2.28	2.36	2.40	2.26
N ₁ P ₁ K ₂	2.32	2.38	2.41	2.30
N ₁ P ₁ K ₃	2.36	2.42	2.46	2.34
N ₁ P ₂ K ₁	2.39	2.45	2.50	2.38
N ₁ P ₂ K ₂	2.41	2.48	2.52	2.39
N ₁ P ₂ K ₃	2.44	2.50	2.53	2.41
N ₁ P ₃ K ₁	2.46	2.52	2.56	2.43
N ₁ P ₃ K ₂	2.49	2.55	2.58	2.46
N ₁ P ₃ K ₃	2.52	2.57	2.61	2.48
N ₂ P ₁ K ₁	2.54	2.60	2.63	2.51
N ₂ P ₁ K ₂	2.59	2.64	2.66	2.58
N ₂ P ₁ K ₃	2.62	2.66	2.69	2.60
N ₂ P ₂ K ₁	2.65	2.69	2.72	2.61
N ₂ P ₂ K ₂	2.67	2.75	2.79	2.64
N ₂ P ₂ K ₃	2.70	2.76	2.79	2.68
N ₂ P ₃ K ₁	2.72	2.79	2.82	2.69
N ₂ P ₃ K ₂	2.75	2.82	2.84	2.71
N ₂ P ₃ K ₃	2.79	2.85	2.87	2.73
N ₃ P ₁ K ₁	2.81	2.86	2.89	2.73
N ₃ P ₁ K ₂	2.83	2.89	2.89	2.78
N ₃ P ₁ K ₃	2.86	2.91	2.94	2.80
N ₃ P ₂ K ₁	2.89	2.95	2.98	2.82
N ₃ P ₂ K ₂	2.92	2.98	3.16	2.85
N ₃ P ₂ K ₃	2.94	3.10	3.30	2.86
N ₃ P ₃ K ₁	2.95	3.16	3.39	2.90
N ₃ P ₃ K ₂	2.96	3.14	3.42	2.91
N ₃ P ₃ K ₃	3.00	3.20	3.46	2.96

Before treatment - 1.96

Phosphorus :

The data in the Table 19 showed the maximum amount of leaf phosphorus in the month of July. Phosphorus content of the leaf however showed a slight decrease in the October sampling. The variation in leaf phosphorus content at different times of the year and due to different levels of phosphorus, in particular was not pronounced. The highest level of the nutrients ($N_3P_3K_3$) exhibited 0.20 to 0.29 per cent leaf P compared to 0.11 to 0.13 per cent with the lowest rates ($N_1P_1K_1$) at different times of sampling.

Potassium :

Potassium concentration of leaf also showed an increasing trend upto the third sampling (July) and a sharp decline was noticed at the last sampling in October (Table 20). The leaf K was found to vary between 1.02 and 1.89 per cent in January, between 1.15 and 1.92 per cent at April, between 1.28 and 1.96 per cent at July. The potassium concentration of the leaf in October with $N_1P_1K_1$ treatment was 1.06 per cent and 1.82 per cent with $N_3P_3K_3$.

Discussion :

The results, in the present experiment revealed that treatment with higher rates of N significantly promoted the growth of the plant. The beneficial effect of nitrogen on growth may be explained from the fact that the nitrogen is the major constituent of protoplasm and high nitrogen increased the size and total number of cells

TABLE 19. Leaf phosphorus content as influenced by treatment with different levels of N, P and K (expressed as per cent dry weight)

Treatments	January	April	July	October
N ₁ P ₁ K ₁	0.11	0.12	0.13	0.12
N ₁ P ₁ K ₂	0.11	0.12	0.13	0.12
N ₁ P ₁ K ₃	0.12	0.13	0.14	0.12
N ₁ P ₂ K ₁	0.12	0.14	0.16	0.12
N ₁ P ₂ K ₂	0.13	0.15	0.18	0.12
N ₁ P ₂ K ₃	0.16	0.19	0.22	0.15
N ₁ P ₃ K ₁	0.18	0.19	0.23	0.17
N ₁ P ₃ K ₂	0.18	0.21	0.24	0.16
N ₁ P ₃ K ₃	0.19	0.20	0.25	0.18
N ₂ P ₁ K ₁	0.13	0.16	0.19	0.12
N ₂ P ₁ K ₂	0.13	0.17	0.20	0.12
N ₂ P ₁ K ₃	0.13	0.17	0.20	0.11
N ₂ P ₂ K ₁	0.18	0.21	0.24	0.17
N ₂ P ₂ K ₂	0.19	0.22	0.24	0.16
N ₂ P ₂ K ₃	0.18	0.20	0.23	0.16
N ₂ P ₃ K ₁	0.20	0.23	0.26	0.18
N ₂ P ₃ K ₂	0.21	0.23	0.25	0.17
N ₂ P ₃ K ₃	0.20	0.24	0.28	0.18
N ₃ P ₁ K ₁	0.18	0.22	0.24	0.16
N ₃ P ₁ K ₂	0.18	0.20	0.23	0.17
N ₃ P ₁ K ₃	0.17	0.22	0.24	0.16
N ₃ P ₂ K ₁	0.19	0.21	0.24	0.17
N ₃ P ₂ K ₂	0.20	0.23	0.26	0.18
N ₃ P ₂ K ₃	0.19	0.23	0.25	0.19
N ₃ P ₃ K ₁	0.20	0.24	0.26	0.18
N ₃ P ₃ K ₂	0.21	0.25	0.28	0.19
N ₃ P ₃ K ₃	0.22	0.27	0.29	0.20

Before treatment - 0.89

TABLE 20. Leaf potassium content as influenced by treatment with different levels of N, P and K (expressed as per cent dry weight).

Treatments	January	April	July	October
N ₁ P ₁ K ₁	1.02	1.15	1.28	1.06
N ₁ P ₁ K ₂	1.16	1.26	1.39	1.20
N ₁ P ₁ K ₃	1.25	1.32	1.42	1.25
N ₁ P ₂ K ₁	1.35	1.43	1.56	1.39
N ₁ P ₂ K ₂	1.39	1.44	1.57	1.42
N ₁ P ₂ K ₃	1.42	1.49	1.59	1.43
N ₁ P ₃ K ₁	1.36	1.52	1.62	1.44
N ₁ P ₃ K ₂	1.47	1.53	1.64	1.48
N ₁ P ₃ K ₃	1.52	1.59	1.68	1.49
N ₂ P ₁ K ₁	1.40	1.48	1.54	1.36
N ₂ P ₁ K ₂	1.52	1.58	1.65	1.48
N ₂ P ₁ K ₃	1.62	1.72	1.79	1.54
N ₂ P ₂ K ₁	1.46	1.53	1.61	1.44
N ₂ P ₂ K ₂	1.63	1.69	1.73	1.56
N ₂ P ₂ K ₃	1.72	1.68	1.79	1.64
N ₂ P ₃ K ₁	1.51	1.65	1.68	1.48
N ₂ P ₃ K ₂	1.68	1.72	1.82	1.61
N ₂ P ₃ K ₃	1.75	1.83	1.92	1.73
N ₃ P ₁ K ₁	1.56	1.65	1.69	1.53
N ₃ P ₁ K ₂	1.72	1.75	1.82	1.69
N ₃ P ₁ K ₃	1.79	1.83	1.89	1.75
N ₃ P ₂ K ₁	1.62	1.68	1.75	1.56
N ₃ P ₂ K ₂	1.75	1.82	1.89	1.71
N ₃ P ₂ K ₃	1.83	1.89	1.92	1.78
N ₃ P ₃ K ₁	1.65	1.69	1.73	1.61
N ₃ P ₃ K ₂	1.79	1.85	1.92	1.75
N ₃ P ₃ K ₃	1.89	1.92	1.96	1.82

Before treatment - 0.76

(Njoku, 1957). Protein and chlorophyll synthesis are markedly associated with application of higher rates of nitrogen (Wadleigh, 1957). Marked improvement in growth of orange trees by additional N application has been reported by many investigators from different citrus growing regions of the world (Klein and Monselise, 1962); Dornelles, 1963; Smith et al., 1968-69; Smith, 1970; Nokrashy et al., 1977).

The effect of phosphorus and potassium although was not so pronounced as recorded with nitrogen, higher levels of P and K, however, increased the height, spread as well as girth of the stem. It may be mentioned here that Hewitt (1963) noticed that phosphorus deficiency decreased deoxyribonucleic acid synthesis as well as that of ribonucleic acid and such an effect chiefly restricted nuclear division and plant growth. The beneficial effect of K in improving growth may be explained from the fact that it is an activator of enzymes, promotes growth in meristematic tissues, neutralizes organic acid and activated stomatal opening. Latzko (1959) concluded that potassium is directly involved in the photosynthetic phosphorylation. Increase in vigour of orange tree (Dornelles, 1963) and crown diameter (Takatsuji and Ishihara, 1980) of mandarin orange has been reported due to potassium application.

The number of fruits per plant and weight of individual fruit increased significantly due to application of higher rates of nitrogen. The increase in fruit number was mainly due to better vegetative growth and improvement in physiological condition.

Spencer (1963), however, found no effect of phosphorus on juice content of Valencia orange while, Weir et al. (1978) found that K increased the juice percentage. In an experiment at Maharashtra, application of NPK improved the juice percentage of citrus (Anon, 1984-85).

The T.S.S. content was found to increase by treatment with 400 g N but at higher rate upto 800 g, a decline in T.S.S. was recorded. A decrease in T.S.S. with increasing level of N was reported from Punjab (Anon, 1982). Phosphorus application had no effect on the T.S.S. content of fruit. In similar experiment, Devilliers (1969) in Washington Navel orange, Smith et al. (1963) in Pineapple orange, Spencer (1963) in Valencia orange and Bar-Akiva et al. (1968) in Marsh grape fruit also found no significant effect with phosphorus application. However, Embelton et al. (1973) reported an increase in T.S.S. with additional application of potassium.

The total and reducing sugar and acidity of fruits were found to increase with higher potassium and phosphorus level from 200 to 400 and 400 to 800 g per plant but the highest level of nitrogen decreased the sugar content of fruits. The percentage of reducing sugar and acidity however, showed no significant variation due to different levels of N, P and K.

The nitrogen content in leaf increased due to increased level of nitrogen application. Thombesi et al. (1962), Leyden (1963) Jones and Embleton (1967) and Reese and Koo (1975) also reported higher leaf N with added nitrogen. The foliar nitrogen decreased as

higher percentage of fruit set and retention. Nabawy et al. (1975) Singh and Singh (1977) also recorded similar increase in fruit number with higher doses of N application.

Treatment with the higher levels of N, P and K showed marked improvement in yield. The highest total yields of 63.15 and 68.94 kg per plant in 1984 and 1985, respectively were obtained by treatment with 800 g nitrogen 600 g phosphorus and 800 g potash per plant in which the leaf nitrogen content was found to vary between 2.96 and 3.46 per cent at different times of the year. The number of fruit per plant and yield in citrus were associated with the level of total N or $\text{NO}_3\text{-N}$ concentration in leaves (Bar-Akiva, 1972, 1973; Embleton et al., 1973; Jorgensen, 1978). Higher fruit yield with N-fertilizers was also obtained by Intrigliolo (1984) in orange cv. Sanguinello Morcato. The highest level of nitrogen (800 g/plant) increased fruit size which was considerably reduced at lower (400 g/plant) level of the nutrient. Kiely et al. (1972) in Valencia orange, Koo and McCornack (1965) in Dancy tangerine, El-Mahmoudi (1959) in Egyptian orange and Leyden (1978) in Red grape fruit also observed similar increase in fruit size with increase in nitrogen rates.

Higher levels of nitrogen and phosphorus and potassium were found to increase the juice content of fruit. An increase in juice percentage of fruit with higher dose of nitrogen was observed by Young and Koo (1973) in Persian lime, Reese and Koo (1974) in Hamlin, Pineapple and Valencia orange, Jorgensen (1978) in Navel orange.

the leaf grew older (Sinha and Randhawa, 1961; Randhawa and Kar, 1967 and Akao et al., 1978). Similarly, leaf P and K also decreased as the age of leaves increased (Randhawa et al., 1964; Deidda and Viridis, 1969).

A marked increase in foliar K content was resulted from treatment with high dose of K. Similar effect was also noted by Feung-Chan and Sharma (1974), Reese and Koo (1975) and Bageleth et al. (1980) in Sweet orange; Takidze (1971), Reese and Koo (1976) and Takatsuji and Ishihara (1980) in mandarin orange.

Experiment 2. Effect of irrigation and different levels of N on growth, yield and fruit quality.

The treatments consisted of three levels of nitrogen at the rate of 200 g (N_1), 400 g (N_2) and 600 g (N_3) N/plant/year and three levels of irrigation at an interval of 10 days (I_1), 20 days (I_2) and 30 days (I_3) alone and in combinations.

Plant height :

The data presented in Table 21 on the increase in plant height over a period of two years showed variation due to the treatments. Although application of nitrogen or irrigation alone influenced the plant height as compared to control, but their various combinations caused marked improvement in this respect. The treatments I_1 i.e. irrigation at 10 days interval in combination with different levels of nitrogen, in general, had higher plant height compared to other levels of irrigation (Table 21). The treatment $N_3 + I_1$, resulted

in maximum increase in plant height (43.76 cm) in the two years, while the untreated plants recorded a height of 32.63 cm (Table 21) only.

Stem girth :

Similar to plant height marked variation in the girth of the stem was recorded due to the different treatments (Table 21). Application of either irrigation or nitrogen did not have much effect in increasing the stem girth over control. However, their combined effect showed beneficial effect. The maximum increase in stem girth (3.68 cm) in a two year study was noted with the highest level of nitrogen (N_3) in combination with irrigation applied at 10 days interval (I_3) and followed by treatment N_1+I_3 (3.26 cm), while the increased was only 2.25 cm in the untreated plants (Table 21).

Spread of the plant :

The increase in spread growth due to the treatments varied significantly over control. However, the variation in this respect in the directions, East-West or North-South was not consistent (Table 21). The treatment (N_3+I_1) which showed the highest increase in plant height and girth also showed the maximum spread (45.30 cm) in East-West direction but in the North-South direction the treatments N_2+I_1 and N_1+I_3 caused the maximum spread (43.42 cm), while the untreated plants showed the minimum spread in both directions (23.76 cm E-W and 25.93 cm N-S). Application of only irrigation or urea showed improvement over control but the increase in spread of the

TABLE 21. Vegetative growth of mandarin orange as influenced by different levels of nitrogen and irrigation.

Treatments	Plant height (cm)	Stem girth (cm)	Plant spread (cm)	
			East-West	North-South
Control	32.63	2.25	23.76	25.93
N ₁	34.53	2.46	39.06	30.10
N ₂	35.53	2.40	38.60	31.03
N ₃	33.50	2.91	38.55	30.76
I ₁	36.53	2.82	36.41	37.96
I ₂	36.20	2.45	33.36	34.60
I ₃	36.07	2.29	32.41	32.12
N ₁ + I ₁	34.46	2.81	37.02	39.24
N ₂ + I ₁	38.86	3.04	40.81	43.42
N ₃ + I ₁	43.76	3.68	45.30	42.49
N ₁ + I ₂	33.43	2.64	34.71	35.77
N ₂ + I ₂	36.30	2.75	39.23	40.10
N ₃ + I ₂	41.56	2.79	40.86	43.14
N ₁ + I ₃	31.90	3.26	34.51	43.42
N ₂ + I ₃	36.30	2.64	37.74	38.00
N ₃ + I ₃	38.20	2.57	38.66	40.50
S. Em ±	1.02	0.07	0.79	0.96
C.D. at 5%	2.04	0.20	2.28	2.27

canopy was much higher with combined application of nitrogen and irrigation.

Number of fruits per plant :

It is evident from the data presented in Table 22 that a combined application of nutrient and irrigation markedly increased the number of fruits per plant. Although, application of urea or irrigation alone produced larger number of fruits as compared to control but the variation did not reach the significant level in the first year of the experiment with the urea treated plants, in particular. The plants treated with 600 g urea (N_3) and irrigated at the interval of 10 days (I_1) produced the maximum number of fruits (310/plant) followed by 293 fruits per plant with 600 g urea (N_3) and irrigation at the interval of 20 days (I_2). The plants under control produced only 217 fruits.

Weight of each fruit :

The data in Table 22 also revealed that all the treatments resulted in greater fruit weight in both the years over the untreated plants. The treatment $N_3 + I_2$ exhibited the maximum fruit weight (73.70 g in 1984 and 90.93 g in 1985), while the corresponding figures for control were 57.71 g and 61.36 g. The other treatments, which improved the fruit weight were $N_3 + I_1$ (80.59 g); $N_3 + I_3$ (78.07 g) and $N_2 + I_1$ (74.20 g).

Yield per plant :

The plants treated with urea and irrigation singly or in

combination proved effective in increasing the yield/plant in both the years and the yield was more in the second year, compared to first year (Table 22). The maximum average yield (25.03 kg per plant) was found with $N_3 + I_1$ treatment i.e. 600 g urea/plant and irrigation at an interval of 10 days. Higher fruit yield (24.31 kg/plant) was also obtained with $N_3 + I_2$ treatment. The untreated plant produced an average of 12.94 kg fruit only.

Yield per hectare :

The data on yield per hectare presented in Table 22 revealed a marked difference due to the treatments. The highest yield (55.66 q in 1984 and 83.42 q in 1985) was obtained under $N_3 + I_1$. Marked improvement in yield was also recorded by treatment with $N_3 + I_2$ (67.51 q) and $N_3 + I_3$ (61.56 q). All the treated plants also showed higher yield compared to the untreated plant (35.94 q/ha). The yield/ha was higher in the second year compared to the first year as the individual yield/plant also showed similar trend.

Diameter of fruit :

The data on fruit diameter presented in Table 23 showed no significant variation over control due to different irrigation and nutrient treatments. The average varied between 4.57 and 5.67 cm.

Peel weight :

The variation in peel weight of fruit due to the treatments was not statistically significant (Table 23). In general, treatment showed a reduction in peel weight compared to control (21.16 g). The

TABLE 22. Number of fruits and fruit yield of mandarin orange as influenced by different levels of nitrogen and irrigation.

Treatments	Number of fruits/plant		Weight of each fruit(g)		Yield (kg/plant)		Yield (Q/ha)	
	1984	1985	1984	1985	1984	1985	1984	1985
Control	213	221	57.71	61.36	12.30	13.58	34.17	37.71
N ₁	241	235	67.46	69.60	16.42	17.11	45.62	45.42
N ₂	228	241	60.60	66.50	13.84	16.06	38.44	44.61
N ₃	243	242	59.35	69.33	14.46	16.81	40.17	46.68
I ₁	276	244	66.73	76.93	18.46	19.28	51.28	53.56
I ₂	262	242	59.17	71.13	15.40	17.40	45.00	48.32
I ₃	221	238	66.64	67.43	14.79	15.99	41.07	44.64
N ₁ + I ₁	227	257	64.26	61.76	17.85	18.41	49.59	51.15
N ₂ + I ₁	261	289	67.50	80.90	17.63	23.36	48.98	64.88
N ₃ + I ₁	309	311	64.86	96.33	20.04	30.03	55.66	83.42
N ₁ + I ₂	246	262	64.43	73.56	15.39	19.40	42.57	53.90
N ₂ + I ₂	257	289	68.90	76.76	17.70	22.09	49.17	61.37
N ₃ + I ₂	271	314	73.70	90.93	20.05	28.57	55.68	79.35
N ₁ + I ₃	250	261	53.96	72.66	13.49	21.27	37.48	59.07
N ₂ + I ₃	287	293	58.72	82.33	16.42	24.15	45.62	67.08
N ₃ + I ₃	261	301	69.04	87.10	18.04	26.32	50.11	73.01
S. Em ±	15.93	4.15	2.01	4.58	1.14	1.30	3.16	3.59
C.D. at 5%	45.99	11.98	5.80	13.22	3.29	3.75	9.12	10.36

average peel weight varied between 17.90 g and 21.16 g.

Pulp weight :

The pulp weight during the first year of the experiment varied between 34.83 and 60.96 g, while in the second year it showed a reduction in general and varied between 32.63 and 48.30 g (Table 23). Treatment with nitrogen and irrigation increased the average pulp weight. $N_3 + I_1$ resulted in the maximum pulp weight (54.63 g) of fruit.

Juice content :

It is evident from the data presented in Table 24 that the treatments increased the juice content in fruit. The fruits from plants treated with $N_2 + I_2$, contained the maximum percentage of juice (43.50%), followed by 43.19 per cent with $N_2 + I_1$ as compared to 38.91 per cent in control fruit. Application of only irrigation (at the interval of 30 days) decreased the juice content (35.01%). In general, higher doses of urea and irrigation at shorter interval proved more effective in increasing juice content of fruit in comparison with other treatments.

Total soluble solids :

The data presented in Table 24 revealed that the total soluble solids content of fruit in general, increased due to combined treatments of N and irrigation when compared to that of control.

The average T.S.S. content of the fruits varied between 10.37 and 11.90% and the treatment $N_3 + I_2$ showed 11.90% T.S.S. in both the years. The other treatments which had more than 11.0% T.S.S.

TABLE 23. Physical characteristics of mandarin orange fruits as influenced by different levels of nitrogen and irrigation.

Treatments	Diameter of fruit(cm)		Peel weight (g)			Pulp weight (g)			
	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
	Control	4.80	4.35	4.57	91.33	20.99	21.16	43.67	32.63
N ₁	5.36	4.79	5.07	19.66	19.00	19.33	54.32	33.63	43.97
N ₂	5.31	5.02	5.16	19.66	19.33	19.49	46.60	35.00	40.80
N ₃	4.83	4.80	4.81	20.30	19.66	19.98	50.73	39.33	45.03
I ₁	5.23	5.36	5.29	18.50	19.33	18.91	54.48	37.30	45.89
I ₂	5.30	5.28	5.29	16.80	19.00	17.90	36.42	34.38	35.40
I ₃	5.06	5.16	5.11	19.66	19.33	19.49	43.01	33.55	38.28
N ₁ +I ₁	4.66	4.83	4.74	20.16	18.66	19.41	44.97	39.30	42.13
N ₂ +I ₁	5.06	5.29	5.17	19.16	19.00	19.08	43.28	44.33	43.80
N ₃ +I ₁	5.50	5.80	5.65	18.86	19.20	19.03	60.96	48.30	54.63
N ₁ +I ₂	5.06	5.05	5.05	18.90	18.33	18.61	34.83	38.13	36.48
N ₂ +I ₂	5.60	5.19	5.39	21.00	19.00	20.00	39.23	41.53	40.38
N ₃ +I ₂	5.80	5.55	5.67	20.36	19.00	19.68	57.35	42.96	50.15
N ₁ +I ₃	4.90	4.86	4.88	19.63	18.33	18.98	46.34	35.92	41.13
N ₂ +I ₃	5.26	5.13	5.19	20.00	20.00	20.00	44.02	37.60	40.81
N ₃ +I ₃	5.43	5.41	5.42	21.86	19.33	20.59	48.88	39.06	43.97
S. Em ±	0.18	0.05		0.65	0.76		4.80	0.82	
C.D. at 5%	N.S.	N.S.		N.S.	N.S.		13.84	2.36	

N.S. = Not significant.

in fresh fruit were N_2+I_1 , N_3+I_1 , N_2+I_2 , N_3+I_2 , N_2+I_3 and N_3+I_3 .

Total and reducing sugar :

Similar to T.S.S., the total sugar content showed significant variation when treated with N and irrigation (Table 24). The maximum total sugar was found under N_3+I_1 (6.94%) and minimum (6.28%) with I_3 treatment i.e. irrigation at the interval of 30 days. No significant variation was observed with fruits harvested from the treated plants in respect of reducing sugar content which varied between 2.39% and 2.55% (Table 24).

Acidity :

The fruits harvested from plants treated with different levels of irrigation and nitrogen showed marked reduction in fruit acidity except in those from the plant, treated with the highest dose of nitrogen. The percentage in fruit acidity was minimum (0.92%) with N_1 followed by 0.93 per cent with I_2, I_1, N_2+I_1 and I_3 compared to 0.99 per cent under control (Table 24).

Leaf analysis :

Nitrogen :

The data presented in Table 25 showed higher nitrogen content in leaf of all the treated plants. The combined application of nitrogen and irrigation markedly influenced the leaf nitrogen concentration. The treatment N_3+I_1 had the highest concentration of the nutrient at all the stage of sampling.

TABLE 24. Fruit quality of mandarin orange as influenced by different levels of nitrogen and irrigation.

Treatments	Juice content of fruit (%)		Total soluble solids(°Brix)		Total sugar(%) fresh weight)		Reducing sugar (%) fresh weight)		Acidity (% fresh weight)						
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985					
Control	39.40	38.43	38.91	10.59	10.59	10.59	6.35	6.24	6.32	2.43	2.42	2.42	1.00	0.99	0.99
N ₁	40.33	39.90	40.11	10.40	10.40	10.40	6.40	6.52	6.46	2.41	2.39	2.40	0.85	1.00	0.92
N ₂	32.29	42.10	37.19	10.87	10.87	10.87	6.35	6.38	6.36	2.52	2.42	2.47	0.90	1.01	0.95
N ₃	40.66	36.60	38.63	10.89	10.39	10.67	6.34	6.33	6.33	2.58	2.52	2.55	1.00	1.09	1.04
I ₁	39.12	43.57	41.34	10.80	10.80	10.80	6.44	6.57	6.50	2.39	2.43	2.41	0.89	0.98	0.93
I ₂	37.92	43.20	40.56	10.44	10.44	10.44	6.40	6.81	6.60	2.42	2.43	2.42	0.86	1.01	0.93
I ₃	36.90	33.13	35.01	10.37	10.37	10.37	6.31	6.26	6.28	2.37	2.42	2.39	0.86	1.00	0.93
N ₁ +I ₁	41.67	40.32	40.99	10.51	10.84	10.67	6.57	6.04	6.30	2.52	2.36	2.44	0.89	0.98	0.93
N ₂ +I ₁	42.12	44.27	43.19	10.88	11.55	11.21	6.72	6.80	6.76	2.57	2.35	2.46	0.94	1.01	0.97
N ₃ +I ₁	42.96	41.87	42.41	11.56	10.56	11.06	6.93	6.96	6.94	2.55	2.42	2.48	1.12	0.97	1.04
N ₁ +I ₂	39.40	44.32	41.86	10.83	11.16	10.99	6.49	6.53	6.51	2.46	2.40	2.43	0.91	1.00	0.95
N ₂ +I ₂	42.73	44.27	43.50	11.63	11.63	11.63	6.66	6.58	6.62	2.54	2.56	2.55	0.98	0.99	0.98
N ₃ +I ₂	41.23	40.37	40.80	11.90	11.90	11.90	6.94	6.75	6.84	2.61	2.43	2.52	1.13	1.00	1.06
N ₁ +I ₃	41.73	43.13	42.43	10.48	10.48	10.48	6.40	6.39	6.39	2.41	2.38	2.39	0.91	0.99	0.95
N ₂ +I ₃	42.10	41.27	41.68	11.47	11.44	11.30	6.62	6.54	6.58	2.56	2.46	2.51	0.98	0.95	0.96
N ₃ +I ₃	42.10	42.30	42.20	11.69	11.69	11.69	6.91	6.51	6.71	2.61	2.44	2.52	1.13	0.99	1.06
S.E.m ±	0.99	1.73		0.12	0.11		0.04	0.11		0.04	0.21		0.10	0.004	
C.D. at 5%	2.85	2.99		0.34	0.31		0.12	0.33		N.S.	N.S.		N.S.	N.S.	

N.S.—Not significant.

TABLE 25. Leaf nitrogen content as influenced by different levels of nitrogen and irrigation (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	2.14	2.16	2.21	2.16
N ₁	2.45	2.54	2.65	2.47
N ₂	2.58	2.69	2.85	2.62
N ₃	2.78	2.89	2.18	2.82
I ₁	2.36	2.37	2.39	2.41
I ₂	2.22	2.24	2.26	2.26
I ₃	2.98	2.21	2.23	2.22
N ₁ +I ₁	2.75	2.77	2.85	2.76
N ₂ +I ₁	2.86	2.92	3.16	2.88
N ₃ +I ₁	2.94	3.12	3.23	2.98
N ₁ +I ₂	2.69	2.72	2.79	2.72
N ₂ +I ₂	2.75	2.86	2.99	2.83
N ₃ +I ₂	2.85	2.93	3.11	2.89
N ₁ +I ₃	2.66	2.68	2.75	2.68
N ₂ +I ₃	2.70	2.78	2.84	2.75
N ₃ +I ₃	2.76	2.86	2.98	2.81

Before treatment - 1.94

Phosphorus :

The phosphorus content of leaf also showed similar trend to that of nitrogen. All the treated plants showed higher amount of leaf phosphorus compared to control at all the stages of sampling and $N_3 + I_1$ treatment exhibited the maximum phosphorus concentration (Table 26).

Potassium :

Similar to nitrogen and phosphorus, leaf K concentration was also found to be influenced by nitrogen fertilization and irrigation (Table 27). Leaf analysis showed an increasing trend of the leaf nutrient from January to July and declined sharply in October. The treatment $N_3 + I_1$ proved to be most effective in this respect.

Discussion :

The results of the experiment on the effect of different levels of nitrogen and irrigation either singly or in combinations showed marked response to growth and vigour of the treated plants and higher dose of the nutrient in combinations with frequent irrigation (10 days interval) significantly increased plant height, stem girth and also the spread of the plant. The beneficial effect of nitrogen on vegetative growth may be explained from the fact that N is indispensable in various physiological and metabolic activities of plant such as chlorophyll, nucleotides, phosphatides, as well as in many enzymes, hormones and vitamins, Protein and chlorophyll

TABLE 26. Leaf phosphorus content as influenced by different levels of nitrogen and irrigation (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	0.11	0.12	0.15	0.11
N ₁	0.14	0.16	0.20	0.15
N ₂	0.12	0.15	0.18	0.14
N ₃	0.16	0.18	0.21	0.17
I ₁	0.13	0.14	0.19	0.13
I ₂	0.12	0.13	0.15	0.12
I ₃	0.11	0.12	0.13	0.11
N ₁ + I ₁	0.16	0.18	0.23	0.19
N ₂ + I ₁	0.19	0.22	0.25	0.21
N ₃ + I ₁	0.22	0.26	0.31	0.25
N ₁ + I ₂	0.14	0.16	0.19	0.17
N ₂ + I ₂	0.15	0.18	0.19	0.17
N ₃ + I ₂	0.18	0.21	0.24	0.20
N ₁ + I ₃	0.12	0.14	0.16	0.13
N ₂ + I ₃	0.18	0.25	0.16	0.14
N ₃ + I ₃	0.16	0.19	0.21	0.18

Before treatment - 0.09

TABLE 27. Leaf potassium content as influenced by different levels of nitrogen and irrigation (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	1.29	1.31	1.41	1.33
N ₁	1.42	1.47	1.52	1.48
N ₂	1.45	1.48	1.56	1.51
N ₃	1.49	1.53	1.62	1.54
I ₁	1.26	1.28	1.34	1.31
I ₂	1.24	1.26	1.29	1.28
I ₃	1.23	1.25	1.28	1.27
N ₁ +I ₁	1.50	1.56	1.71	1.58
N ₂ +I ₁	1.53	1.65	1.78	1.67
N ₃ +I ₁	1.63	1.68	1.79	1.69
N ₁ +I ₂	1.48	1.52	1.68	1.56
N ₂ +I ₂	1.49	1.53	1.73	1.54
N ₃ +I ₂	1.54	1.58	1.74	1.62
N ₁ +I ₃	1.35	1.39	1.58	1.40
N ₂ +I ₃	1.41	1.46	1.62	1.48
N ₃ +I ₃	1.48	1.51	1.68	1.54

Before treatment - 0.89

synthesis are markedly associated with the application of higher dose of nitrogen (Wadleigh, 1957). In the present investigation irrigation increased the capacity of plant to absorb the nutrients applied, more efficiently and therefore, the combined effects resulted in better growth in mandarin orange trees. Koo (1980) recorded increased tree size in Valencia orange with supplemental irrigation and fertilization. The observation recorded in the present investigation on plant growth were in conformity with the observations made by workers on different citrus species at different citrus growing regions of the world (Klein and Monselise, 1962; Dornelles, 1963; Smith et al., 1968-69, Nokrashy et al., 1977; Goell, 1983). In long term irrigation trials with grape fruit, Goell (1983) found that suboptimally irrigated or partially stressed trees did not grow to the same size as those receiving optimum water. Such trees were more compact with a higher canopy. He, however, observed that a short period of moisture stress was very effective in initiating and promoting vegetative growth flushes.

Treatment with $N_3 + I_1$ i.e. the highest level of nitrogen and irrigation at an interval of 10 days produced 310 fruits/plant compared to 217 fruits under control. The other treatments also were effective in producing larger number of fruits, particularly the combined application of nutrient and irrigation. The results clearly indicates that the maintenance of optimum soil moisture in the orchard through irrigation causes absorption and utilization of applied nutrients more efficiently and it is manifested through better

plant growth and flowering. Application of fertilizer and irrigation, caused increased translocation of nutrients from the leaves to the fruit and resulted in higher yield. Fruit production was increased substantially by irrigation in grape-fruit as reported by Koo (1964). He (1980) also obtained increased fruit production with nitrogen, potash and irrigation treatment, In an experiment with two water regimes on different citrus crops, Yusufi and Gutov (1985) noted that all species of lemons, mandarins and oranges had a high leaf water content in semi-hydroponics. From the results of the investigation, it is suggested that irrigation might have increased the water retaining capacity which helped in better photosynthetic activity and enhanced the yield of mandarin orange.

Koo and Smajstrla (1985) recorded increased fruit production by 39.64% over control and the increase being directly related to the increase in ground coverage due to irrigation and fertilizer treatment.

Beneficial effect on increasing individual fruit weight was also observed due to the treatments, particularly with nitrogen and irrigation. Koo et al. (1974) found increased fruit weight with nitrogen, phosphorus and potash and split irrigation. Irrigation increased the number of fruits by 56% and fruit weight of 70% in orange as reported by Vieira (1985).

The results showed that the diameter of fruit increased due to the treatments. Increased fruit size of orange was obtained with NPK and split irrigation (Koo et al., 1977).

The juice content of fruits, total soluble solids and sugar increased mainly due to combined application of nitrogen and irrigation. The total soluble solids was found to be maximum (11.90%) with $N_3 + I_2$ treatment in both the years. However, the treatment $N_3 + I_1$ showed maximum sugar content in the fruits. In general, treatment with different levels of nitrogen and irrigation caused less acidity, as compared to the untreated fruits. Kuriyama et al. (1983) noted marked improvement in fruit quality in pot experiment keeping the soil moist during fruit development (July and September) and drying during maturity (October-November). Koo and Smajstrala (1985) studied the effect of trickle irrigation and fertilization on fruit production and juice quality of Valencia orange and found that irrigation and partial fertilization reduced both T.S.S. and acid concentration in the juice.

Leaf nitrogen, phosphorus and potash contents increased due to the treatments and the influence of the combined application was very much pronounced.

The leaf nutrient content was found to increase after application of nutrients and irrigation and declined during October. It indicates that the nutrients have been sufficiently utilized during the growth and development of the fruits. The treatment $N_3 + I_1$ had higher leaf nutrient concentration in all the samplings and also resulted in maximum yield of better quality fruits. Thombesi et al. (1962), Leyden (1963) and Reese and Koo (1975) also reported higher Leaf N, P and K with added N. Plessis and Smart (1970) observed that

N content was highest in young leaves sampled in September but during the following two months it declined rapidly. In sweet orange, Gupta and Nauriyal (1972) recorded the highest amount of nitrogen in August and lowest in February.

Experiment 3. Effect of application of urea and Zn as foliar spray on growth and yield of mandarin orange.

The details of the treatments employed in this experiment are given below :

Control, urea- 400 g N/tree (soil), $ZnSO_4$ - 0.5% (foliar spray), urea (soil) + urea - 0.5% (foliar spray), urea (soil) + urea - 1% (foliar spray), urea (soil) + urea - 1.5% (foliar spray), urea (soil) + Zn, urea (soil) + urea - 0.5% + Zn, urea (soil) + urea - 1% + Zn, urea (soil) + urea - 1.5% + Zn.

Plant height :

The plant height presented in Table 28 showed significant variation due to treatments compared to control. Soil application of urea (400 g/tree) alone and also foliar application of zinc sulphate (0.5%) although increased plant height significantly but the other treatments were more effective in this respect. Application of 400 g urea and subsequent foliar application of 1.5 per cent urea and 0.5 per cent zinc sulphate caused the maximum increase (44.30 cm) in plant height in a period of two years, while the untreated plants showed an increase of 28.70 cm in plant height. In general, foliar

application of urea resulted in greater increase in plant height (Table 28).

Stem girth :

The girth of the stem in a period of two years also showed significant variation due to the treatments as compared to the untreated plants (Table 28). Similar to the plant height, the treatment with urea (soil) + urea (1.5%) + Zn (0.5%) also caused maximum increase in stem girth (3.38 cm), while the increase was only 2.44 cm in the untreated plant. The treatments which were effective in increasing the plant height also proved effective in increasing the stem girth during the period of the experiment (Table 28).

Spread of the plant :

In the present investigation, a marked variation in the spread growth of the plant was recorded due to different treatments (Table 28). The plants treated with urea (soil) + urea (1.5%) + Zn (0.5%) exhibited the maximum spread in both directions (48.10 cm East-West and 45.43^{cm} in North-South) while the untreated plants showed 28.83 and 26.70 cm spread in East-West and North-South directions, respectively. The foliar application of urea, in general, was found to promote the growth of the tree canopy.

Number of fruits per plant :

It is evident from the data presented in Table 29 that the number of fruits harvested from the treated plants were much higher compared to the untreated plants. The treatments which were effective

TABLE 28. Vegetative growth of mandarin orange as influenced by application of urea and zinc.

Treatments	Plant height(cm)	Stem girth(cm)	Plant spread(cm)	
			East-West	North-South
Control	28.70	2.44	28.83	26.70
Urea 400 g/tree (soil)	35.76	2.89	35.23	34.16
Zinc 0.5%	37.90	2.96	31.40	34.93
Urea(soil) + Urea 0.5%	40.13	3.26	39.46	38.38
Urea(soil) + Urea 1%	42.02	3.12	39.37	39.80
Urea(soil) + Urea 1.5%	42.76	3.13	38.90	41.70
Urea(soil) + Zn	40.40	3.09	35.86	38.10
Urea(soil) + Urea 0.5% + Zn	42.86	3.12	41.81	40.07
Urea(soil) + Urea 1% + Zn	42.52	3.14	43.20	41.76
Urea(soil) + Urea 1.5% + Zn	44.30	3.38	48.10	45.43
S.Em ±	0.60	0.10	0.74	0.64
C.D.at 5%	1.78	0.29	2.19	1.90

in promoting the vegetative growth were also found to produce more number of fruits per plant. The maximum number of fruits were produced by treatment with urea (soil) + urea (1.5%) + Zn (0.5%) in both the years (192 in 1984 and 200 in 1985), while 95 and 96 fruits were harvested from the untreated plants in the respective years. The other treatments which produced larger number of fruits were urea (soil) + urea (1% spray), urea (soil) + urea (1.5% spray) and urea (soil) + urea (1% spray) + Zn (0.5%).

Weight of each fruit :

The maximum weight of individual fruit (89.41 g) was obtained by treatment with urea (soil) + urea (1.5%) + Zn (0.5%) and minimum (60.15 g) in the untreated plants (Table 29). The weight of each fruit was more than 70 g when the plants were treated with urea as foliar spray. The other treatments also increased fruit weight compared to control and the differences were significant.

Yield per plant :

Soil (400 g/plant) and foliar application of urea (1.5%) and zinc produced the highest average yield (16.09 kg per plant) which is about 10 kg more than in the untreated plant (Table 29). The yield per plant, in general, was higher in the first year as compared to second year of the experiment. Either soil application of urea or only zinc spray or the combination could not influence much the yield per plant as compared to control. However, foliar application of urea resulted in significantly higher yield per plant in both the years under investigation.

h 7. Showing untreated plant.



Photograph 8. Plant treated with urea (0.5 %) + Zn (0.5 %).



• Photograph 9. Plant treated with urea (1.5 %) + Zn (0.5 %)



Photograph 10. Plant treated with urea (2 %) + Zn (0.5 %)

Yield per hectare :

The data on yield/hectare presented in Table 29 revealed a marked difference due to treatments used in this experiment. The yield of fruit per hectare was maximum (44.69 quintal) when the plants were treated with 400 g urea (soil) + urea (1.5%) + Zn (0.5%), while the fruit yield was 16.18 quintals only in the untreated plants. Higher fruit yield per hectare was obtained by soil and foliar application of urea and zinc and the yield varied between 16.15 and 47.78 quintals in the first year (1984), while it was between 16.21 and 41.61 quintals during the second year (1985).

Diameter of fruit :

The size of the fruits as evident from the data presented in Table 30 on diameter showed an increase due to the different treatments. The variation in fruit diameter (4.90 to 6.21 cm) was statistically significant.

Peel weight :

The peel weight presented in Table 30 did not vary significantly in the first year (1984) except by treatment with soil and foliar application of urea, while it showed appreciable change during the second year (1985). The average peel weight varied between 11.89 and 18.89 g.

Pulp weight :

The pulp weight varied between 44.27 g and 56.56 in the first

TABLE 29. Number of fruits and fruit yield of mandarin orange as influenced by application of urea and zinc.

Treatments	Number of fruits/ plant		Weight of each fruit (g)		Yield (kg/plant)		Yield (Q/ha)					
	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean			
Control	95	96	95	59.20	61.11	60.15	6.56	5.85	6.20	16.15	16.21	16.18
Urea 400 g/tree (soil)	159	115	137	67.94	66.11	67.02	11.03	7.66	9.34	30.65	28.39	29.52
Zinc 0.5%	109	133	121	67.20	70.50	68.85	7.38	9.25	8.31	20.49	25.71	23.10
Urea(soil)+Urea 0.5%	171	186	178	67.60	73.05	70.32	11.58	13.41	12.49	36.29	37.27	36.78
Urea(soil)+Urea 1%	188	189	188	74.82	72.45	73.63	14.09	11.42	12.75	39.14	31.72	35.43
Urea(soil)+Urea 1.5%	192	197	194	79.62	78.21	78.91	16.27	13.50	14.58	45.13	37.50	41.31
Urea (soil) + Zn	133	132	132	70.78	68.97	69.87	9.40	9.01	9.20	26.12	25.02	25.57
Urea(soil)+Urea 0.5%+Zn	168	187	177	81.40	73.97	77.68	13.75	11.66	12.70	38.20	32.40	35.30
Urea(soil)+Urea 1%+Zn	182	191	186	79.68	77.90	78.79	14.56	12.25	13.40	40.44	34.03	37.23
Urea(soil)+Urea 1.5%+Zn	192	200	196	89.57	89.25	89.41	17.20	14.98	16.09	47.78	41.61	44.69
S. Em ±	12.40	0.96		2.45	2.46		1.18	0.39		1.30	1.08	
C.D.at 5%	36.83	2.85		7.21	7.30		3.50	1.15		3.86	3.20	

TABLE 30. Physical characteristics of mandarin orange fruits as influenced by application of urea and zinc.

Treatments	Diameter of fruit(cm)		Peel weight (g)		Pulp weight (g)	
	1984	1985	1984	1985	1984	1985
Control	4.93	4.88	11.02	12.76	44.27	48.11
Urea 400 g/tree(soil)	5.29	5.21	15.05	15.10	50.42	50.62
Zinc 0.5%	5.52	5.22	17.60	17.31	55.59	51.77
Urea(soil) + urea 0.5%	5.31	5.28	18.30	16.67	55.64	53.07
Urea(soil) + urea 1%	5.31	5.29	13.87	13.37	48.16	46.54
Urea(soil) + urea 1.5%	5.52	5.52	21.53	16.25	50.62	51.87
Urea(soil) + Zn 0.5%	5.76	5.32	16.65	16.05	50.26	51.32
Urea(soil) + urea 0.5% + Zn	6.12	5.87	13.35	12.45	53.13	50.22
Urea(soil) + urea 1% + Zn	6.30	6.13	16.92	13.77	54.45	50.16
Urea(soil)+urea 1.5%+ Zn	6.24	6.01	18.30	18.32	56.56	55.70
S. Em ±	0.16	0.03	2.78	1.08	1.77	1.30
C.D. at 5%	0.47	0.08	8.25	3.08	5.25	3.86

year and was significant over control with most of the treatments, while it varied between 48.11 g and 55.70 g in the second year and could not reach the significant level with most of the treatments (Table 30). The average pulp weight showed appreciable variation due to different treatments and was found to vary between 46.19 g and 56.13 g.

Juice content :

The juice content, in general, was found to be influenced by the various treatments. It was noted that fruits harvested in 1984 contained appreciably higher percentage of juice compared to that of 1985 (Table 31). The juice content of fruits obtained from the different treatments varied between 35.18% and 42.04%.

Total soluble solids :

The total soluble solids of fruits presented in Table 31 showed significant increase over control in almost all the treatment. The fruits harvested from the plants treated with urea (soil) + urea (1.5%) + Zn (0.5%) showed the maximum T.S.S. (11.85 per cent) compared to 10.44 per cent in those from control plants and 10.37 per cent in urea (soil) treated plants.

Total sugar :

The total sugar content of fruits did not show significant variation over control due to the treatments (Table 31). The total sugar percentage was found to vary between 6.36 and 6.85. The variation in this respect in the first and second year were, however, not consistent.

Reducing sugar :

The reducing sugar content of fruits varied appreciably due to the treatments and the difference was statistically significant in both the years of the experiment (Table 31). The treatment which showed the maximum T.S.S. content also showed highest percentage of reducing sugar in the fresh fruits in both the years (2.69% and 2.67%), while it was minimum in the untreated plants (2.16 and 2.19%).

Acidity :

The treatments with nutrients did not cause any significant variation in acidity in fruits, while that the treated plants, in general, showed a reduction in fruit acidity (Table 31). Although treatment with zinc (0.5%) resulted in slightly higher acidity (1.06%) over the fruits under control, the acidity in fruits under the treatments varied between 0.83 and 1.06 per cent.

Leaf analysis.

Nitrogen :

The N content of leaves analysed four times during the period of growth presented in Table 32 showed a general increase from January to July and then declined in October. All the treated plants had higher leaf N content (2.26-2.72 per cent) as compared to control (2.21 to 2.29 per cent).

Phosphorus :

Phosphorus concentration of leaves presented in Table 33

TABLE 31. Fruit quality of mandarin orange as influenced by application of urea and zinc.

Treatments	Juice content of fruits(%)		Total soluble solids(°Brix)		Total sugar (% fresh weight)		Reducing sugar(% fresh weight)		Acidity (%)						
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985					
Control	39.95	32.71	36.33	10.43	10.46	10.44	6.38	6.35	6.36	2.16	2.19	2.17	1.06	1.03	1.04
Urea 400 g/tree (soil)	40.45	36.29	38.37	10.38	10.36	10.37	6.54	6.52	6.53	2.28	2.38	2.33	0.92	0.93	0.92
Zinc 0.5%	41.15	29.21	35.18	10.85	10.90	10.87	6.50	6.53	6.51	2.29	2.29	2.29	1.08	1.04	1.06
Urea(soil)+ Urea 0.5%	39.88	32.27	36.07	10.48	10.49	10.49	6.93	6.48	6.85	2.46	2.42	2.44	0.98	0.97	0.97
Urea (soil)+ Urea 1%	39.25	31.72	35.48	10.50	10.57	10.53	6.60	6.61	6.60	2.51	2.39	2.45	0.94	0.94	0.94
Urea (Soil)+ Urea 1.5%	41.62	37.50	39.56	10.53	10.56	10.54	6.62	6.65	6.63	2.54	2.45	2.49	0.97	1.00	0.98
Urea(soil)+ Zinc 0.5%	42.18	30.29	36.23	10.68	10.59	10.63	6.58	6.57	6.57	2.28	2.40	2.34	0.89	0.89	0.89
Urea(soil)+ Urea 0.5% + Zn	43.15	32.40	37.77	11.22	11.23	11.22	6.72	6.45	6.58	2.51	2.53	2.52	0.86	0.86	0.86
Urea(soil)+Urea 1% + Zn	42.93	38.03	40.48	11.26	11.28	11.27	6.78	6.66	6.57	2.54	2.56	2.55	0.83	0.84	0.83
Urea(soil)+Urea 1.5% + Zn	42.47	41.61	42.04	11.85	11.86	11.85	6.93	6.78	6.85	2.69	2.67	2.68	0.89	0.90	0.89
S.Em ±	0.67	0.56		0.20	0.20		0.10	0.08		0.01	0.01		0.04	0.04	
C.D.at 5%	1.99	1.66		0.59	0.59		N.S.	N.S.		0.29	0.29		N.S.	N.S.	

N.S. = Not significant

TABLE 32. Leaf nitrogen content as influenced by application of urea and zinc (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	2.18	2.21	2.29	2.22
Urea 400 g/tree(soil)	2.36	2.38	2.41	2.39
Zinc (0.5%)	2.26	2.26	2.27	2.26
Urea(soil)+ Urea 0.5%	2.42	2.44	2.47	2.46
Urea(soil)+ Urea 1%	2.45	2.50	2.54	2.52
Urea (soil) + Urea 1.5%	2.51	2.56	2.59	2.59
Urea(soil) + Zn 0.5%	2.40	2.43	2.41	2.44
Urea(soil)+Urea 0.5% + Zn	2.54	2.58	2.63	2.60
Urea(soil)+Urea 1% + Zn	2.48	2.51	2.58	2.53
Urea(soil)+Urea 1.5% + Zn	2.58	2.63	2.72	2.64

Before treatment - 1.98

TABLE 33. Leaf phosphorus content as influenced by application of urea and zinc (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	0.09	0.10	0.10	0.09
Urea 400 g/tree (soil)	0.11	0.13	0.14	0.12
Zinc 0.5%	0.10	0.10	0.10	0.10
Urea(soil) + Urea 0.5%	0.12	0.12	0.13	0.11
Urea(soil) + Urea 1%	0.13	0.14	0.16	0.13
Urea(soil) + Urea 1.5%	0.14	0.14	0.16	0.13
Urea(soil) + Zn 0.5%	0.12	0.13	0.15	0.13
Urea(soil) + Urea 0.5%	0.13	0.14	0.17	0.13
Urea(soil) + Urea 1% + Zn	0.15	0.16	0.18	0.14
Urea(soil) + Urea 1.5%+ Zn	0.16	0.18	0.21	0.17

Before treatment - 0.09

TABLE 34. Leaf potassium content as influenced by application of urea and zinc (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	1.18	1.21	1.26	1.23
Urea 400 g/tree(soil)	1.25	1.26	1.31	1.27
Zinc 0.5%	1.26	1.26	1.26	1.26
Urea(soil)+Urea 0.5%	1.37	1.39	1.42	1.41
Urea(soil) + Urea 1%	1.28	1.32	1.36	1.33
Urea(soil)+ Urea 1.5%	1.29	1.32	1.36	1.33
Urea(soil)+Zn 0.5%	1.26	1.27	1.35	1.28
Urea(soil)+Urea 0.5%	1.36	1.37	1.41	1.33
Urea(soil)+Urea 1% + Zn	1.41	1.43	1.45	1.38
Urea(soil)+Urea 1.5% + Zn	1.45	1.48	1.54	1.45

Before treatment - 0.85

showed similar variation like leaf nitrogen, although the variation was less pronounced. The leaf P content varied between 0.09 and 0.16 in January, 0.10 and 0.18 in April, 0.10 and 0.21 in July and between 0.09 and 0.17 in October.

Potassium :

Similar to nitrogen and phosphorus, the leaf potassium content also increased from January to July and then declined during October. The leaf K content varied between 1.25 and 1.54 due to treatments, while it was between 1.18 and 1.26 in the untreated plants (Table 34).

Discussion :

Results of experiments showed that application of urea in soil and foliar resulted in marked improvement in growth and vigour of the plants. The treatments with foliar application of urea and zinc, in general, influenced the vegetative growth appreciably. Morton and Watson (1948) found that adequate nitrogen supply increased the rate of leaf production and markedly promoted cell size and leaf area and thereby increased the tree vigour. The effect of Zn in influencing plant growth may be explained from the fact that Zn is highly effective in regulating plant growth because zinc plays a key role in enzyme system (e.g. carbonic anhydrase) which regulates plant growth (Kellin and Mann, 1940). It is also involved in the bio-synthesis of plant auxin IAA (Skoog, 1940). Photosynthetic activity of plant is

enhanced in presence of Zn (Samoladas, 1964) and its importance for protein synthesis is well established (Possingham, 1956). The observations recorded in the present investigation regarding the plant growth were in full conformity with the observations of many scientists working on citrus (Klein and Monselise, 1962; Dornelles, 1963; Smith et al., 1968-69; No krashy et al., 1977; Bopaiah et al., 1982; Anon. 1985). The treatments, which were effective in the improvement of vegetative growth were equally effective in influencing the fruit number, yield/plant and also the yield per hectare. The plants produced 196 fruits by treatment with urea (soil) + urea (1.5%) + Zn (0.5%) compared to 95 fruits under control, clearly indicating a marked improvement in the yield. Singh (1961) in an experiment with the different levels of nitrogen observed that increase in the level of nitrogen increased the production and initial fruit set in mandarin orange. The effect of nitrogen in fruit production is primarily due to enhanced plant growth and higher fruit set and retention. Increased yield with Zn application was reported by many scientists (Samoladas, 1965; Chanturiya, 1974; Chanturiya and Mikaberid e, 1976). Similar to the present investigation, increased number of fruits per tree with urea + $ZnSO_4$ spray was also recorded at Ludhiana, Punjab (Anon. 1984). A significant increase in yield due to nitrogen fertilization was also reported by Sato and Ishihara (1964). Treatment with urea and zinc showed an increase in fruit weight. The fruit weight recorded was more than 70 g in all the urea (foliar) treated plants.

The physical characteristics and chemical composition of

fruits were also influenced very much with the treatments. The juice content was found more in the treated fruits compared to the untreated ones. The total soluble solid contents also showed significant increase over control in almost all the treatments. However, in the present investigation the total sugar did not vary significantly, although the reducing sugar content showed variation due to the treatments and the difference was statistically significant. The results indicated that the acidity of the fruit in general, showed reduction due to the treatments as compared to control.

In Kinnow mandarin, urea application increased the juice percentage, T.S.S., total sugar and also showed lower acidity than control (Lodhi and Rashid, 1980).

Higher concentrations of nitrogen, phosphorus and potassium were recorded in the leaves of the treated plants. All the three nutrients showed a gradual increase upto July and subsequently the leaf nutrient concentration declined. Thombesi et al. (1962) and Reese and Koo (1975) also reported higher leaf content of nitrogen, phosphorus and potash and further subsequent decrease N, P and K with application of nitrogen. The declining trend of the nutrients in the leaves after July is possible because of the mobilization of the nutrients to the growing fruits on the tree. In an experiment with Washington Navel orange and Torocco orange K values of leaves rose gradually from April to July, sharply from July to August and declined steadily from August to March. (Diedda and viridi, 1969).

Experiment 4. Effect of Mg, Cu, Zn, Fe and B on growth, yield and fruit quality.

The treatments consisted of one level each of magnesium sulphate (2.0%), copper sulphate (0.4%), zinc sulphate (0.5%), ferrous sulphate (0.25%) and boric acid (0.1%). The nutrients were sprayed singly or in various combinations.

Plant height :

The plant height presented in Table 35 showed significant variation due to treatment with Mg, Cu, Zn, Fe and B over the untreated plants. The influence was more pronounced when the nutrients were applied in combination. The maximum increase (43.76 cm) in plant height was recorded with Mg+Cu+Zn+ treatment in a period of two years. Application of Zn alone was found effective in increasing the plant height (39.40 cm) followed by Mg, Cu, Fe and B (Table 35).

Stem girth :

It is clear from the data in Table 35 that the stem girth in general, increased significantly due to treatments. The mean final girth was maximum (3.22 cm) with Mg+Cu+Zn+B and Mg+Cu+Zn treatments. While the minimum girth (2.23 cm) was recorded by the untreated control and the girth in other treatments was in between the two.

Spread of the plant :

The spread of the plant presented in Table 35 showed significant variation over control in all the treated plants in the both

Table 35. Effect of foliar application of Mg, Cu, Zn, Fe and B on vegetative growth of mandarin orange.

Treatments	Plant height (cm)	Stem girth (cm)	Plant East-West	Spread (cm) North-South
Control	30.96	2.23	26.93	27.77
Mg (2%)	36.70	2.38	34.26	34.93
Cu (0.4%)	38.33	3.00	36.71	35.66
Zn (0.5%)	39.40	2.63	38.21	38.20
Fe (0.25%)	37.80	2.31	36.20	35.63
B (0.1%)	37.20	2.44	33.13	34.63
Cu + Zn	42.80	3.08	39.37	38.33
Mg+Cu+Zn	43.76	3.22	39.94	39.86
Mg+Cu+Zn+B	42.10	3.22	40.86	39.68
Mg+Cu+Zn+Fe+B	42.53	3.15	39.77	39.37
S. Em ±	1.04	0.05	0.76	0.76
C.D. at 5%	3.08	0.14	2.25	2.25

directions i.e. East-West and North-South. Application of Mg+Cu+Zn+B caused maximum spread in the East-West direction (40.86 cm). The same treatment also showed greater spread growth (39.68 cm) in the North-South direction, while the spread was 26.93 cm and 27.77 cm in the two directions under control. Application of Zn alone resulted in better spread of the orange trees compared to other treatments (Mg, Cu, Fe and B). In general, the spread was slightly better in East-West compared to North-South direction.

Number of fruits per plant :

The treatment with Mg and micronutrients was found to influence the number of fruits/plant in both the years of the experiment (Table 36). Application of Mg (2.0%) and combined application of the nutrients markedly increased the number of fruits per plant compared to control and the differences were significant. The plants treated with Mg+Cu+Zn+B+Fe produced the largest number of fruits (442/plant) followed by 427 per plant with Mg+Cu+Zn, while the untreated plants produced an average of 338 fruits/plant.

Weight of each fruit :

The weight of individual fruit varied considerably due to the treatments (Table 36) and the weight increased by more than 25 g with most of the combined application of Mg and micronutrients as compared to control. It was noted from the data that fruit weight in general, was more in the second year (1985) of the investigation compared to that in the first year (1984).



Photograph 15. Plant treated with Mg (2 %) + Cu (0.4 %) + Zn (0.5 %) + B (0.1 %)



Photograph 16. Plant treated with Mg (2 %) + Cu (0.4%) + Zn (0.5 %) + B (0.1 %) + Fe (0.25 %)

Yield per plant :

The average yield per plant increased considerably with all the treatments except Cu when applied either singly or in combination. The yield/plant varied between 22.39 kg and 46.78 kg in the first year (1984) and between 28.50 kg and 51.45 kg in the second year (1985). The treatments Cu+Zn, Mg+Cu+Zn, Mg+Cu+Zn+B and Mg+Cu+Zn+B+Fe showed marked improvement in the fruit yield per plant and the increase was more in the second year compared to the first year of the experiment (Table 36)

*Yield per hectare :

The data on yield/ha presented in Table 36 revealed marked difference due to the treatments used in this experiments. Application of Mg + Cu + Zn produced 131.67 quintal^ε fruit per hectare, which was 175.65% more over the control (Table 36). Treatment with Mg, Zn, Fe or B alone also increased the fruit yield. However, foliar application of Cu did not cause higher yield per hectare over control. It was further noted that combined application of the nutrients proved very effective in the production of mandarin orange in both the years.

Diameter of the fruit :

Treatment with Mg and micronutrients used in this investigation, singly or in combinations showed improvement in fruit diameter compared to untreated plant but the variation was not statistically significant. Foliar application of Mg + Cu + Zn + B showed maximum diameter (6.30 cm).

TABLE 36. Effect of foliar application of Mg, Cu, Zn, Fe and B on number of fruits and fruit yield of mandarin orange.

Treatments	Number of fruits/ plant			Weight of each fruit (g)			Yield (kg/plant)			Yield (Q/ha)		
	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean
Control	317	359	338	80.39	79.70	80.04	25.48	28.50	26.99	70.66	79.16	74.96
Mg (2%)	417	405	411	98.14	89.73	93.93	40.98	36.27	38.62	113.60	100.74	107.17
Cu (0.5%)	303	303	303	73.95	98.99	86.47	22.39	29.72	26.05	62.13	82.56	72.34
Zn (0.4%)	343	378	360	93.20	108.17	100.68	32.08	42.67	37.37	89.06	118.52	103.79
Fe (0.25%)	383	391	387	97.84	80.66	89.25	36.25	33.33	34.79	100.66	92.32	96.49
B (0.1%)	343	343	343	97.40	106.83	102.11	33.28	36.63	34.95	92.40	101.76	97.08
Cu+Zn	417	403	410	102.80	96.98	99.89	42.16	39.25	40.70	117.03	109.03	113.03
Mg+Cu+Zn	429	426	427	101.00	120.76	110.88	43.37	51.45	47.41	120.43	142.91	131.67
Mg+Cu+Zn+B	423	413	418	101.56	115.76	108.66	42.96	47.74	45.35	119.26	132.62	125.94
Mg+Cu+Zn+B+Fe	442	441	442	105.66	108.56	107.11	46.78	47.78	47.28	129.90	132.73	131.31
S. Em ±	16.95	13.30		2.51	7.17		1.36	2.83		3.69	7.89	
C.D. at 5%	50.35	39.51		7.69	21.30		4.04	8.40		10.96	23.43	

Peel weight :

The variation in peel weight of fruit due to different treatments was statistically significant. In general, treatment with nutrients caused reduction in peel weight as compared to control in the first year of the experiment (1984), while the effect in this respect was not consistent in the second year (1985). The minimum peel weight was noted with boron treatment and average maximum peel weight was recorded with Mg+Cu+Zn treatment (Table 37).

Pulp weight :

It is evident from the data in Table 40 that spraying of nutrients either singly or in combination showed beneficial effect in increasing the pulp weight of orange fruit and the variation was statistically significant. Among the different nutrients used in this investigation Zn (80.32 g) and B (92.63 g) were found effective in increasing the pulp weight of fruits. Better pulp weight was also recorded with Mg+Cu+Zn+Fe+B (98.65 g) and Mg+Cu+Zn+B (85.92 g) treatments, while the fruit of the untreated plants produced 54.18 g pulp only (Table 37).

Juice content :

It is evident from the data presented in Table 38 that foliar application of nutrients did not show any appreciable difference in the juice content of fruits. Fruits from plants treated with Mg+Cu+Zn+B contained the maximum amount of juice (46.37%), followed by 46.23 per cent with Zn treatment, while those from B treated plants contained the minimum amount (42.78%).

Table 37. Effect of foliar application of Mg, Cu, Zn, Fe and B on physical characteristic of mandarin orange fruit.

Treatments	Diameter of fruit (cm)		Peel weight (g)		Pulp weight(g)					
	1984	1985	1984	1985	1984	1985				
Control	5.50	5.30	5.40	5.40	27.17	25.46	26.31	54.12	54.24	54.18
Mg (2%)	5.40	5.23	5.31	5.31	22.62	24.00	23.31	55.20	90.32	72.76
Cu (0.4%)	5.11	5.01	5.06	5.06	19.05	31.70	25.37	63.95	67.28	65.61
Zn (0.5%)	5.91	5.58	5.74	5.74	26.37	28.44	27.40	93.37	67.28	80.32
Fe (0.25%)	5.50	5.45	5.47	5.47	22.62	22.30	22.46	54.79	65.32	60.05
B (0.1%)	5.61	5.50	5.55	5.55	20.96	22.77	21.86	93.87	91.39	92.63
Cu + Zn	5.73	5.73	5.73	5.73	23.63	24.08	23.85	68.83	58.32	63.57
Mg + Cu + Zn	5.80	5.63	5.71	5.71	28.37	30.02	29.19	77.04	72.90	74.97
Mg + Cu + Zn + B	6.38	6.22	6.30	6.30	27.12	29.27	28.19	88.79	83.06	85.92
Mg + Cu + Zn + B + Fe	6.11	5.75	5.93	5.93	24.48	25.83	25.15	104.41	92.89	98.65
S. Em ±	0.16	0.15			2.24	3.20		5.42	5.19	
C.D. at 5%	N.S.	N.S.			N.S.	N.S.		16.10	15.41	

Total soluble solids :

The total soluble solid content of fruit although showed variation due to the treatments, the difference was not statistically significant (Table 38). The average T.S.S. content of fruit was maximum (11.25%), when treated with Mg+Cu+Zn+Fe+B.

Total and reducing sugar :

The variation in total and reducing sugar contents of fruits in the different treatment was not statistically significant (Table 38). Treatment with Mg+Cu+Zn+Fe+B however, resulted in the maximum concentration of total (7.22%) and reducing sugars (3.03%) in the fresh fruit. The non-reducing sugar content was maximum (4.6%) when treated with Mg+Cu+Zn+B. The variations in respect of different sugar fractions in fruit in the first and second years were, however, not pronounced.

Acidity :

The plants treated with different nutrients showed marked reduction in fruit acidity as compared to control. Application of micronutrients alone (Mg- 1.08, Cu- 0.84, Zn- 0.96, B-0.98 and Fe- 1.18%) showed reduction in fruit acidity compared to control (1.43%). The acidity varied between 0.84% and 1.43% due to treatments. It was further noted that acidity in the harvested fruits of second year was higher compared to those harvested in the first year (Table 38).

TABLE 38. Effect of foliar application of Mg, Cu, Zn, Fe and B on fruit quality of mandarin orange.

Treatments	Juice content of fruits (%)		Total soluble solids (°Brix)		Total sugar(%) fresh weight)		Reducing sugar (% fresh weight)		Non-reducing sugar(% fresh weight)		Acidity (%)							
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985						
Control	45.26	41.74	43.50	10.44	10.66	10.55	6.52	6.46	6.49	2.49	1.42	1.45	4.03	4.03	4.03	1.28	1.58	1.43
Mg (2%)	46.54	45.16	45.85	10.56	10.95	10.75	6.46	6.36	6.41	2.52	2.48	2.50	3.93	3.88	3.90	1.01	1.16	1.08
Cu (0.4%)	43.13	43.22	43.17	10.54	10.35	10.44	6.44	6.40	6.42	2.42	2.36	2.39	4.03	4.04	4.03	0.83	0.85	0.84
Zn (0.5%)	46.51	45.95	46.23	11.28	10.69	10.98	6.45	6.41	6.43	2.48	2.43	2.45	3.97	3.98	3.97	0.94	0.99	0.96
Fe (0.25%)	44.68	41.55	43.11	10.55	10.80	10.67	6.53	6.47	6.50	2.74	2.65	2.69	3.79	3.81	3.80	1.01	1.35	1.18
B (0.1%)	44.17	41.39	42.78	10.55	10.50	10.52	6.64	6.60	6.62	2.55	2.45	2.50	4.09	4.15	4.12	0.97	1.00	0.98
Cu+Zn	45.18	42.68	43.93	10.53	10.44	10.48	6.50	6.49	6.49	2.60	2.53	2.57	3.89	3.93	3.91	1.07	1.46	1.26
Mg+Cu+Zn	43.86	42.41	43.13	11.45	11.00	11.22	6.57	6.52	6.54	2.51	2.44	2.47	4.05	4.08	4.06	1.06	1.47	1.26
Mg+Cu+Zn+B	44.67	48.08	46.37	10.46	11.10	10.78	7.02	6.99	7.00	2.42	2.38	2.40	4.60	4.61	4.60	1.21	1.56	1.38
Mg+Cu+Zn+B+Fe	46.10	42.95	44.52	11.73	10.78	11.25	7.19	7.26	7.22	3.07	3.00	3.03	4.12	4.39	4.25	1.27	1.18	1.22
S. En ±	0.28	0.75	0.17	0.28	0.16	0.10	0.0004	0.08					0.20	0.63		0.05	0.10	
E.D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S. = Not significant.

Leaf analysis :Nitrogen :

The data presented in Table 39 revealed that nitrogen content in leaf increased appreciably due to the treatments with various nutrients. Leaf N content was higher in the month of January, declined markedly in the month of April and increased again in the month of July and then declined in the month of October, irrespective of the treatments. In all the dates of sampling, control plants had the lowest leaf N content.

Phosphorus :

The leaf P content was also found to vary in a manner similar to that of N. All the treated plants had higher amount of leaf phosphorus in comparison to control plants at all the stages of sampling. The highest leaf P contents in the treated plants in the months of January, April, July and October were 0.27, 0.26, 0.29 and 0.28 per cent, respectively and the corresponding figures in the untreated plants were 0.15, 0.13, 0.21 and 0.14 (Table 40).

Potassium :

The leaf potassium content was found to vary between 1.46 and 2.10 per cent due to the various treatments at different stages of sampling, while in the untreated plants it varied between 1.17 and 1.42 per cent during the same period (Table 41). Similar to leaf N and P, the leaf K content was higher in January, decreased in the

TABLE 39. Effect of foliar application of Mg, Cu, Zn, Fe and B on leaf nitrogen content (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	2.46	2.23	2.60	2.36
Mg (2%)	2.73	2.61	2.78	2.68
Cu (0.4%)	2.54	2.42	2.66	2.49
Zn (0.5%)	2.58	2.46	2.66	2.50
Fe (0.25%)	2.75	2.65	2.83	2.67
B (0.1%)	2.59	2.50	2.65	2.48
Cu + Zn	2.87	2.84	2.98	2.81
Mg +Cu + Zn	2.78	2.65	2.87	2.69
Mg + Cu + Zn + B	2.86	2.82	2.89	2.78
Mg + Cu + Zn + B + Fe	2.85	2.78	2.95	2.81

Before treatment - 1.96

TABLE 40. Effect of foliar application of Mg, Cu, Zn, Fe and B on leaf phosphorus content (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	0.15	0.13	0.21	0.14
Mg (2%)	0.23	0.22	0.25	0.21
Cu (0.4%)	0.22	0.21	0.25	0.20
Zn (0.5%)	0.20	0.20	0.23	0.19
Fe (0.25%)	0.23	0.23	0.26	0.22
B (0.1%)	0.23	0.23	0.26	0.22
Cu + Zn	0.26	0.22	0.27	0.20
Mg +Cu + Zn	0.25	0.26	0.29	0.24
Mg + Cu + Zn + B	0.26	0.24	0.28	0.28
Mg + Cu + Zn + B + Fe	0.27	0.25	0.27	0.27

Before treatment - 0.09

TABLE 41. Effect of foliar application of Mg, Cu, Zn, Fe and B on leaf potassium content (expressed as per cent dry weight).

Treatments	January	April	July	October
Control	1.28	1.17	1.42	1.36
Mg (2%)	1.85	1.78	1.91	1.87
Cu (0.4%)	1.75	1.46	1.87	1.78
Zn (0.5%)	1.84	1.80	1.89	1.86
Fe (0.25%)	1.93	1.86	1.98	1.96
B (0.1%)	1.79	1.69	1.85	1.82
Cu + Zn	1.85	1.82	1.89	1.86
Mg + Cu + Zn	1.72	1.69	1.84	1.86
Mg + Cu + Zn + B	1.92	1.84	1.96	1.94
Mg + Cu + Zn + B + Fe	1.95	1.86	2.10	1.99

Before treatment - 0.75

month of April and increased during July sampling and declined again in the month of October (Table 41).

Discussion :

Treatment with magnesium, zinc, copper, iron and boron showed beneficial effect on plant growth, particularly, when applied in combinations. Spraying of Zn alone proved effective in increasing the plant height followed by Mg, Cu, Fe and B, while treatment with Cu caused greater stem girth compared to other nutrients. Foliar application of Zn also resulted in the maximum growth in respect of spread of the plants. The role of micronutrients in regulation of plant growth is already established. The micronutrients take part in many vital metabolic activities in plants necessary for better growth and development and their deficiency is reflected in foliar symptoms and poor growth of plant.

Zinc is activator of enzyme, involves in protein synthesis and has a direct influence on the level of auxin-IAA in plants (Kedlin and Mann, 1940; Skoog, 1940; Possingham, 1956). In an experiment, Reed and Parker (1937) recorded development of healthy leaves of normal size in the first growth flush following foliar spray of $ZnSO_4$. They also noted improvement in shoot growth and also flowering. Increased photosynthesis with application of zinc was noticed by Chantunya and Mikaberidze (1976).

Cu also activate^s several enzymes in plant, help^s in chlorophyll synthesis and is involved in carbohydrate and protein metabolism.

In the present investigation, the plants responded well to application of micronutrients as they are usually deficient in the porous and highly leached soil in Darjeeling hills. The nutritional deficiency is the major factor for the decline Darjeeling mandarin orange. Similar to present observation Ishihara et al. (1974) also observed vigorous growth even by the treatment of Cu containing fungicides.

Optimum amount of Fe is also necessary for some of the vital plant metabolic functions such as chlorophyll synthesis, various enzymatic reactions, respiration and photosynthesis (Halfacre and Barden, 1979). Wallihan and Garber (1966) noted a close relationship between yield of Navel orange trees and Fe concentration in the leaves.

Boron regulates metabolism involved in translocation of carbohydrate, cell wall development and also RNA. However, contrary to the present study Smith and Reuther (1951) found no difference in tree size of Valencia orange as a result of treatment with different levels of boron.

Magnesium is the metallic constituent of chlorophyll (Wills-lattes, 1906) and regulates the uptake of other nutrients. Similar to the present investigation, beneficial effect of Mg and Zn on growth of mandarin orange was also observed by Ghosh et al. (1985).

Spraying of micronutrients either singly (except Cu) or in combination proved very effective in producing higher yield. Treatment with Mg+Cu+Zn+Fe+B also showed marked increase in yield. The average fruit yield was higher in the second year compared to that

in the first year, this is possibly due to supply of sufficient amount of micronutrients necessary for better plant growth which resulted higher yield due to increased growth, better flowering and higher fruit set.

The treatment with micronutrients resulted in higher individual fruit weight, particularly by more than 25 g, when they were applied in combinations. Improvement in fruit size (diameter) as compared to untreated control was also recorded with the application of micronutrients although the variation was not significant. It may be mentioned that Dikshit et al. (1977) obtained better-sized fruit through spraying of zinc or ferrous sulphate in Kinnow mandarin tree.

The juice content of fruits, T.S.S. and total sugar were also influenced due to the micronutrient treatments. In general, the combined application of micronutrients caused improvement in the quality of fruits. The effect of Zn in improving fruit quality was reported by Chanturya (1975), Bacha (1977) and Dikshit et al. (1977). Improvement of fruit quality by using Mg was reported (Hase and Ishihara, 1972; Kuznestov and Koridge, 1977). Ishihara et al. (1974) noted increased sugar content and optimum sugar acid ratio following treatments of Cu containing fungicides in Satsuma mandarin orange. Zinc and boron also improved fruit quality of Satsuma orange (Talakwadze, 1973).

The nitrogen, phosphorus and potash content in leaf increased

appreciably due to the treatment with various micronutrients. The leaf analysis data indicated higher concentration in the month of January, a reduction in the month of April, an increase in the month of July and again a decline during December. The reduction is due to mobilization of nutrients from leaves to its reproductive parts. Plessis and Smart (1970) observed that P content was highest in young leaves sampled in September but during the following two months it declined rapidly. In sweet orange leaf Nauriyal et al. (1968) recorded the highest concentration of nitrogen in August and lowest in February.

Experiment 5. Effect of pruning and nutrients application on rejuvenation of declined orange trees.

In this experiment, four levels of nitrogen at the rate of 400 g (N_1), 600 g (N_2), 800 g (N_3), 1000 g (N_4)/plant/year and magnesium (2% as a $MgSO_4$), zinc (0.5% as a $ZnSO_4$) and pruning alone or in combinations along with a common level of phosphorus and potash (400 g P_2O_5 and 600 g K_2O /plant/year) were applied on 50 year old mandarin orange trees.

Plant height :

The data presented in Table 42 clearly showed positive response in increasing the height of the orange trees over control with all the treatments under investigation. The increase in plant height was maximum (40.50 cm) with the application of 1000 g nitrogen and 400 g phosphorus and 600 g potassium along with pruning, whereas it was only 117.13 cm under control.

Increase in the level of nitrogen increased the height of the plant, treatment with zinc showed greater response to plant height compared to magnesium. Better plant height was also noted with $N_3PK+Mg+Zn+pruning$ and $N_2PK+Zn+pruning$ treatments.

Stem girth :

Similar to the plant height and girth also varied significantly over control due to the treatments. It was maximum (3.12 cm) by treatment with $N_3PK+Mg+Zn+pruning$, while the girth growth was 1.83 cm only in the untreated plants. The treatments which caused more than 3.0 cm increase during the period of investigation were $N_3PK+Zn+pruning$, $N_4PK+pruning$, $N_3PK+Mg+pruning$, N_4PK+ (Table 42).

Spread of the plant :

The increase in spread of the canopy was found to vary due to different treatments and the variation was significant over control. The treatment $N_3PK+Mg+Zn+pruning$ showed the highest spread (38.55 cm) in East-West direction followed by 37.92 cm with $N_3PK+Mg+pruning$ and 37.82 cm with $N_3PK+Zn+pruning$ treatments. The increase of plant spread under control was only 18.64 cm (Table 42).

Similar to East-West spread the North to South spread of the plant was also increased. In a two-year study the highest increase in North-South direction was 37.16 cm with $N_4PK+pruning$ treatment compared to 18.34 cm under control (Table 42).

Number of fruits per plant :

The data on the number of fruits per plant presented in

TABLE 42. Effect of pruning and nutrients on vegetative growth of declined mandarin orange

Treatments	Plant height (cm)	Stem girth (cm)	Plant spread (cm)	
			East-West	North-South
Control (without pruning)	17.13	1.83	18.64	18.39
Control (pruning)	22.26	2.16	21.90	23.13
N ₁ + P + K	29.13	2.52	23.14	22.66
N ₂ + P + K	31.64	2.81	26.93	26.56
N ₃ + P + K	35.86	2.94	30.30	30.86
N ₄ + P + K	38.05	3.04	24.90	33.13
Zn + Mg	29.07	2.24	27.80	24.76
N ₂ + P + K + Zn + Pruning	39.63	3.00	24.20	30.90
N ₂ + P + K + Mg + Pruning	34.48	2.96	24.61	28.44
N ₁ + P + K + Pruning	31.16	2.72	27.50	28.60
N ₂ + P + K + Pruning	33.06	2.82	28.39	26.89
N ₃ + P + K + Pruning	34.72	2.94	30.30	31.43
N ₄ + P + K + Pruning	40.50	3.05	35.96	37.16
N ₃ +P+K+Zn + Pruning	37.66	3.11	37.82	31.27
N ₃ +P+K+Mg + Pruning	33.56	3.03	37.92	27.83
N ₂ +P+K+Zn+Mg + Pruning	38.56	2.94	36.56	30.36
N ₃ +P+K+Zn+Mg + Pruning	40.01	3.12	38.55	31.13
S.E.M ±	1.43	0.24	1.09	0.94
C.D. at 5%	4.12	0.69	3.14	2.70

Table 43 revealed that $N_2PK+Mg+Zn+pruning$ produced the largest number of fruits (632/plant), followed by 604 fruits per plant under $N_3PK+Zn+pruning$. The corresponding figures under control were 420 and 459 in pruned and unfertilized plant.

Weight of each fruit :

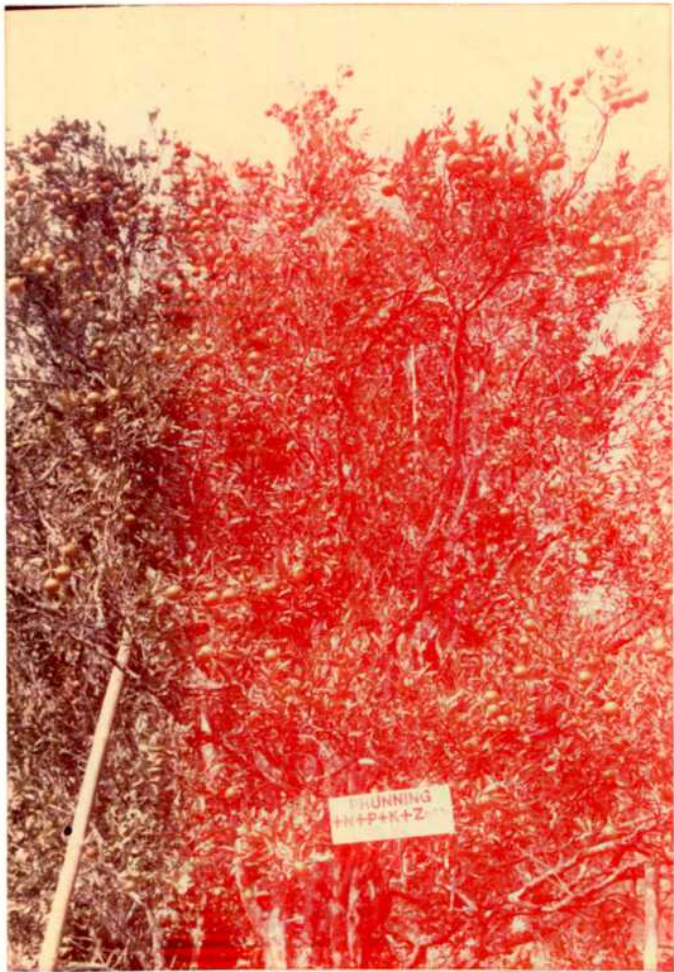
Almost all the treatments responded well to increase the individual fruit weight. The treatment $N_3PK+Mg+pruning$ caused maximum fruit weight (68.42 g) compared to 58.06 g in the untreated plants. Other treatments, which proved effective in increasing the fruit weight were $N_3PK+Zn+pruning$ (68.38 g), $N_2PK+Mg+Zn+pruning$ (66.16 g) and $N_2PK+Zn+pruning$ (66.07 g) (Table 43).

Yield per plant :

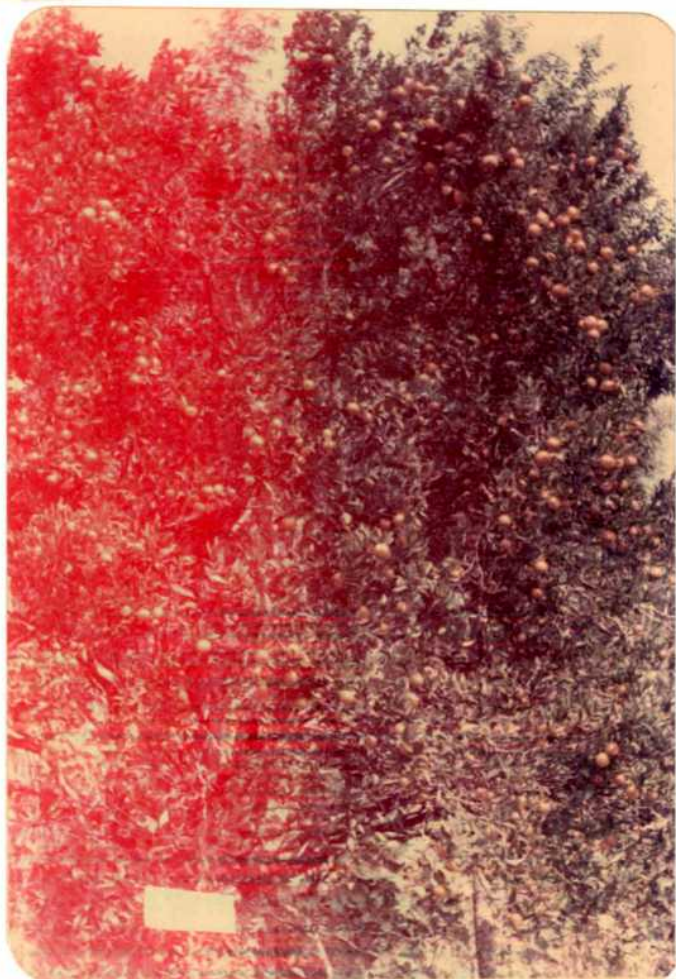
The treatments with different nutrients and pruning proved highly effective in producing higher yield per plant. Almost all the treatments recorded significantly higher yield in both the years of the investigation. The maximum average yield per plant was 45.68 kg by treatment with $N_2PK+Mg+Zn+pruning$ followed by 41.32 kg under $N_3PK+Zn+pruning$ treatment compared to 24.47 kg in the unfertilized and unpruned plants and 26.58 kg in pruned and unfertilized plant (Table 43).

Yield per hectare :

The variation in yield per hectare, obtained during the two years showed significant effect due to the treatments. In general, the treatments caused higher yield in the second year. A



Photograph 17. Plant treated with $N_{600}P_{400}K_{600} + Zn (0.5\%) + Pruning$



Photograph 18. Plant treated with $N_{800}P_{400}K_{600} + Mg (2\%) + Zn (0.5\%) + Pruning$

TABLE 43. Effect of pruning and nutrients on number of fruit and fruit yield of declined mandarin orange.

Treatments	Number of fruits/ plant			Weight of each fruit (g)			Yield (kg/plant)			Yield (Q/ha)		
	1984	1985	Mean	1984	1985	Mean	1984	1985	Mean	1985	1985	Mean
Control (without pruning)	415	426	420	56.84	59.28	58.06	24.59	24.36	24.47	67.66	67.26	67.46
Control (pruning)	487	431	459	54.07	61.34	57.70	29.86	23.30	26.58	64.73	82.93	73.83
N ₁ +P+K	449	498	473	48.66	54.64	51.65	27.60	24.26	25.93	67.38	76.63	72.00
N ₂ +P+K	503	506	504	57.01	58.26	57.63	27.44	28.95	28.19	80.42	76.16	78.29
N ₃ +P+K	518	516	517	58.32	56.10	57.21	29.08	30.07	29.57	83.53	83.76	83.64
N ₄ +P+K	526	535	530	60.30	60.53	60.41	31.49	32.35	31.92	89.85	87.43	88.64
Zn + Mg	686	490	588	58.36	62.46	60.41	36.64	28.61	32.63	79.48	95.10	87.29
N ₂ +P+K+Zn+Pruning	560	598	579	62.82	69.33	66.07	38.82	36.60	37.71	101.68	107.80	104.74
N ₂ +P+K+Mg+Pruning	566	559	563	58.44	68.26	63.35	38.67	32.67	35.67	90.76	107.40	99.08
N ₁ +P+K+Pruning	520	535	527	57.80	58.60	58.20	30.51	30.97	30.74	86.04	89.14	87.59
N ₂ +P+K+Pruning	542	516	529	51.71	59.93	55.82	32.49	26.84	29.66	74.56	90.23	82.39
N ₃ +P+K+Pruning	556	550	553	56.56	60.80	58.68	33.81	31.06	32.43	86.26	93.86	90.06
N ₄ +P+K+Pruning	583	545	564	54.08	64.80	59.44	37.61	31.25	34.43	86.80	105.36	96.08
N ₃ +P+K+Zn+Pruning	604	603	604	62.57	74.20	68.38	44.85	37.80	41.32	105.01	124.66	114.83
N ₃ +P+K+Mg+Pruning	611	549	580	56.21	76.63	68.42	46.84	30.85	38.84	85.69	130.10	107.89
N ₂ +P+K+Zn+Mg+Pruning	626	639	632	56.32	80.00	66.16	55.35	36.01	45.68	100.01	153.73	126.87
N ₃ +P+K+Zn+Mg+Pruning	613	516	564	63.20	65.23	64.21	40.40	32.63	36.51	90.63	112.20	101.41
S.E.M +	10.34	15.58		1.63	1.63		1.58	1.56		4.34	4.79	(1.5)
C.D. at 5%	29.68	44.72		4.67	4.67		4.53	4.47		12.45	13.74	(4.5)

production of 126.87 quintal fruits per hectare was recorded due to the treatment $N_2PK+Mg+Zn+pruning$ while the untreated plants produced 67.46 quintals per hectare. Higher production of fruits was also obtained with the treatments $N_3PK+Zn+pruning$ (114.83 q), $N_3PK+Mg+Zn+pruning$ (107.89 q) and $N_3PK+Mg+Zn$ (101.41 q) in the declined mandarin orange plants (Table 43).

Diameter of the fruit :

However, the fruit diameter showed considerable variation due to the treatments in both the years of investigation. The effect of $N_3PK+Zn+pruning$ was found superior and caused maximum increase (5.22 cm). The untreated plant produced fruits with an average diameter of 4.66 cm. The fruit diameter was more than 5.0 cm with $N_2PK+Zn+pruning$, $N_2PK+Mg+pruning$, $N_2PK+Mg+Zn+pruning$ and $N_3PK+Mg+pruning$ treatments (Table 44).

Peel weight :

The variation in peel weight of fruit due to different treatment was not statistically significant. The peel weight varied between 16.85 and 20.39 g. The effect of different treatments was not very effective in this respect (Table 44).

Pulp weight :

It is evident from the data in Table 44 that the maximum average pulp weight (47.86 g) of fruit was caused by treatment with $N_3PK+Mg+pruning$, followed by 47.70 g with $N_3PK+Zn+pruning$. The pulp weight was higher in the first year of the investigation compared to

TABLE 44. Physical characteristics of declined mandarin orange fruit as influenced by pruning and nutrients.

Treatments	Diameter of fruit(cm)		Peel weight (g)		Pulp weight(g)		
	1984	1985	1984	1985	1984	1985	Mean
Control (without pruning)	4.72	4.61	18.36	18.23	40.91	38.60	39.75
Control (pruning)	4.79	4.69	18.08	17.22	43.29	36.85	40.07
N ₁ +P+K	4.86	4.47	18.40	15.84	36.23	32.82	34.52
N ₂ +P+K	4.83	4.74	17.30	18.11	41.29	38.90	40.09
N ₃ +P+K	4.80	4.74	18.46	19.74	37.64	38.73	38.18
N ₄ +P+K	4.94	4.95	18.85	17.47	42.51	42.83	42.67
Zn + Mg	4.76	4.84	19.21	19.08	44.25	39.27	41.76
N ₂ +P+K+Zn+Pruning	5.08	5.04	20.02	20.15	49.30	42.67	45.98
N ₂ +P+K+Mg+Pruning	5.08	4.96	17.55	19.68	50.71	40.57	45.64
N ₁ +P+K+Pruning	4.73	4.72	17.55	18.18	41.71	39.61	40.66
N ₂ +P+K+Pruning	4.88	4.84	17.03	16.68	42.90	34.92	38.91
N ₃ +P+K+Pruning	5.05	4.76	16.24	17.73	44.55	38.16	41.35
N ₄ +P+K+Pruning	4.74	4.76	16.03	17.43	48.76	36.65	42.70
N ₃ +P+K+Zn+Pruning	5.27	5.17	21.37	17.72	52.22	43.19	47.70
N ₃ +P+K+Mg+Pruning	5.03	4.99	19.64	18.67	56.98	38.75	47.86
N ₂ +P+K+Zn+Mg+Pruning	5.03	5.07	22.56	18.22	57.43	37.40	47.41
N ₃ +P+K+Zn+Mg+Pruning	4.76	4.85	17.20	18.75	47.69	39.98	43.83
S. Em ±	0.11	0.08	0.81	1.97	1.97	1.46	
C.D. at 5%	0.31	0.22	N.S.	N.S.	5.65	4.19	

N.S. = Not significant.

the second year. The treatments, in general, resulted in increase in pulp weight of fruit.

Juice content :

It is revealed from the data presented in Table 47 that all the treatments increased the juice content of fruit significantly which varied between 32.40 and 44.63 per cent. The maximum amount of juice (44.63%) was obtained with $N_2PK+Zn+pruning$ treatment and minimum (32.40%) in the fruits of control plants. The treatments which produced higher juice content in the fruits of declined mandarin plants were $N_2PK+Mg+Zn+pruning$ (43.60%), $N_3PK+pruning$ (41.08%), N_2PK (40.38%), $N_2PK+Mg+pruning$ (40.24%), $N_2PK+pruning$ (40.17%) and $N_1PK+pruning$ (40.00%).

Total soluble solids :

The total soluble solid content of the fruits increased due to the different treatments compared to control but the difference was not significant (Table 45). Application $N_3PK+Mg+Zn+pruning$ ^(in control) in the first year (1984) of investigation showed 9.21% and 10.36% T.S.S., respectively, while it was found to vary between 9.67 and 10.35% in the second year (1985).

Total sugar :

The total sugar content in the fruit juice varied between 6.13 and 6.48 per cent due to different treatments compared to 6.14 per cent in control (Table 45). The maximum concentration of total sugar was found in the fruit harvested from plants treated with $N_2PK+Mg+pruning$. The variation among the treatments was not significant.

TABLE 45. Fruit quality of mandarin orange as influenced by pruning and nutrients.

Treatments	Juice content of fruits (%)		Total soluble solids (°Brix)		Total sugar (% fresh weight)		Reducing sugar (% fresh weight)		Acidity (%)						
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985	Mean	Mean			
Control (without pruning)	35.62	29.18	32.40	9.21	9.67	9.44	6.12	6.17	6.14	2.77	2.53	2.65	0.96	0.97	0.96
Control (pruning)	39.76	38.35	39.05	10.02	10.05	10.03	6.13	6.17	6.15	2.97	2.41	2.69	0.97	0.97	0.97
N ₁ +P+K	34.81	31.53	33.17	10.08	10.10	10.09	6.15	6.29	6.22	2.48	2.44	2.46	0.96	0.96	0.96
N ₂ +P+K	40.72	40.05	40.38	9.90	9.73	9.81	6.14	6.12	6.13	2.44	2.43	2.43	0.97	0.98	0.97
N ₃ +P+K	39.37	37.60	38.48	10.21	10.09	10.15	6.13	6.23	6.18	2.51	2.43	2.47	0.98	0.99	0.98
N ₄ +P+K	36.52	35.33	35.92	10.71	10.16	10.43	6.12	6.21	6.16	2.51	2.48	2.49	1.00	1.00	1.00
Zn + Mg	35.43	39.79	37.61	10.18	10.20	10.19	6.25	6.17	6.21	2.65	2.51	2.58	0.97	0.96	0.96
N ₂ +P+K+Zn+pruning	43.17	46.10	44.63	10.23	10.21	10.22	6.18	6.24	6.21	2.72	2.43	2.57	0.98	0.97	0.97
N ₂ +P+K+Mg+pruning	40.13	40.35	40.24	10.25	10.22	10.23	6.28	6.69	6.48	2.60	2.41	2.50	0.97	0.97	0.97
N ₁ +P+K+pruning	41.06	38.95	40.00	10.15	10.19	10.17	6.17	6.12	6.14	2.45	2.50	2.47	0.95	0.97	0.96
N ₂ +P+K+pruning	39.60	40.74	40.17	10.18	10.13	10.15	6.18	6.16	6.17	2.51	2.36	2.43	0.95	0.97	0.96
N ₃ +P+K+pruning	40.68	41.48	41.08	10.13	10.15	10.14	6.15	6.15	6.15	2.67	2.41	2.54	0.99	0.98	0.98
N ₄ +P+K+pruning	39.59	40.13	39.86	10.21	10.19	10.20	6.17	6.32	6.24	2.63	2.35	2.49	0.99	1.01	1.00
N ₅ +P+K+Zn+pruning	37.02	40.42	38.72	10.23	10.26	10.24	6.20	6.24	6.22	2.68	2.44	2.56	0.99	0.97	0.98
N ₅ +P+K+Mg+pruning	34.83	38.94	36.88	10.33	10.34	10.33	6.24	6.31	6.27	2.78	2.63	2.71	0.96	0.98	0.97
N ₂ +P+K+Zn+Mg+pruning	45.58	41.62	63.60	10.35	10.35	10.35	6.23	6.20	6.21	2.08	2.67	2.87	0.98	0.95	0.96
N ₃ +P+K+Zn+Mg+pruning	38.43	36.03	37.23	10.36	10.35	10.35	6.25	6.20	6.22	2.85	2.46	2.65	0.98	0.97	0.97
S. Em ±	2.69	1.54		0.03	0.05		0.03	0.04		0.08	0.05		0.03	0.01	
C.D. at 5%	7.72	4.42		N.S.	N.S.		N.S.	N.S.		N.S.	N.S.		N.S.	N.S.	

N.S. = Not significant.

Reducing sugar :

The highest concentration of reducing sugar was obtained by treatment with $N_2PK+Mg+Zn$ +pruning (2.87 per cent). Although the treatments showed a beneficial effect over control, the increase in concentration did not attain a significant level (Table 45).

Acidity :

The acidity of fruits varied appreciably due to the treatments. However, an increasing trend in respect of acidity was noted with higher N level in combination with P and K. The concentration varied between 0.96 and 1 per cent and the difference among the treatments was not statistically significant (Table 45).

Leaf analysis.

Nitrogen :

The nitrogen content in leaf at four stages of growth have been presented in Table 46. The treatments, in general, showed an increase in the leaf N content compared to that of the untreated plants. The nutrient concentration in the leaf increased steadily from January to July and then declined. It was between 1.91 and 2.47% in January, 2.18 and 2.65% in April, 2.21 and 2.71% in July and 2.18 and 2.69% in October.

Phosphorus :

Phosphorus concentration in leaves presented in Table 47 did not show any consistent variation due to treatments. The percentage of P varied between 0.08 and 0.17% at different stages of sampling (Table 47).

TABLE 46. Leaf nitrogen content as influenced by pruning and nutrients (expressed as per cent dry weight).

Treatments	January	April	July	October
Control (without pruning)	1.91	2.18	2.21	2.18
Control (only pruning)	2.20	2.24	2.28	2.24
N ₁ +P+K	1.98	2.28	2.48	2.42
N ₂ +P+K	2.10	2.46	2.56	2.51
N ₃ +P+K	2.23	2.58	2.63	2.61
N ₄ +P+K	2.41	2.65	2.70	2.68
Zn+Mg	2.22	2.28	2.28	2.25
N ₂ +P+K+Zn+Pruning	2.32	2.56	2.51	2.47
N ₂ +P+K+Mg+Pruning	2.39	2.59	2.62	2.59
N ₁ +P+K+Pruning	2.21	2.41	2.49	2.42
N ₂ +P+K+Pruning	2.26	2.45	2.58	2.56
N ₃ +P+K+Pruning	2.35	2.63	2.64	2.63
N ₄ +P+K+Pruning	2.28	2.48	2.71	2.69
N ₃ +P+K+Zn+Pruning	2.36	2.54	2.64	2.62
N ₃ +P+K+Mg+Pruning	2.46	2.54	2.61	2.53
N ₂ +P+K+Zn+Mg+Pruning	2.47	2.58	2.62	2.58
N ₃ +P+K+Zn+Mg+Pruning	2.28	2.37	2.64	2.56

Before treatment - 1.62

TABLE 47. Leaf phosphorus content as influenced by pruning and nutrients (expressed as per cent dry weight).

Treatments	January	April	July	October
Control (without pruning)	0.08	0.09	0.11	0.10
Control (pruning)	0.10	0.11	0.13	0.11
N ₁ +P+K	0.12	0.13	0.14	0.12
N ₂ +P+K	0.13	0.13	0.14	0.13
N ₃ +P+K	0.13	0.14	0.15	0.14
N ₄ +P+K	0.14	0.15	0.16	0.15
Zn + Mg	0.11	0.12	0.13	0.12
N ₂ +P+K+Zn	0.13	0.13	0.14	0.13
N ₂ +P+K+Mg	0.12	0.13	0.14	0.12
N ₁ +P+K+Pruning	0.12	0.12	0.13	0.13
N ₂ +P+K+Pruning	0.13	0.14	0.15	0.14
N ₃ +P+K+Pruning	0.14	0.15	0.16	0.15
N ₄ +P+K+Pruning	0.15	0.16	0.17	0.15
N ₃ +P+K+Zn+Pruning	0.13	0.14	0.15	0.14
N ₃ +P+K+Mg+Pruning	0.14	0.15	0.16	0.14
N ₂ +P+K+Zn+Mg+Pruning	0.13	0.14	0.15	0.14
N ₃ +P+K+Zn+Mg+Pruning	0.14	0.15	0.15	0.15

Before treatment - 0.09

TABLE 48. Leaf potassium content as influenced by pruning and nutrients
(expressed as per cent dry weight)

Treatments	January	April	July	October
Control (without pruning)	0.81	0.84	1.04	0.84
Control (pruning)	0.84	0.96	1.08	0.95
N ₁ +P+K	0.89	0.96	1.04	0.93
N ₂ +P+K	0.92	1.01	1.09	0.94
N ₃ +P+K	0.94	1.02	1.12	0.96
N ₄ +P+K	0.98	1.06	1.16	1.01
Zn + Mg	0.86	0.86	0.86	0.86
N ₂ +P+K+Zn+Pruning	0.92	1.01	1.08	0.98
N ₂ +P+K+Mg+Pruning	0.93	1.02	1.09	1.02
N ₁ +P+K+Pruning	0.90	1.01	1.05	0.95
N ₂ +P+K+Pruning	0.93	1.02	1.10	0.98
N ₃ +P+K+Pruning	0.96	1.03	1.13	0.98
N ₄ +P+K+Pruning	0.98	1.04	1.14	1.02
N ₃ +P+K+Zn+Pruning	0.94	1.04	1.14	1.04
N ₃ +P+K+Mg+Pruning	0.94	1.06	1.13	1.06
N ₂ +P+K+Zn+Mg+Pruning	0.94	1.03	1.08	1.04
N ₃ +P+K+Zn+Mg+Pruning	0.96	1.07	1.11	1.05

Before treatment - 0.75

Potassium :

It is revealed from the data presented in Table 48 that potassium content of leaf was also influenced by the application of nutrients along with pruning treatment. The nutrient content varied between 0.81 to 1.14 per cent.

Discussion :

Results of the experiments showed that application of higher dose of nitrogen in combination with phosphorus and potash + pruning caused marked improvement in the height of the declined plants. Maximum increase in stem girth was found with $N_3PK+Mg+Zn$ +pruning treatment and the spread of the plant was also maximum by the same treatment particularly, in the East-West direction. The beneficial effect of nitrogen on growth may be explained from the fact that N is the major constituent of many compounds of physiological importance in metabolism, such as chlorophyll, nucleotides, phosphatides, as well as in many enzymes, hormones and vitamins. Protein and chlorophyll synthesis are closely associated with the application of higher doses of nitrogen (Wadleigh, 1957). Marked improvement in growth of orange tree by N application was recorded by many investigators in different citrus growing regions of the world (Klein and Monselise, 1962; Dornelles, 1963; Smith *et al.*, 1968-69; Nokrashy *et al.* 1977). The beneficial effect of Zn it is mainly due to its important role in enzyme system (e.g. carbonic anhydrase) which regulates the plant growth (Kellin and Mann, 1940). Beside, Zn stimulates photosynthetic

activity (Samoladas, 1964) and its presence is important for protein synthesis (Possingham, 1956). While Mg is the only metallic constituent of chlorophyll (Willslattes, 1906) and it is a component of carboxylase and peptidase. The beneficial effect of Zn and Mg on growth of mandarin orange was also observed by Ghosh et al. (1985). The higher yield in the declined plants is the direct effect of application of N, P, K, Mg and Zn along with pruning of water sprouts diseased shoots etc.

The declined plant produced 632 fruits each by treatment with $N_2PK+Mg+Zn$ and pruning compared to 420 under control. Marked increase in yield was also recorded in plants under $N_3PK+Zn+pruning$ treatment. Singh (1961) in an experiment with different levels of nitrogen observed that increase in the levels of nitrogen increased the flower production and initial fruit set of mandarin orange. The beneficial effect of nitrogen in fruit production is due to the formation of larger number of branches, higher fruit set and retention, and enhanced fruit growth. A significant increase in yield due to higher levels of nitrogen fertilization was also reported by Sato and Ishihara (1964). Chanturiya and Mikaberidge (1976) in an experiment on the utilization of Zn, Mo and Cu by mandarin orange trees reported that in addition to N, P and K, application of Zn at 3 g per tree increased the yield by 30 per cent over control. The physiological role of Zn and Mg in photosynthesis, leaf pigment content and carbohydrate metabolism as the pre-requisite of yield components are well established (Singh and Kumar, 1983). The yield of fruits was,

however, higher in second year of experiment. This may be explained from the fact that supply of nutrient in two consecutive years caused greater uptake and utilization in the second year which resulted in more yield due to increased growth and higher percentage of fruit set. Azzony et al. (1970) reported that application of $\text{Ca}(\text{NO}_3)_2$ at 0.75 and 1 kg N per tree increased the fruit yields which was however, found to increase considerably in the second year.

Treatment with different nutrients and pruning proved highly effective in production of higher yield/plant. The highest yield of 45.68 kg was obtained by treatment with 600 g nitrogen, 400 g phosphorus, 600 g potassium, Zn (0.5%), Mg (2%) and pruning in which the leaf nitrogen content was varied between 2.47 and 2.62 per cent at different times of the sampling. The higher level of nitrogen (800 g/plant) in combination with P, K, Zn (0.5%) and pruning showed increased fruit size (diameter), which was considerably reduced with low (400 g/plant) level of N. The beneficial effect of pruning in this investigation is due to induced vegetative growth resulting in better photosynthesis and consequently encouraged flowering and fruiting by maintaining of a balance between vegetative growth and production. Tavadge (1983) reported that separation of closed crowns of mandarin trees reduced the yield in the first year but economically improved both yields and quality in the subsequent years over unpruned control. Raciti et al. (1982) recorded that mechanical pruning caused no fall in total yield over 3 years. Similar result also obtained by Borrell et al. (1983) that pruning stimulated growth and improved yield in

Valencia Late orange. Sanikidze (1981) recommended hard pruning as most economic method to obtain higher yield of aged mandarin tree. Treatment with different nutrient and pruning influenced considerably the fruit size (diameter) of declined mandarin orange. Kiely et al. (1972) in Valencia orange, Koo and McCornack (1965) in Dancy tangerine, El-Mohmoudi (1959) in Egyptian orange and Leyden (1978) in Red grape fruit also observed similar increase in fruit size with increased rate of nitrogen. Larger fruit size was obtained in a pruning and fertilizer trial by Iwagaki et al. (1985).

In the present investigation higher percentage of juice (44.63%) was found by treatment with N_2PK+Zn and pruning. An increase in juice percentage of fruit with higher dose of nitrogen was obtained by Young and Koo (1973) in Persian lime, Reese and Koo (1974) in Hamlin, Pineapple and Valencia orange, Jorgensen (1978) in Navel orange.

In general, the treatments increased the total soluble solid content of fruit and also various sugar fractions. However, the acidity of fruits was not influenced appreciably due to the treatments. It appears that pruning caused better admittance and distribution of light in all the portion of the plants and thereby increased the photosynthetic activity and carbohydrate production which was mobilized to the developing fruits and improved the fruit quality. Borrell et al. (1983) obtained better quality fruit in Valencia Late orange by mechanized pruning. While, Raciti et al. (1982) found little effect of pruning on fruit quality in three orange cultivars.

Fruit quality was generally lowest in the pruned and heavily fertilized plants and better in non-pruned, low fertilized plants (Iwagaki et al., 1985).

The nitrogen, phosphorus and potassium content in leaf increased due to increased level of nitrogen. Thombesi et al. (1962), Leyden (1963) and Reese and Koo (1975) also reported higher leaf N, P and K with added N. The effect of Zn and Mg on the leaf tissue composition, however, was not so pronounced. The nutrient content in leaf was found to increase steadily from January to July and then declined.

Plessis and Smart (1970) observed that N content was highest in young leaves sampled in September but during the following two months it declined rapidly. Leaf N, P and K decreased in the month of October. Similar observations were made by Deidda and Virdis (1969) and Randhawa et al. (1964).

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Experiment 1. Effect of different levels of N, P and K on growth, yield and fruit quality.

The results of the experiment on the effect of different levels of N, P, K and their interactions on the growth, yield and fruit quality of orange variety Darjeeling mandarin, are summarised below.

The levels of nitrogen and potassium were 400, 600 and 800 g each/plant/year and that of phosphorus were 200, 400 and 600 g, and were applied in June and September.

In this experiment the growth of the plant (height, girth and spread of crown) increased significantly with the increase in the level of N. Higher level of P and K also influenced the plant growth but the effect was less pronounced than with N. The interactions of N x P, N x K, P x K and N x P x K also promoted the vegetative growth of the orange plant. Maximum increase (44.21 cm) in plant height in the two-year period was noted with the highest level of the nutrients ($N_3P_3K_3$). However, girth growth was maximum (4.91 cm) with $N_3P_2K_3$ treatment. The plant treated with the highest level of N (800 g/plant), P (600 g/plant) and K (800 g/plant) exhibited the maximum increase in spread of crown in East-West (49.19 cm) and North-South (46.83 cm) direction).

The fruit production increased markedly with higher rates of the nutrients. The plants treated with 800 g N produced an average of 778 fruits per plant compared to 538 fruits with 400 g N. The interaction effect of N x K was however, more pronounced compared to N x P and P x K. Treatment with $N_{800}P_{600}K_{800}$ produced the highest number of fruits per plant (933 in 1984 and 857 in 1985) compared to an average production of 514 fruits with the lowest level of the nutrients ($N_{400}P_{200}K_{400}$). Higher production was also obtained with $N_3P_3K_2$, $N_3P_1K_3$, $N_3P_2K_2$, $N_3P_2K_3$ and $N_3P_3K_1$ treatments.

The individual fruit weight was maximum with $N_3P_3K_1$ treatment and the yield was maximum (211.23 g/ha) by treatment with highest level of the nutrients ($N_3P_3K_3$).

Fruit size (diameter) increased appreciably with the application of N, P and K. The plants treated with 800 g K_2 /plant produced 42.68 per cent juice (maximum) compared to 38.74 per cent (minimum) with 400 g N/plant. The $N_3P_3K_3$ treatment produced 42.20 per cent juice.

The highest T.S.S. percentage was found under $N_1P_2K_1$ treatment (11.18). As regard, total sugar treatment combination of $N_2P_3K_2$ resulted in the highest average (7.15%) followed by 7.08 per cent with $N_3P_1K_2$. The treatment $N_1P_3K_3$ exhibited the maximum (3.18%) reducing sugar in fruit in 1985.

The leaf nutrients (N, P and K) were found to increase gradually upto July and then declined during October. The increase in

the leaf nutrient status was related with the increase in the level of fertilizer application.

It is, therefore, suggested that a high yield in mandarin orange plant of Darjeeling, is possible with the application of 800 g N, 600 g P_2O_5 and 800 g K_2O /plant/year.

Experiment 2. Effect of irrigation and different levels of N on growth, yield and fruit quality.

In this experiment, the effect of three levels of nitrogen @ 200 g (N_1), 400 g (N_2), 600 g (N_3)/plant/year and three levels of irrigation, at an interval of 10 days (I_1), 20 days (I_2) and 30 days (I_3) alone and in combinations were studied on 7 years old mandarin orange trees.

Application of nitrogen or irrigation alone influenced vegetative growth (plant height, stem girth and plant spread) over control but their various combinations resulted in marked improvement of these growth parameter. The vegetative growth was maximum (44.21 cm increase in plant height, 3.68 cm plant girth and 45.30 cm plant spread in the East-West direction) under N_3+I_1 treatment i.e. higher level of nitrogen in combination with frequent irrigation (10 days interval).

The maximum number of fruits was obtained with N_3+I_1 treatment (310/plant) followed by 293 fruits under N_3+I_2 compared to 217 from the untreated plant. All the treatments showed beneficial effect

in increasing the individual fruit weight. The highest level of the nutrient (N_3) in combination with frequent irrigation (I_2) exhibited maximum fruit weight (73.70 g in 1984 and 90.93 g in 1985), the fruit weight in the untreated plants were 57.71 g and 61.36 g in the respective years. Marked improvement in fruit yield/ha was recorded under the treatments N_3+I_1 (69.54 q), N_3+I_2 (67.51 q), N_3+I_3 (61.56 q) The yield was only 35.94 q/ha in the control plant.

In general, the treatments showed a reduction in peel weight of fruit compared to control. The average pulp weight, however, increased due to treatments with nitrogen and irrigation.

The fruit size (diameter) did not vary significantly over control due to different nutrient and irrigation treatments.

The maximum juice content (43.50%) was found in the fruits harvested from N_2+I_2 treated plants and minimum with I_3 (35.01%) treatment. The combined treatments mainly showed significant variation in respect of T.S.S. and total sugar content of fruits. The maximum T.S.S. and total sugar (6.84%) was recorded with N_3+I_2 treatment. The reducing sugar content of fruits did not vary appreciably due to the treatments. In general, the fruits of treated plants contained more acid. Higher percentage of fruit acidity was noted with N_3 and its combination with different irrigation frequencies.

Leaf nitrogen, phosphorus and potash contents increased due

to treatments and the influence of the combined application was very pronounced.

From the results of the investigation, it is concluded that application of 600 g N in the form of urea along with irrigation at an interval of 10 days gave the highest yield (69.54 q/ha) in mandarin orange.

Experiment 3. Effect of application of urea and Zn as foliar spray on growth and yield of mandarin orange.

In this experiment, the effect of 400 g urea as soil application as well as foliar application (0.5%, 1% and 1.5%) was studied. Zinc was also applied as foliar spray ($ZnSO_4$ - 0.5%) alone and in combination with different nitrogen treatments (twice a year) on 7-year old mandarin plants during 1984 and 1985. Soil application of urea (400 g) and subsequent foliar application of 1.5 per cent urea and 0.5 per cent zinc showed the maximum increase (44.30 cm) in plant height in the two years of the investigation. Similar to plant height, soil application of urea and foliar application of urea (1.5%) + Zn showed maximum stem girth (3.38 cm) and spread of the canopy (48.10 cm in East-West and 45.43 in North-South). The number of fruits harvested in the second year was more compared to the first years harvest. The treatments which were effective in influencing the vegetative growth resulted higher fruit production in terms of number, weight and yield. The maximum number of fruits (196) and individual

fruit weight (89.41 g) were obtained by treatment with 400 g urea (soil) + urea (1.5%) and Zn (0.5%) as foliar spray, while the corresponding figures were 95 and 60.15 g in the untreated plant. The yield/ha showed a marked difference due to treatments used in this experiment. The maximum fruit yield/ha (44.69 q) was also obtained with soil and foliar application of urea and Zn, while the untreated plant produced only 16.18 quintals fruit/ha. A significantly higher fruit yield was obtained by the application of urea (soil) + urea (1.5%), urea (soil) + urea (1%) + Zn, urea (soil) + urea (0.5%), urea (soil) + urea (1%) and urea (soil) + urea (0.5%) + Zn.

The peel weight did not vary due to the treatments although the pulp weight showed appreciable variation in the present investigation. The size (diameter) of the fruit was 6.21 cm due to various treatments in comparison to 4.90 cm in control.

The juice content, in general, was found to increase under different treatments and it varied between 35.18 and 42.04 per cent. The fruits from plants treated with 600 g urea (as soil application) + 1.5 per cent spray with zinc (0.5%) contained more juice (42.04%), total soluble solids (11.85%) and total sugar (6.85%) compared to control plant (i.e. 36.33%, 10.44% and 6.36%, respectively). The percentage of acidity did not show significant variation due to treatments.

Nitrogen, phosphorus and potassium content in leaf increased with the spray of urea (1.5%) and zinc (0.5%) as compared to untreated plants. All the treated plants had higher leaf N, P and K

concentration over control. The nutrient content was found to increase from January to July and declined in October. The treatments that produced higher yield (44.69 q/ha) also showed higher leaf nutrient content (2.72% N, 0.21% P and 1.54% K).

Therefore, soil application of urea @ 400 g/plant along with foliar application of urea (1.5%) + Zn (0.5%) proved very effective, ✓ in increasing the production of Darjeeling mandarin orange.

Experiment 4. Effect of Mg, Cu, Zn, Fe and B on growth, yield and fruit quality.

In the present investigation the treatments consisted of one level each of copper sulphate (0.4%), zinc sulphate (0.5%), boric acid (0.1%), magnesium sulphate (2 %) and ferrous sulphate (0.25%). Magnesium and micronutrients were sprayed either singly or in various combinations on 15 years old mandarin orange plants in the month of May and September. A soil application of 600 g N, 400 g P and 600 g K in two split doses was done to supply N, P and K to the plants.

The influence of magnesium and micronutrients was significant in respect of vegetative growth i.e. plant height, stem girth and spread of the canopy. The effect in these nutrient was more pronounced when applied in combinations. Treatment with Cu+ Zn + Mg showed the maximum increase in height (43.76 cm) stem girth (3.22 cm) and also the spread of the plant (39.94 cm in East-West and 39.86 cm in North-South).

The plants treated with Mg + Cu + Zn also produced the largest

Number of average fruits (427) plant followed by Mg+Cu+Zn+B (418), 338 fruits were produced in control plants. The fruit weight increased considerably due to various treatments and most of the combined applications caused an increase in fruit weight by 28 g over that under control.

Treatment with magnesium and micronutrients except Cu resulted in higher fruit yield than control and the yield/plant varied between 22.39 kg and 46.78 kg in the first year and between 28.50 kg and 51.45 kg in the second year. The treatments Mg+Cu+Zn+Fe, Mg+Cu+Zn+B showed marked improvement in the yield. Application of Mg+Cu+Zn produced 131.67 q fruits per hectare compared to 74.96 q in the untreated plant.

The maximum pulp weight (98.65 g) was recorded with the Mg+Cu+Zn+Fe+B, but the variation in peel weight of fruit was not significant over control. Improvement in fruit size was recorded due to the treatments and foliar application of Mg+Cu+Zn+B showed greater diameter (6.30 cm).

Application of Mg, Cu, Zn, Fe and B in combination increased the juice content whereas effect of these nutrients on T.S.S., total sugar, reducing sugar and acidity of fruit juice was not significant.

The total soluble solids content of fruits and also different sugars fractions were not influenced very much due to treatments

and the fruits harvested from the treated plants showed marked reduction in fruit acidity.

The leaf nitrogen, phosphorus and potassium content increased appreciably due to application of magnesium and micronutrients. The nutrient concentration was maximum in the month of July and minimum in October.

It is, therefore, concluded that, foliar application of Mg 2% + Cu 0.4% + Zn 0.5% and Mg+Cu+Zn+B (0.1%) produced higher yield in Darjeeling mandarin orange.

Experiment 5. Effect of pruning and nutrients application on rejuvenation of declined orange trees.

An experiment was conducted to improve the fruit production of declined mandarin orange trees (50-year old) in Darjeeling district. The treatments consisted of four levels of nitrogen (400 g, 600 g, 800 g and 1000 g/plant), one level each of phosphorus (400 g), potassium (600 g), zinc (0.5%) and magnesium (2%). Pruning was also included as treatment. The results obtained in this investigation are summarised below.

The increase in plant height was much higher with all the treatments over control. It was maximum with N_4PK +pruning (40.50 cm) and the treatment $N_3PK+Mg+Zn$ +pruning also resulted almost similar increase in height (40.01 cm). Stem girth was also influenced with the treatments and $N_3PK+Mg+Zn$ +pruning produced the maximum girth of stem (3.12) and the untreated plants showed an increase of 1.83 cm.

The spread of the plant also showed positive response due to treatment.

The treatment $N_2PK+Mg+Zn+pruning$ produced the largest number of fruits (632/plant) followed by 604 fruits with $N_3PK+Zn+pruning$ and the untreated plants produced 420 fruits only. A yield of 126.87 q/ha was found with $N_2PK+Mg+Zn+pruning$ treatment while, it was 67.46 q in the untreated plants. A higher production was also obtained with $N_3PK+Zn+pruning$ (114.83 q/ha). The fruit weight was maximum (68.42 g) with $N_2PK+pruning$ followed by $N_3PK+Zn+pruning$ (68.38 g) and the fruit weight of untreated plant was 58.06 g.

The fruit size (diameter) also varied to the treatments and it was maximum (5.22 cm) with $N_3PK+Zn+pruning$.

The maximum amount of juice (44.63%) was obtained with $N_2PK+Zn+pruning$ and minimum (32.40%) in the untreated plant. The fruits obtained from plants treated with different macro- and micro-nutrients along with pruning showed beneficial effect in improving quality of fruits (total soluble solids, total sugar, reducing sugar) compared to those from the untreated plants. The acidity was found to increase from N_1 to N_4 level in combination with P and K.

An increase in the leaf nutrient (nitrogen, phosphorus and potassium) concentration was observed in the treated plants. The nutrient content in the leaf increased steadily up to July and then declined progressively and was lowest in October sampling.

From the results of the investigation, it is concluded that application of 600 g nitrogen in the form of urea along with 400 g P, 600 g K, zinc (0.5%), Mg (2%) + pruning gave the highest yield (126.87 q/ha) in the declined mandarin orange plant of Darjeeling district.

•

BIBLIOGRAPHY

BIBLIOGRAPHY

Aiyappa, K.M. and Subramaniam, C.K. (1958) And now foliar nutrition.
Indian Hort., 2 : 7-9.

Akao, S.; Kobota, S. and Hayashida, M. (1978) Utilization of reserve nitrogen especially autumn nitrogen by Satsuma trees during the development of spring shoots. J. Jap. Soc. Hort. Sci., 47 : 31-38.

Akhmedov, G. (1983) Effect of irrigation regimes on lemon quality. Referativnyi Zhurnal, 55 : 9.55-6.45.

Alla, M.A.S.; El-Nokrashy, M.A.; El-Zokrani, S. and Salem, S.E. (1985) Effect of nitrogen fertilization on growth of root system, yield and fruit quality of Valencia orange tree in sandy soil. Agric. Res. Review, 59 : 93-101.

Allwright, W.J. (1938) Final report on the fertilizer trials at Rustenberg, Western Transvaal. Citrus Grower (S.Africa), 52 : 5-19.

Anderson, C.A. (1966) Effects of phosphorus fertilizer on yield and quality of Valencia oranges. Proc. Fla. Sta. Hort. Soc., 79 : 36-40.

Anderson, C.A. and Calvert, D.V. (1967) Effect of phosphorus fertilizer on young citrus trees on flat-wood soils. Proc. Fla. Sta. Hort. Soc., 80 : 19-25.

- Anderssen, F.G. (1937) Citrus manuring - its effect on cropping and on the composition and keeping quality of oranges. J. Pomol. Hort. Sci., 15 : 117-59.
- Anonymous (1953) Citrus Fertilization. A.R. Conseil Exp. Rec. Agron. Alger., pp.21-25.
- Anonymous (1965) Annual Report of the Citrus Dieback in India Project under PL-480.
- Anonymous (1983) Annual Report improvement in the production of Horticultural Crops in Hilly Region of Darjeeling District, B.C.K.V.
- Anonymous (1984) Research Report All India Co-ordinated Fruit Improvement Project. PAU, Ludhiana.
- Anonymous (1984) Research Report All India Co-ordinated Fruit Improvement Project, Wynad, Kerala.
- Anonymous (1985) Research Report All India Co-ordinated Fruit Improvement Project, Ahamed Nagar, Maharashtra.
- A.O.A.C. (1970) Official Methods of Analysis. Association of Official Agricultural Chemists 11th Ed. Washington, D.C.
- Aso, P.J. and Dantur, N.C. (1969) Seasonal variations in major nutrient concentration in leaves of Valencia orange. Rev. Industr. Agric. Tucuman, 46 : 35-46.
- Azzony, M.Eb.; Zidan, Z.; Maximos, S. and Naggar, S.Eb. (1970) Yield and fruit quality of Navel orange trees as affected by nitrogen fertilization. Res. Bull., Faculty of Agri., Ain Shams Univ. Cairo, U.A.R. No.176, p.14.

- Bacha, M.A.A. (1977) Responses of Succawry and Balady orange trees to foliar sprays of zinc and copper. Indian J. Agril. Sci., 45 : 1989-93.
- Bageleth, M.; Feigenbaum, S. and Bar-Akiva, A. (1980) Potassium fertilization experiment in a Shamouti orange groves. Pamphlets. Volcani Centre Bet Dagan, 220 : 28.
- Bajwa, B.S. and Kaura, N.R. (1952) Manuring citrus trees. Indian J. Hort., 9 : 29-32.
- Bar-Akiva, A. (1972) Nitrate content of leaves of differentially fertilized citrus trees. Soil Sci. and Pla. anal., 3:65-69.
- Bar-Akiva, A.; Hiller, V. and Pati, J. (1968) Effect of phosphorus and chicken manure on yield, fruit quality and leaf composition of grape fruit trees. Proc. Amer. Soc. Hort. Sci., 93 : 145-52.
- Bar-Akiva, A. (1973) Nitrate estimation in citrus leaves as a means of evaluating nitrogen fertilizer requirement of citrus trees. Int. Soc. Citriculture, 1 : 159-64.
- Basso, C.; Mielniczuk, J. and Bohnen, H. (1983) Influence of NPK fertilization on nutrient concentration in Valencia orange. Pesquisa Agropecuria Brasileria, 18 : 17-21.
- Bayers, E. and Jonbert, G.F. (1952) Mineral deficiencies in citrus in citrus dal area. Fmg. S. A. Afr., 27 : 508-10.

- Bopaiah, M.G. and Srivastava, K.C. (1982) Effect of different levels of nitrogen on Coorg mandarin raised on Poncirus trifoliata rootstock. South Indian Hort., 30 : 134-36.
- Borrell Garica, M. and Diaz, A. (1983) Effect of mechanized pruning on the yield of citrus fruit. Monografia, Centro de Mecanizacion Agropecuaria, Cuba, 3, p.15.
- Bouma, D. (1959) Growth, yield and fruit quality in factorial experiments with citrus in relation to changes in phosphorus nutrition. Australia J. Agric. Res., 10 : 41-51.
- Bziava, S.M.; Kvirkveliia, V.K. (1980) Crown management in young lemon trees cultivar Gruziskii. Suptrop. Kul'tury, No.3/4, pp.67-73.
- Calabrese, F. (1965) Fruit growth rhythm and changes in the nitrogen content of the leaves in the mandarin varieties Avana and Tardivo di Ciaculli Rev. Ortoflorofruttic Ital., 49 : 453-59.
- Calvert, D.V. (1970) Response of Temple oranges to varying rates of nitrogen, potassium and magnesium. Proc. Fla. Sta. Hort. Soc., 3 : 10-15.
- Calvert, D.V. and Reitz, H.J. (1966) Response of citrus growing on calcareous soil and application of magnesium. Proc. Fla. Sta. Hort. Soc., 19 : 6.
- Cameron, S.H. and Appleman, D. (1934) Total nitrogen in developing flowers and young fruits of Valencia oranges. Proc. Amer. Soc. Hort. Sci., 32 : 204-207.

- Camp, A.F. (1947) Magnesium in citrus fertilization in Florida. Soil Sci., 63 : 43-52.
- Chanturiya, I.A. (1974) The effect of zinc on mandarin yield and quality. Subtrop. Kul'tury, No.4, pp.61-64.
- Chanturiya, I.A. (1975) The effect of zinc on mandarin yield and quality. Subtrop. Kul'tury, No.4, pp. 16-64.
- Chanturiya, I.A. and Mikaberidze, V.E. (1976) Studies of the utilization of zinc molybdenum and copper fertilizers by mandarin trees. Subtrop. Kul'tury, No.3/4, pp.99-103.
- Chapman, H.D. (1960) Leaf and soil analysis in citrus orchards. Calif. Agric. Expt. Sta. Ext. Sev. Manual., 25.
- Chapman, H.D. (1968) The mineral nutrition in citrus. The Citrus Industry. Vol.II. pp. 204-212.
- Chapman, H.D. and Brown, S.M. (1950) K in relation to citrus nutrition. Soil Sci., 55 : 87-100.
- Chapman, H.D. and Kelley, W.P. (1943) The mineral nutrition of citrus. The Citrus Industry, 1 : 719-66.
- Chapman, H.D.; Brown, S.M. and Rayner, D.S. (1951) Nutrient deficiencies of citrus symptoms, cause and control. Citrus leaves, 25 : 17-28.
- Chapman, J.C. (1982) The effect of potassium and nitrogen fertilizers on the yield, fruit quality and leaf analysis of Imperial mandarins. Australian J. Exp. Agric. Anim. Husb., 22 : 331-36.
- Chhonkar, V.S. and Tiwari, R. (1966) Studies on the effect of foliar application of urea on Kagzilime (C. aurentifolia Swingle). Indian J. Hort., 23 : 114-19.

- Chilembewe, E.H.C. (1985) Fruit yield response of Marsh Seedless grape fruit to supplementary irrigation. Acta Hort.No.158,pp.163-68
- Chowdhury, S. (1954) Deficiency disease of citrus in Assam, India, F.A.O. Plant Prot. Bull., 2 : 151-53.
- Crous, P.A. (1937) Superphosphate experiment in white river. Citrus Gr. (S. Africa), 51 : 15-17.
- Deidda, P. and Viridis, M. (1969) Variations in the contents of certain major elements in the leaves and fruit of different citrus sp., in relation to biological stages in the annual cycle. Studi Sassar sez.III, 17 : 217-40.
- Deidda, P. and Casu, M. (1980) Preliminary result of a fertilizer trial on Washington Navel orange. Studi Sassar Sez.III, 28:81-88.
- Devilliers, J.I. (1969) The effect of differential fertilization on yield. Fruit quality and leaf composition of Navel oranges in Chapman, H.D.(ed). Proc.First Int.Citrus Symp., 3 : 1661-68.
- Dikshit, C.K.; Yamdagni, R. and Jindal, P.C. (1977) A note on the effect of micro-nutrients spray on quality of Kinnow - A mandarin hybrid. Haryana J. Hort. Sci., 6 : 153-54.
- Dikshit, N.N. (1958) Preliminary studies on citrus die-back in Coorg. II. Effect of micro-element sprays and irrigation on occurrence of chlorosis, Sci. and Cult., 24 : 91-94.
- Dornelles, C.M. (1963) Initial results of an experiment on the manuring of orange trees. Fertilite, 19 : 25-30.

El-Mahmoudi (1959) Effect of three nitrogen levels on growth and fruiting of young trees on sandy soils. Agric. Res. Rev., 37 : 68-78.

Embleton, T.W. and Jones, W.W. (1973) Valencia orange creasing, fruit colour and other factors affecting crop value as influenced by N, K and Mg and their interrelation citricultura, Nurcia-Valencia, Espana, Int. Soc., Citriculture, 1 : 93-101.

Fawcett, H.S. (1936) Citrus diseases and their control. McGraw-Hill Book Company. Inc. New York.

Feungchan, S. and Sharma, B.B. (1974) Nutrient composition of sweet orange leaves (C. sinensis (L.) Osbeck) as affected by potassium nitrate foliar sprays. India J. Hort., 31 : 313-20.

Feungchan, S. and Sharma, B.B. (1974) Studies on the effect of potassium nitrate spray in sweet orange (C. sinensis L. Osbeck). Philippines J. Plant Industry, 39 : 119-26.

Finch, A.H. and McGeorge, W.T. (1945) Fruiting and physiological responses of Marsh grape fruit trees to fertilization. Ariz. Agr. Exp. Sta. Tech. Bull., 105 : 423-54.

Ford, H.W.; Reuther, W. and Smith, P.F. (1957) Effect of nitrogen on root development of Valencia orange trees. Proc. Amer. Soc. Hort. Sci., 70 : 237-44.

Franciosi, R.; Salas, P.; Mercado, D. and Duarte, O. (1985) Supplementary foliar application of N, P, K to Washington Navel orange trees affected by tristeza. Proc. Trop. Reg., Amer. Soc. Hort. Sci., 24 : 73-76.

- Ghosh, D.; Mitra, S.K. and Bose, T.K. (1985) Effect of magnesium, zinc, copper, boron, manganese and iron on growth, yield and fruit quality of mandarin orange. Proc. IIIrd Nat. Citrus Sem. Indian Soc. Citriculture, p.12.
- ✓ Ghosh, S.P. (1985) Citrus. In Fruits of India. Trop. and Sub-trop. Ed. T.K. Bose, Naya Prakash, Calcutta-6, India.
- Ghosh, S.P.; Verma, A.N. and Govind, S. (1981) Nutritional requirement of bearing khasi mandarin orange trees in Meghalaya. Nat. Symp. Trop. and Subtrop. Fruit Crops, Bangalore, p.48.
- Goell, A.; Colomb, A.; Kalmar, D.; Mantell, A. and Sharon, S. (1983) Moisture stresses - a potent factor for affecting vegetative growth and tree size in citrus. Fruit Tree Res. Sta. Volcani Centre. Bet Dagon, Israel, pp.503-506.
- Golan, E. (1963) Low volume spraying as a corrective measure for zinc deficiency in citrus, Fruits d' Outre Mer., 18 : 157-58.
- Goldwebber, S.M.; Bose, M. and Lynch, S.T. (1956) Some effect of nitrogen phosphorus and potassium fertilization on the growth, yield and fruit quality of persian lime. Proc. Fla. Sta. Hort. Sci., 69 : 328-32.
- Gordon Halfcare, R. and John, A. Barden (1979) Horticulture. McGraw Hill Book. Co., pp. 301-16.
- Gupta, O.P. and Nauriyal, J.P. (1972) Seasonal fluctuation in nitrogen content of healthy and declined sweet orange trees. Haryana J. Hort. Sci., 1 : 1-4.
- Hase, Y. and Ishihara, M. (1972) Studies on the potassium nutrition of Satsuma trees. II. The effect of potassium application and fruiting on the growth and nutrient composition of the tree and on fruit quality. Bull. Hort. Res. Sta. A. (Hiratsuka), 11 : 77-102.

- Hayman-Herchberg, Lotte. (1956) A survey of the effect of fertilizing practices on the macro-nutrient composition of citrus leaves in Israel. *Ktavim*, 6 : 17-33.
- Hernandez, J. (1979) Effect of phosphorus, potassium and nitrogen levels on yield, fruit quality and foliar content of Valencia orange trees. *Cultivos tropicales*, 1 : 23-36.
- Hewitt, E.J. (1963) The essential nutrient elements requirements and interactions in plants. Plant Physiology, Vol.III. Ed. by F.C. Steward.
- Hirobe, M. (1981) Experiments with nitrogen fertilizers for Satsuma trees. I. Effects of nitrogen fertilizer rates on growth, yield and fruit quality. *Bull. Kanagawa Hort. Expt. Stn., Japan*, No.28, pp. 1-13.
- Hiroce, R.; Gallo, J.R.; Teofilo Sobrinho, J.; Gaetano, A.A.; Rodriguez, O. and Pompeu Junior, J. (1984) Effect of 27 years of NPK fertilization of leaf macro and micro-nutrient content of Baianinha orange. In *Anais do VII. Congresso Brasileiro de Fruiticultura*. Brazil; Em. presa Catarinense de Fe Quisa Agropecuria S.A., 2 : 603-11.
- Hong, S.D. and Chung, S.K. (1979) Effect of N,P and K fertilizer levels on the growth, yield and fruit quality of Satsuma trees. *Kagawa Daigaku No.Gokna. Gakuayuta Hokoku*, 23 : 172-99.
- Iley, J.R. (1963) Studies on the effect of zinc ethrelerebisaltheocarbonate (Zineb) on citrus seedlings grown in solution cultures and soil on its digradation by sun light and soil micro-action. *Diss. Abstr.*, 24 : 1779.

- Innes, R.E. (1946) Fertilizer experiments on grape fruit in Jamaica, Trop. Agric., Trinidad, 23 : 131-33.
- Intrigliolo, F. (1984) Effect of three nitrogen fertilizers on a orange variety. In Vith International Calloquium for the optimization of plant nutrition. Proc. Vol.3. Montpellier, France, AIONP/GERDAT, pp.983-91.
- Intrigliolo, F.; Scuderi, A. and Raciti, G. (1981) Variations in leaf Mineral content of nucellar Torocco orange trees during the course of a year. Technica Agricola, 33 : 63-79.
- Ishihara, M. (1976) Leaf analysis as a guide to nitrogenous fertilizer application in Satsuma mandarin orange orchards. Japan Agr. Res. Quart., 10 : 74-78.
- Ishihara, M.; Knonno, S.; Yokomizo, H. and Sato, K. (1965) Studies on the boron deficiency and excess in citrus. Part III. Boron application experiment (1) and interaction between calcium and boron. Bull.Hort.Res.Sta., Hiratsuka, No.4, pp.45-66.
- Ishihara, M.; Nishiba, S.; Futal, S.; Sakaguchi, S.; Hashimoto, T.; Yanase, M.; Shibuya, H.; Teraoka, Y.; Hamaoka, S.; Yokomizo, H.; Konno, S. and Takatsuji, T. (1974) Studies on the copper deficiency of citrus. II. The influence of copper containing fungicides on the recovery from the copper deficiency and copper contents of the plants and soils in Satsuma orchards. Bull. Fruit Tree Res. Sta., Hiratsuka, No.1, pp. 33-56.

- Iwagaki, I.; Kawase, K.; Suzuki, K. and Takatsuji, T. (1985) Effect of pruning and fertilization on vegetative growth and fruit quality of Satsuma. Bull. Fruit Tree Res. Sta., Japan, B (Okitsu), No.12, pp.45-59.
- Iwaski, J. and Owada, A. (1960) Studies on the control of alternate bearing in citrus. II. The effect of fertilizing in late autumn on the number of flowers and the growth of shoots. J. Hort. Ass., Japan, 29 : 101-106.
- Jackson, M.L. (1967) Soil chemical analysis. Prentice Hall of India. New Delhi.
- Jones, W.W. and Embleton, T.W. (1967) Yield and fruit quality of Washington Navel orange trees as related to leaf nitrogen and nitrogen fertilization. Proc. Amer. Soc. Hort. Sci., 91 : 138-48.
- Jones, W.W. and Embleton, T.W. (1968) Some guide lines for the use of nitrogen leaf analysis for citrus. Calif. Citrogr., 54 : 4.
- Jones, W.W. and Parkar, E.R. (1949) Effects of nitrogen, phosphorus and potassium fertilizers and organic materials on the composition of Washington Navel orange juice, Proc. Amer. Soc. Hort. Sci., 53 : 91-109.
- Jones, W.W. and Smith, P.F. (1964) Nutritional deficiencies in citrus chap. II. Hunger signs in crops. Divid Mc.Kay Co., New York.
- Jorgensen, K.R. (1978) Leaf and soil analysis - guide to fertilizing citrus, Quinsland Agric. J., 104 : 17-21.

- Kacharva, O.N. (1985) Fertilization system in mandarin plantations. Subtrop. Kul'tury, No.6, pp.45-50.
- / Keilin, D. and Mann, T. (1940) Carbonic anhydrase. Biochem. J., 34 : 1163.
- Kiely, T.B.; Cox, J.E.; Cradock, F.W. and Barkus, B. (1972) Nutrition studies on Valencia oranges. Agril.Gaz. N.S.W., 83 : 20-22.
- Klein, L. and Monselise, S.P. (1962) Effect of urea sprays during winter on growth and nitrogen content of orange spring flush and flowers. Reprinted from 6th Congress Int. Agrumic. Med. Nice, pp. 334-36.
- Kodama, M.; Akamatsu, S.; Bessho, Y.; Owada, A. and Kubo, S. (1977) Effect of nitrogen fertilizing on the composition of Satsuma juice. J. Jap. Soc. Food Sci. Tech., 24 : 398-403.
- Kodua, M.A. (1980) Effect of boron and manganese on mandarin yield and quality of mandarin under clean cultivation, green manure and liming. Subtrop. Kul'tury, 4 : 91-93.
- Koo, R.C.J. (1964) Effect of frequency of irrigations on yield of orange and grape fruit. Proc. Fla.Sta.Hort.Soc., 76 : 1-5.
- Koo, R.C.J. (1980) The influence of N, K and irrigation on tree size and fruit production of 'Valencia' orange. Proc. Fla. Sta. Hort. Soc., 92 : 10-13.
- Koo, R.C.J. and McCornack, A.A. (1965) Effects of irrigation and fertilization on production and quality of Dancy tangerine. Proc. Fla. Sta. Hort. Soc., 78 : 11-15.

- Koo, R.C.J. and Reese, R.L. (1977) Influence of fertility and irrigation treatments on fruit quality of 'Temple' orange. Proc. Fla. Sta. Hort. Soc., 89 : 49-51.
- Koo, R.C.J. and Smajstrla, A.G. (1985) Effect of trickle irrigation and fertilization on fruit production and juice quality of 'Valencia' orange. Proc. Fla. Sta. Hort. Soc., 97 : 8-10.
- Koo, R.C.J.; Young, T.W.; Reese, R.L. and Kesterson, J.W. (1974) Effect of nitrogen, potassium and irrigation on yield and quality of lemon. J. Amer. Soc. Hort. Sci., 99 : 289-91.
- Krishnamurthy, S. and Randhawa, G.S. (1953) Rate of potassium in the nutrition of fruit crop - A review. Indian J. Hort., 16 : 195-82.
- Kuriyama, T.; Shimoosako, M.; Yoshida, M. and Shiraishi, S. (1983) The effect of soil moisture on the fruit quality of Unshiu mandarin (Citrus unshiu marc.). In Proc. Int. Soc. Citriculture, 2 : 524-27.
- Kuznestov, A.V. and Koridge, A.V. (1977) The effect of magnesium on the quality and the amino acid composition of Satsuma. Subtrop. Kul'tury, 56 : 159-61.
- Kuznestov, A.V. and Treshchov, A.G. (1979) Removal of nutrient elements by a mandarin crop under different levels of magnesium nutrition Sbornik Nauchnuikh, Trudov. Unit. Druhty Narodnia Patrisa. Lumcunly, 89 : 68-72.

- Labanauskas, C.K. (1962) Correction of manganese deficiencies in grape fruit trees by foliar sprays in desert areas of southern California. Proc. Amer. Soc. Hort. Sci., 80 : 268-73.
- Labanauskas, C.K. and Puffer, R.E. (1964) Effect of foliar applications of manganese, zinc and urea on Valencia orange yield and foliar composition. Proc. Amer. Soc. Hort. Sci., 84 : 158-64.
- Labanauskas, C.K.; Jones, W.W. and Embleton, T.W. (1962) Effect of nitrogen, phosphorus, potassium, lime stone gypsum and manure soil applications on soil pH and on macro and micro-nutrient concentrations in Washington Navel orange leaves. Proc. Amer. Soc. Hort. Sci., 80 : 259-67.
- Labanauskas, C.K.; Jones, W.W. and Embleton, T.W. (1963) Effect of foliar applications of manganese, zinc and urea on yield and fruit quality of Valencia oranges, and nutrient concentration in leaves, peel and juice. Proc. Amer. Soc. Hort. Sci., 82 : 142-53.
- Latzko, E. (1959) Die Funktion des Kaliums in stoffweehsel der energiereichen phosphate pflanzliche and Kierisher Organismen Arochimica, 3 : 148-64.
- Leyden, R.F. (1963) Chemical composition of grape fruit leaf tissue as influenced by rootstock, variety, cultural practice, fertilizer and season. J. Rio Grande Vally, Hort. Soc., 17 : 72-73.

- Leyden, R.F. (1978) Nitrogen and phosphorus fertilization of Red grape fruit. J. Rio Grande Valley Hort. Soc., 32 : 55-59.
- Lisanti, L.E. and Catalano, M. (1956) The ascorbic acid content of oranges grown in the met apontino district. Effect of fertilizing with ferrous sulphate. Nuovo G. Bot. Ital, 63 : 220-38.
- Lodhi, B.F. and Rashid, A. (1980) Effect of soil application of urea on seasonal variations in total leaf nitrogen of Kinnow mandarin. Pakistan J. Sci., 32 : 57-62.
- Lomtadze, Z.K. (1979) Effect of different nitrogen rates of mandarin yield in the condition of the Kalkhida low land. Subtrop. Kul'tury, No.6, pp.100-104.
- Magnitsi, K.P. and Takidze, R.M. (1972) The interrelationship of ions in mendarin trees nutrition. Subtrop. Kul'tury, 6 : 87-91.
- Majorana, G. (1960) Symptoms of copper deficiency experimentally confirmed on sweet orange and mandarin trees in Catania Province. Teen agric., 12 : 645-61.
- Mani, V.S.; Bhatnagar, M.P. and Asana, R.D. (1959) Zinc sprays help control citrus die-back and chlorosis. Indian Hort., 3 : 20.
- Mann, M.S.; Munshi, S.K.; Bajwa, M.S. and Arora, C.L. (1979) Leaf nutrients in healthy and declining sweet orange trees in punjab orchards. Indian J. Agric. Sci., 43 : 120-25.

- Mann, M.S. and Sidhu, B.S. (1983) Mineral composition of Kinnow leaves as affected by foliar application of zinc and copper. Punjab Hort. J., 23 : 17-20.
- Mann, M.S.; Thakkar, P.N. and Mann, S.S. (1985) Effect of micronutrient sprays on sweet orange (Citrus sinensis L. Osbeck). Proc. III Nat. Citrus Sem., Indian Soc. Citriculture, p.19.
- Millella, A. (1968) Seasonal variations in the nitrogen, phosphorus and potassium contents of sweet orange leaves. Studi. Sassar. Sez III, 16 : 544-56.
- Mitra, S.K.; Ghosh, D. and Bose, T.K. (1985) Response of mandarin orange (Citrus reticulata Blanco) to differential doses of major nutrients. Proc. IIIrd Nat. Citrus Sem. Indian Soc. Citriculture, p. 11.
- Morris, A.A. (1937) The effect of differential fertilizer treatments on the yield and quality of fruit from mature bearing Valencia late trees of Mazoe. Citrus Estate, Southern Rhodesia. Nazoe Citrus Exp. Sta. Rpl., pp. 107-53.
- ✓ Morton, A.Ge and Watson, D.S. (1948) A physiological study of leaf growth. Ann. Botany (London) (N-5), 2 : 281-310.
- Moss, G.I. (1972) The role of potassium in determining fruit quality of sweet orange. Aust.J.Exp. Agric. Anim. Hubs., 12:195-202.
- Mouma, D. and McIntyre, G.A. (1963) A factorial field experiment with Citrus. J. Hort. Sci., 38 : 175-98.

- Nabawy, El, S.M.; Desouky, I.M. and El-Hannawy, H.M. (1975) Effect of nitrogen rate and time of application on fruit set and fruit drop of Washington Navel orange. *Annu. Agric. Sci. Univ., Ain Shams*, 20 : 167-70.
- Nadareishvili, M.YA. (1984) Effect of mineral fertilizers on growth and development of mandarins in Kalkhida low lands. *Subtrop. Kul'tury*, No.3, 66-70.
- Nauriyal, J.P.; Bakshi, J.C. and Dhillon, R.S. (1968) Decline of sweet orange trees in Punjab. *J. Res. P.A.U.*, 5 : 366-77.
- Nijjar, G.S. and Singh, R.A. (1971) Survey of mineral nutrition status of sweet orange orchards in Amritsar district. *Punjab Hort. J.*, 11 : 32-39.
- Njoku, E. (1957) The effect of mineral nutrition and temperature on leaf shape in *Ipomea caerulea*. *New Phytol.*, 56 : 154-71.
- Nokrashy, M.A.; Zorkani, S.E. and Shorleagey, M.A.E. (1977) Effect of different rates of nitrogen fertilization on the growth and yield of Balady orange trees. *Agril.Res.Rev.*, 55 : 39-45.
- ✓ Panse, V.G. and Sukhatme, P.V. (1976) Statistical Methods for Agricultural Workers. Published by I.C.A.R., New Delhi, India.
- Parker, E.R. (1936) Experiment on the treatment of mottle-leaf of citrus trees. *Proc.Amer.Soc.Hort.Sci.*, 33 : 82-86.
- Parker, E.R. (1937) Effect of zinc application on the crop of grapefruit trees affected with mottle leaf. *Hilgardia*, 11:35-53.
- Parker, E.R. and Butcheler, L.D. (1942) Effect of fertilizers on orange yields. *Calif. Agr. Exp. Stat. Bull.*, p. 673.
- Pat, J. and Zafrir, Y. (1963) The effect of nitrogen fertilization on growing of Shamouti orange trees on heavy soil (French). *Fruits d' Outre Mer.*, 18 : 151-52.

- Plessis, S.F. Du (1985) Irrigation of citrus. Citrus and Subtrop. Fruit J., No. 614, pp. 12-14.
- Plessis, S.F. Du and Anderson, T. (1983) Effect of moisture storage on fruit growth of Valencia. Inf. Bull. Citrus and Subtrop. Fruit Res. Inst., No. 134, pp. 5-6.
- Plessis, S.E. Du and Smart, G. (1970) The effect of time of sampling on leaf composition of citrus. S. Afr. Citrus J., No.439, p. 13, 15, 17, 20.
- Plessis, S.F. Du and Smart, G. (1982) Evaluation of magnesium sources for citrus trees. Fruit Res. Inst. S. Africa, No.123, pp.15-19.
- Possingham, J.V. (1956) The effect of mineral nutrition on the content of free amino acids and amides in tomato plants. I.A. Comparison of effects of deficiencies of Cu, Zn, Mn and Mo. Aust. Biol. Sci., 9 : 539-51.
- Prasad, R.N.; Ghosh, S.P.; Verma, A.N.; Ram, P.; Barooah, R.C. and Govind, S. (1981) Nutritional status of mandarin orchards (Citrus reticulata Blanco) in North Eastern Hill of India. Beitrage Zur Tropischem Landirvtschaft and Veteri-normedsin, 19 : 397-403.
- Raciti, G.; Spina, P.; Scuderi, A. and Intrigliolo, F. (1982) Three years of mechanical pruning of citrus in Italy. Frutticoltura 44 : 35-46.
- Randhawa, N.S. (1970) Citrus decline in India, causes and control. Punjab Agricultural University, Punjab, p. 34.

- Randhawa, G.S.; Khanna, R.C. and Jain, N.L. (1964) Seasonal changes in fruits and bearing shoots of grape fruit (C. *paradisi* MacF.). Indian J. Hort., 21 : 21-33.
- Randhawa, G.S. and Kar, P.L. (1967) Seasonal changes in the mineral composition of non-bearing and bearing shoots of mandarin (Citrus *reticulata* Blanco). Indian J. Hort., 24 : 38-39.
- Reed, H.S. and Hass, A.R.C. (1923) Studies on the effect of sodium, potassium and calcium on young orange trees. Univ. Calif. Agric. Expt. Sta. Tech. Pub., 11 : 1-32.
- Reed, M.S. and Parker, E.F. (1937) Effect of zinc on growth, Calif. Citrog., 22 : 411-12.
- Reese, R.L. and Koo, R.C.J. (1974) Responses of 'Hamlin', 'Pineapple' and 'Valencia' orange trees to nitrogen and potash application. Proc. Fla. Sta. Hort. Soc., 87 : 1-5.
- Reese, R.L. and Koo, R.C.J. (1975) Nitrogen and potassium fertilization effects on leaf analysis tree size and yield of the three major Florida orange cultivars. J. Amer. Soc. Hort. Sci., 100 : 195-97.
- Reese, R.L. and Koo, R.C.J. (1976) Influence of fertility and irrigation on yield and leaf and soil analysis of temple orange. Proc. Fla. Sta. Hort. Soc., 89 : 46-48.
- Reuther, W. and Smith, P.F. (1952) Relation of N, K and Mg fertilization to some fruit qualities of Valencia orange. Proc. Amer. Soc. Hort. Sci., 59 : 1-12.
- Reuther, W.; Smith, P.F. and Specht, A.W. (1948) A comparison of the mineral composition of Valencia orange leaves from the major producing areas of the united states. Proc. Fla. Sta. Hort. Soc., 61 : 38-45.

- Rosset, F.; Hefer, S.V.; Helff, K.A.W.; Langeneggr, W. and Lehoux, F.H. (1962) Yield and quality responses of Valencia orange trees to fertilization. S.Afr. J.Agric.Sci., 5 : 351-72.
- Sahota, G.S. and Arora, J.S. (1981) Effect of N and Zn on 'Hamlin' sweet orange (Citrus sinensis Osbeck). J.Jap.Soc.Hort.Sci., 50 : 281-86.
- Sakamoto, T.; Okuchi, S.; Sato, K. and Okamoto, S. (1964) Effect of ten years phosphate fertilization on the content of inorganic macro-elements in Satsuma orange leaves and phosphorus content of the soil. J.Jap.Soc.Hort.Sci., 33 : 204-12.
- Samoladas, T.H. (1964) The effect of micro-elements on the yield and metabolism of the Unshiu mandarin. Citrus unshiu Marc. (Russian). Bot. Zurnal, 49 : 428-32.
- Samoladas, T.H. (1965) Microelements and mandarins. Sadovodestvo No.8, p.36.
- Sato, K. and Ishihara, M. (1964) Effect of nitrogen and potassium application on the growth leaf analysis and fruit bearing of mandarin oranges. Potash Rev. Subj., 24 : 3.
- Sanikidze, A.B. (1981) Effect of hard pruning on the growth, cropping, and fruit quality of aged mandarin trees. Subtrop. Kul'tury, No.1, pp.13-17.
- Shawky, I.; El-Tomi, A. and Nasr, A.F. (1979) Effect of nitrogen fertilization on Navel oranges. Egyptian J. Hort., 6 : 1-12.

- Singh, A.R. and Singh, R.P. (1977) Effect of nitrogen on growth, yield and quality of Nagpur mandarin (Citrus reticulata Blanco). Haryana J. Hort. Sci., 6 : 31-34.
- Singh, M.P. and Agrawal, K.C. (1961) Studies on die-beack in citrus. Indian J. Hort., 18 : 295-301.
- Singh, R. and Mishra, K.K. (1980) Effect of foliar application of micro-nutrients on Kinnow mandarin. Punjab Hort. J., 20 : 143-48.
- Singh, R.L. (1961) Studies on the effect of 3 levels of nitrogen on growth and cropping of mandarins and sweet orange budded on different rootstocks. III. Effect on the fruit set and yield. Hort. Adv., 5 : 179-96.
- Singh, V.P. and Kumar, R. (1983) Micronutrient hunger in crop plants. Farmers and Parliament, 28 : 9-11.
- Sinha, R.B. and Randhawa, G.S. (1961) Seasonal changes in mineral composition of twigs of different growth flushes in sweet orange. Hort. Adv., 5 : 25-38
- Skoog, F. (1940) Relationship between zinc and auxin in growth of higher plants. Amer. J. Bot., 27 : 939.
- Smith, P.F. (1963) Nitrogen in citrus fertilizing, citrus Ind., 44/1, 91/10.
- Smith, P.F. (1955) Relation of boron level to production and fruit quality of grape fruit and oranges. Proc. Fla. Sta. Hort. Soc., 68 : 54-59.
- Smith, P.F. (1964) Effect of K level and substrate lime on growth, fruit quality and nutrition status of Valencia oranges tree. Pl. anal. and fert. Probls., 4 : 332-43.
- Smith, P.F. (1970) A comparison of nitrogen sources and rates of old, high yielding Valencia orange tree in Florida. J. Amer. Soc. Hort. Sci., 95 : 15-17.

Smith, P.F. and Reuther, W. (1951) The response of young Valencia orange trees to different boron supply in sand culture. Plant Physiol., 26 : 110-14.

Smith, P.F. and Reuther, W. (1954) Citrus modification chap.6 in Fruit Nutrition, ed. N.F.Childers, Somerset Press Somerville, New Jersey.

Smith, P.R.; Scudder, G.U. and Andhrucias, J.R. (1968-69) Comparison of nitrogen sources, rates and placement of the performance of pineapple orange trees. Proc. Fla. Sta.Hort.Soc., 81 : 25-29.

Smith, P.F.; Scudder, G.K.Jr. and Harnoiar, G. (1963) Twenty years of differential phosphate application on Pineapple orange. Proc. Fla. Sta. Hort. Soc., 76 : 7-12.

Spencer, W.F. (1959) Phosphorus and growth of citrus tree feeder roots, citrus Mag., 22 : 18-19.

Spencer, W.F. and Wander, I.W. (1960) A composition of magnesium sources in young orange trees. Citrus Ind., 41 : 5-6, 8, 10, 24.

Spencer, W.F. (1963) Phosphorus fertilization of citrus. Univ. Fla. Agric. Exp. Sta. Bull., 653 : 48.

Suzuki, F.T.; Kinpara, M.; Sakaibara and Fukai, N. (1972) Effect of application of phosphate and lime on the growth and fruiting of Satsuma mandarin trees. J. Jap. Soc. Hort. Sci., 41 : 157-64.

- Sujuki, T.; Okamoto, S. and Katagi, S. (1977) Relationship between leaf nitrogen content during the summer and autumn seasons and fruit quality of young Satsuma trees. J. Jap. Soc. Hort. Sci., 45 : 323-28.
- Takatsuji, T. and Ishihara, M. (1980) Studies on the potassium nutrition of Satsuma orange. II. Influence on cold hardiness and leaf composition. Bull. Fruit Res. Sta., No.7, pp.45-62.
- Takidze, R. (1971) The diagnosis of mandarin potassium nutrition. Subtrop. Kul'tury, No.6, pp.52-56.
- Talakvadze, K.B. (1973) The effect of soil and foliar-applied minor elements on mandarin yield. Subtrop. Kul'tury, No.3, pp. 58-60.
- Tavadze, L.E. (1983) Effect of pruning on the separation of closed crowns of mandarin trees, increased productivity and fruit quality improvement. Subtrop. Kul'tury, No.6, pp.95-97.
- Thombesi, L.; Cale, M.T. and Fiorelli, E. (1962) Studies on foliar diagnosis in the mineral nutrition of citrus. Prog. Agric. Bologna, 8 : 1210-25.
- Tomita, E. (1971) Effect of summer application of water and nitrogen on fruit quality and flowering of Satsuma trees. J. Jap. Soc. Hort. Sci., 40 : 225-29.
- Tsotsonava, D.T. and Marshaniya, I. (1973) The effect of long term application of different forms of potassium fertilizers on mandarin trees growth and productivity. Subtrop. Kul'tury, No.3, pp. 39-44.

- Vander Plank, J.E. and Turner, F.A.S. (1936) Are our sour oranges due to lack of phosphorus? *Fag. S.Afr.*, pp. 59-60.
- Vieira, D.B. (1985) Importance of citrus irrigation. In *Proc. Inst. Symp. Citrus productivity. Jaboticabal, Brazil. UNESP., FeL/UNI CAMP, Limeira, SP, Brazil*, pp.22-29.
- Wadleigh, C.H. (1957) Growth of plants in soil. Year book of Agriculture. U.S.D.A., Washington.
- Wallihan, E.F. and Embleton, T.W. (1968) Progress with iron sprays for citrus. *Calif. Citrog.*, 53 : 462-66.
- Wallihan, E.F. and Garber, M.J. (1966) How much iron is enough? *Calif. Citrog.*, 51 : 450-59.
- Weir, R.G.; Bevinpton, K.B.; Duncan, J.H. and Cradock, F.W. (1978). The effect of phosphorus on fruit quality, leaf analysis and yield of Valencia oranges. *Proc. Int. Soc. Citriculture, Australia*, pp. 292-95.
- Willslattes, R. (1906) Zur Kenntniss der Zusammen Setzung des chlorophyls. *Ann. Chem.*, 350 : 48-82.
- Young, T.W. and Koo, R.C.J. (1973) Effects of nitrogen, potassium and magnesium fertilization on Persian lime in sandy loam soil. *Proc. Fla. Sta. Hort. Soc.*, 86 : 322-26.
- Yusufi, G.I. and Gulov, S.M. (1985) Characteristics of the water regime on different citrus crops. *Subtrop.Kul'tury*, No.2, pp. 132-39.
- Zargoza Adriaensens, S. and Alonso Cabo, E. (1981) Frequency of manual pruning of citrus (First Result). *Anales de Instituto Nacional de Inuestigaciones Agrarias*, No.15, pp. 133-42.