GROWTH OF SEEDLINGS OF TRIFOLIATE ORANGE (*Poncirus trifoliata* (L) Rafinesque) AND RANGPUR LIME (*Citrus limonia* Osbeck) AS INFLUENCED BY PHOTOPERIOD AND CERTAIN GROWTH REGULATORS

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BANGALORE

1979

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Thesis submitted to the
University of Agricultural Sciences, Bangalore,
in partial fulfilment of the requirements for
the degree of

MASTER OF SCIENCE (AGRICULTURE)

in

HORTICULTURE

Bangalore October 1979

DIVISION OF HORTICULTURE
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BANGALORE

CERTIFICATE

This is to certify that the thesis entitled "GROWTH OF SEEDLINGS OF TRIFOLIATE ORANGE (Poncirus trifoliata (L) Rafinesque) AND RANGPUR LIME (Citrus limonia Osbeck) AS INFLUENCED BY PHOTOPERIOD AND CERTAIN GROWTH REGULATORS" submitted by Mr.M.M.GANAPATHY for the degree of MASTER OF SCIENCE (AGRICULTURE) in HORTICULTURE of the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

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ACKNOWLEDGEMENT

It is my proud privilege to express my gratitude to Dr.U.V.Sulladmath, Chairman of my Advisory Committee, Professor and Head of the Division of Horticulture, University of Agricultural Sciences, Bangalore, for suggesting the problem, guidance, abiding interest and critical perusal of the manuscript.

I am deeply indebted to Dr.K.C.Srivastava, Senior Scientist (Hort) and Head, Citrus Experiment Station, Gonicoppal and Member of my Advisory Committee for providing all facilities, keen interest and guidance throughout the course of the study and for critical appraisal of the manuscript.

I owe a debt of gratitude to Dr.K.S.Krishna Sastry, Professor of Crop Physiology, Dr.N.Sundararaj, Professor of Statistics, Members of my Advisory Committee, for their valuable suggestions and guidance during the course of these investigations.

I express my sincere gratitude to Dr.B.C.Uthaiah for his guidance and encouragement all along.

I am grateful to Dr.G.S.Randhawa, Director, Indian Institute of Horticultural Research, Bangalore, for sponsoring my candidature for higher studies.

My thanks are also due to Mr.V.R.Srinivasan, Mr.K.S. Shamasundaran and Mr.P.Jagadeesan for their help in statistical analysis. I am also thankful to all my colleagues and friends who have helped me during the course of my work and preparation of this manuscript.

Lastly, I am indebted to my family members who encouraged me to pursue my higher studies.

Bangalore,
October 8 , 1979

(M.M.Ganapathy)

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INTRODUCTION

CHAPTER I

INTRODUCTION

Citrus fruits occupy a prominent place among the fruits cultivated in our country, occupying an area of about 1,05,396 hectares with an estimated total production of 1.2 million tonnes of fruits. They rank next to mango and banana. The fruits are attractive, juicy and are rich sources of essential health promoting ingredients like vitamins, minerals, sugars, acids and salts. They also possess certain medicinal values.

During the last two decades the area and production of citrus have declined considerably due to the advent of the malady referred to as 'die-back' or 'decline'. It is a complex disease involving several factors. The factor or factors involved may not be the same in all the regions. Studies carried out in citrus growing areas of the world to tackle this problem have at best helped in identifying several factors contributing to this malady. Among the several diseases, gummosis, stump rot and root rot caused by *Phytophthora* species are of major concern when mandarins and sweet oranges are raised from seedlings.

Success or failure in the cultivation of citrus fruits is largely attributable to selection of the right kind of root stock for a given soil type or for a particular variety. Rootstocks impart resistance in varying degree to virus and fungal diseases, salts and frosts, apart from their favourable influence such as adaptability, precocity, quality of fruits and production. The performance of the scion is dependent upon the choice of rootstock to a large extent.

Rootstock trials conducted in different citrus growing countries have shown that Poncirus trifoliata is one of the most promising rootstocks for several citrus species and varieties. It has been reported from several countries that trifoliate orange selections such as Texas, Barnes, U.S.D.A. and Argentina are most tolerant to Phytophthora citrophthora and Phytophthora parasitica. It is also tolerant to tristeza and most other virus diseases besides being cold hardy. In addition to good yield of quality fruits it is a dwarfing rootstock enabling easier cultural practices and harvesting. Another most popular rootstock now being recommended and used widely is Rangpur lime (Citrus limonia). Since the most serious demerit of this rootstock is its high susceptibility to exocortis, Trifoliate orange seems to be the best alternative rootstock.

However, the main drawback with trifoliate orange is its extremely slow growth in the nursery. The trifoliate orange seedlings require usually 22-24 months or more to attain the girth suitable for budding. Because of this limitation it has not been possible to use this rootstock commercially. Normally it takes nearly 2 to 3 years for a citrus budding on this rootstock to be ready for field planting. Hence studies were undertaken with the main objective of accelerating the growth of trifoliate orange seedlings through manipulation of photoperiods and use of gibberellic acid.

The responses of trifoliate orange were compared with those of Rangpur lime which happens to be the most widely used rootstock in recent times in our country.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Among various citrus rootstocks, trifoliate orange (Poncirus trifoliate (L) Rafinesque) and Rangpur lime (Citrus limonia Osbeck) are considered as highly promising (Singh, 1969; Phillips, 1969; Chadha, 1970; Cameron et al., 1972; Bakhshi et al., 1973; Aiyappa et al., 1974; Hearn et al., 1974; Bhullar and Nauriyal, 1975; Anonymous, 1975). The slow growth of trifoliate orange in the nursery is the main drawback for its use as a rootstock commercially. Attempts have been made to accelerate growth and improve the thickness of stem by manipulating photoperiod and use of certain growth regulators. Some of the important relevant findings relating to the use of gibberellic acid and growth retardants and manipulation of photoperiod in order to bring about desired growth in plants are reviewed hereunder.

2.1. Photoperiod and plant growth

Significant increase in seedling growth under extended photoperiod has been reported in grape fruit. Khol (1960) increased the growth of grape fruit seedlings by using low intensity night light to supplement eight hour day light compared with day light alone. Warner and Worku (1966) also obtained similar increase in growth rate of trifoliate orange seedlings under extended photoperiod. Nine-fold increase in the growth rate was recorded by providing supplementary incandescent light during dark as compared to control. However, they failed to increase the stem diameter with increased light. The growth of the trifoliate orange seedling was most favourably influenced under extended photoperiod as compared to that of Cleopatra mandarin, rough lemon, sweet orange and Troyer citrange.

Warner (1971) observed increase in shoot growth of trifoliate orange and Cleopatra mandarin seedlings under 16 hours photoperiod as compared to eight hours. Similar increase in growth of trifoliate orange with 16 hours photoperiod when compared to 8 hour photoperiod was reported by Stathakopoulous and Erickson (1966). Fedorov (1974) reported 7 to 10 times growth in apple, pears, plums, sour cherry, red and black currants, goose berries and raspberries under extended photoperiod as compared to one or two growth peaks in control. Ribanje (1974) observed favourable effect of increased day length on twig elongation, number of leaves and internodal length of tea bush. Increase in petiole length, epidermal and parenchyma cell length, cell number of xylem rows and size of leaf lamina have been noted in two cultivars of strawberries (Pathak and Singh, 1978).

2.2. Gibberellic acid and plant height

Several workers have reported increase in height of citrus seedlings due to application of gibberellic acid (Singh *et al.*, 1959; Srivastava and Singh, 1969; Kumar, 1971).

Randhawa and Singh (1959) observed increase in the height of citrus lemon seedlings due to foliar application of 10 to 100 ppm gibberellic acid. The maximum increase in height (71.4%) was recorded with 100 ppm of gibberellic acid.

Monselise and Halevy (1960) used 50, 100, 200, 400, 800, 1600 ppm of gibberellic acid as foliar application on 6 months old sweet lime seedlings. In all treatments they observed increase in shoot length over control. Ahmed and Khan (1964) treated eight months old rough lemon seedlings with 100 to 200 ppm of gibberellic acid and found that maximum increase in height at 100 ppm gibberellic acid (100%) as compared to control (40%). Bhambota and Kaul (1966) observed significant increase in height of two varieties of Rough lemon seedlings when sprayed with higher concentrations of gibberellic acid. The increase in height with 150 ppm gibberellic acid was 168.53 per cent over control. Shant and Rao (1973) recorded gradual increase in height of *Citrus aurantifolia* seedlings with increase in concentrations of gibberellic acid upto 300 ppm. At the highest concentration, the increase in height was 183 per cent. Further increase in the concentration of gibberellic acid resulted in long and narrow leaves.

2.3. Gibberellic acid and stem girth

Ahmed and Khan (1964) recorded increase in stem girth due to application of 10 and 25 ppm gibberellic acid. In contrast, Nishiura and Iba (1964) reported decrease in trunk girth of citrus plants treated with 10, 50, 100 ppm of gibberellic acid. Bhambota and Keul (1966) studied the effect of gibberellic acid on stem girth of Rough lemon seedlings. The studies revealed that two application of gibberellic acid at 50, 100 and 150 ppm significantly increased the stem girth. The maximum increase over control was 34.68 per cent due to gibberellic acid at 150 ppm.

Increase in girth of acid lime seedlings by foliar application of gibberellic acid at 300 ppm has been recorded (Shant and Rao, 1973). However, Randhawa and Iwata (1963) have shown significant decrease in terminal girth of citrus when treated with gibberellic acid as compared to control. The decrease in girth was proportional to the elongation of the internodes. Kumar (1971) recorded increase in girth in Citrus aurantifolia treated with gibberellic acid in the beginning but he failed to record any significant difference as compared to control in the final observations.

2.4. Gibberellic acid and internodal number and length

The effect of gibberellic acid on internodal number and length in Citrus aurantifolia was studied and the results showed significant response in the beginning but the effect of gibberellic acid was not persistent. In the final observations there was no significant difference between the treatments and control (Kumar, 1971).

Panda and Purohit (1965) studied the effect of gibberellic acid on internodal growth of forest plants and they have reported that the effect of gibberellic acid on the extension of individual internodes depends on the concentration, position of internode and time of application. The number of internodes showing stimulated growth was more in plants treated with higher concentrations of gibberellic acid and higher concentrations induced extension of lower internodes which had stopped elongation much earlier.

2.5. Gibberellic acid and leaf number

Randhawa and Iwata (1963) applied gibberellic acid to four months old citrus seedlings and found that gibberellic acid at 400 ppm increased the number of leaves to maximum extent. Bhambota and Kaul (1966) studied the effect of gibberellic acid on number of leaves in citrus seedlings and noted maximum number of leaves at 100 ppm, and at higher concentrations the number of leaves per plant was reduced. However, Monselise and Halvey (1960) failed to notice any significant difference in number of leaves in the citrus plants treated with gibberellic acid.

2.6. Plant growth and retardants

It is generally accepted that the application of Cycocel (2-chloroethyl trimethyl ammonium chloride) and Alar (succinic acid 2-2 dimethyl hydrazide) retards plant growth and increases the stem girth (Wittwer and Tolbert, 1960; Jerie and Taylor, 1971; Modlibowska, 1971; Singh and Sharma, 1973).

Pieringer and Newhall (1970) studied the growth retarding activity of four quarternary ammonium derivatives by the application of foliar sprays on grape fruit seedlings. Alar in some cases was moderately effective as a growth retardant and in others it was inactive or somewhat active as growth stimulant. The heptyl derivative at 3000 and 6000 ppm was effective in reducing the growth of 3 year old lemon trees for a relatively short period, but a 1000 ppm application appeared to stimulate growth both of lemon trees and grape fruit seedlings.

Ryugo and Sansavini (1972) recorded increase in diameter in young sweet cherry due to application of Alar. Husabo (1972) concluded that Alar at 0.2 per cent or Cycocel at 0.75, 0.5 or 0.25 per cent was most effective growth retardant for shortening shoot and internodes of pear trees. Garg and Singh (1976) opined that Cycocel at 250, 500, 750 ppm effectively reduced height and strengthened the stem of cape gooseberry plant.

Seth and Singh (1976) found that Alar and Cycocel suppressed the vegetative growth and internodal distance in 3-4 year old Red Delicious apple seedlings. Bist and Kaul (1977) observed reduced shoot growth in sub-tropical peach trees by application of 1000 ppm and 2000 ppm of Alar. Similar suppression of shoot growth and increase in shoot thickness due to Alar application in apple and pear has also been reported (Grauslund, 1976; Teskey and Rajput, 1977).

2.7. Plant growth as influenced by photoperiod, gibberellic acid and growth retardants

Karnatz (1973) studied the effect of gibberellic acid and photoperiod on the growth of Black currant (*Ribus nigrum*) seedlings. Black currant seedlings grown under day length of 8 to 12 hours were very dwarf in habit as compared with those grown under day length of 16 or 20 hours. Weekly sprays of 250 ppm of gibberellic acid were ineffective in promoting appreciable elongation of the main stem in short days, although they strongly increased lateral branching. Under long day conditions gibberellic acid had little effect on elongation growth or branching. Shanmugam and Muthuswamy (1973) studied the changes in the nutrient status due to the photoperiod and growth regulator in the leaves of two chrysanthamum varieties and observed higher level of nitrogen, potassium and calcium during their vegetative phase.

Pathak and Singh (1978) studied the effect of gibberellic acid and photoperiod on the anatomy of petiole and leaf lamina in strawberry plant. Gibberellic acid treatment and prolonged light exposure increased the petiole length, parenchyma cell length and cell number. Short days with gibberellic acid showed greater response in older leaves whereas continuous long day was more effective in the first leaf.

2.8. Leaf analysis

Lewis and Hull (1960) recorded significant increase in the foliar nitrogen content in one year old Montmorency cherry trees due to foliar application of gibberellic acid at 100, 500 and 1000 ppm. However, gibberellic acid treatment did not alter the percentage of phosphorus and potassium in cherry trees. Salah (1960) failed to record any change in the nitrogen content of the apple seedlings treated with single application of gibberellic acid, but the leaves from the plants which received second and third application of gibberellic acid showed less nitrogen than seedlings not treated with gibberellic acid. Shant and Rao (1973) opined that increase in concentration of gibberellic acid decreased nitrogen, phosphorus and potassium in the shoots of Citrus aurantifolia seedlings.

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

The present investigations on acceleration of growth in nursery stage of two citrus rootstocks trifoliate orange (*Poncirus trifoliata* (L) Rafinesque) and Rangpur lime (*Citrus limonia* Osbeck) were conducted during the year 1977-78 at the Citrus Experiment Station, Gonicoppal, Kodagu, Karnataka. The Experiment Station is situated at an altitude of 950 M from the mean sea level. The average rainfall of the area is about 1800 mm which is evenly distributed over a period of 6 months from May to October. The mean maximum temperature seldom goes above 36°C and the mean minimum temperature rarely goes below 15°C. The humidity generally fluctuates between 80 and 90 per cent. The meteorological observations recorded at the Citrus Experiment Station, Gonicoppal are presented in Appendix 1.

The details of the material used and the methods followed in carrying out the experiment are given below.

3.1. Selection of mother trees

Fifteen year old healthy and vigorous trifoliate orange and Rangpur lime trees were selected as mother trees.

3.2. Selection of fruits and seed extraction

Fruits of uniform colour and size were selected from a single trifoliate orange plant and seeds were extracted by making a shallow cut through the rind around the centre and twisting the two halves of the fruit apart. The seeds were then squeezed into a sieve and washed several times till they were free from pulp and mucilage. The moisture was removed by spreading the seeds on a cloth in a shady place. The following day the seeds were treated with a fungicide (Benlate) and stored in a polythene bag. The same procedure was adopted for collecting the Rangpur lime seeds.

3.3. Preparation of seed bed

Raised seed beds of 180 cm length, 90 cm width and 25 cm height were prepared. Sieved river sand was spread evenly to form a 7-10 cm thick layer over the raised seed bed of 25 cm height. Ten days prior to sowing the beds were treated with 0.1 per cent Benlate. Dusting with BHC was done periodically around the beds to keep away the ants.

3.4. Sowing of seed

Fresh seeds were sown within 2-3 days after extraction. They were sown in lines 2.5 cm apart with a spacing of 1.5 cm between the seeds. After sowing the seed bed was covered with a 2 cm layer of clean river sand. Regular watering and plant protection measures were attended to. Periodical observations on germination were recorded.

3.5. Preparation of secondary bed

In this experiment, polythene bags of 200 gauge of size 30 x 13.5 cm were used. The bags were punched to have 12 vents and were filled with 5 kg soil compost prepared by mixing jungle soil and sand in the proportion of 5:1.

3.6. Transplanting of seedlings

The trifoliate orange and Rangpur lime are polyembryonic in nature and hence one seed may give rise to 2-3 seedlings. Two months old trifoliate orange and Rangpur lime seedlings were transplanted in polythene bags. Uniform seedlings free from diseases and insect pests were selected and those with diseased or deformed roots were discarded. The seedlings which were markedly smaller than average were eliminated as also seedlings markedly larger than average and showing abnormal foliage characters.

The following two experiments were carried out.

3.7. Experiment I

To study the effects of photoperiod and gibberellic acid (GA_3) on the growth of trifoliate orange and Rangpur lime seedlings, this experiment was carried out.

The details of the experiment were as under.

3.7.1. Design : Split split plot design.

3.7.2. Main plot treatments

Three levels of photoperiod:

i. 12 hours photoperiod (Control) i.e., 12 hours light and 12 hours dark

ii. 16 hours photoperiod (L_1) i.e., 16 hours light and 8 hours dark

iii. 20 hours photoperiod (L_2) i.e., 20 hours light and 4 hours dark

3.7.3. Sub-plot treatments

Two rootstock species:

i. Trifoliate orange (V_1)

ii. Rangpur lime (V_2)

3.7.4. Sub-sub plot treatments

Four concentrations of gibberellic acid:

i. GA at 0 ppm (G_0)

ii. GA at 100 ppm (G_1)

iii. GA at 200 ppm (G_2)

iv. GA at 300 ppm (G_3)

Treatment combinations	..	24
Number of seedlings per plot	..	10
Replications	..	4
Total number of experimental plants	..	480 each of trifoliate orange and Rangpur lime.

The required photoperiod was provided by using 16 numbers of 1.2 M long fluorescent tube lights of 40 W. The tube lights were suspended 0.9 M above the top of the plants for the duration of the experiment.

The gibberellic acid (GA_3) spray was given to trifoliate orange and Rangpur lime at concentrations of 0, 100, 200 and 300 ppm starting from 45 days after transplanting. The second spray was given 60 days thereafter. Two grams of fertilizer mixture per plant was applied 45 days after transplanting and before the growth regulator treatments were superimposed. After 60 days of application of growth regulators a second dose of 3 g of the mixture was applied. The fertilizer mixture was prepared by mixing together calcium ammonium nitrate, single super phosphate and muriate of potash in the proportions of 1:1 ½ so that 5 g of the mixture could supply 0.45 g N, 0.35 g each of P_2O_5 and K_2O per plant.

3.8. Experiment II

The study was conducted to find out the effect of alar, cycocel and pinching on the growth of trifoliate orange and Rangpur lime seedlings when they had attained sufficient height. The trifoliate orange and Rangpur lime seedlings sprayed with 100 ppm GA_3 in the first experiment were used. The first treatment was given after the final observations of the first experiment and the second treatment one month thereafter.

3.8.1. Design: Randomised block design.

3.8.2. Treatments: Eight treatments as below:

i. Alar 1000 ppm

ii. Alar 500 ppm

iii. Alar 250 ppm

iv. CCC 1000 ppm

v. CCC 500 ppm

vi. CCC 250 ppm

vii. Pinching the growing shoot

viii. GA at 100 ppm (Control)

Number of seedlings per plot	..	5
Replications	..	4
Total number of experimental plants	..	160 each of trifoliate orange and Rangpur lime

3.9. Observations

The following observations were recorded at 60 days interval after the foliar application of growth regulators in the first experiment.

In the second experiment observations were recorded after 30 days of the differential treatment.

3.9.1. Plant height

The plant height (cm) was measured from the collar (level of soil surface) to the growing tip of the plant. A permanent marking with paint was made at the collar.

3.9.2. Plant girth

The plant girth (cm) was measured at 1 cm above the soil surface. A permanent mark with paint was made at that point to facilitate subsequent measurements.

3.9.3. Internodal length

The third internode from the bud tip was selected for recording internode length every time. The length between the nodes was taken as internodal length (cm).

3.9.4. Number of nodes per plant

The number of nodes from base of the plant was counted at the time of observation.

3.9.5. Number of leaves per plant

The number of fully opened leaves observed in the plant at the time of counting was recorded.

3.10. Leaf sampling

The leaves were collected 30 days after the second spray of gibberellic acid. About five months old leaves with petiole were sampled for leaf analysis from each plant as suggested by Chapman (1960). The samples were immediately dried, powdered and preserved for further chemical analysis. The dried and powdered samples were utilized for estimation of nitrogen, phosphorus and potassium. The experimental data (Experiment I) was analysed by adopting the split split plot design (Sundararaj *et al.*, 1972).

3.11. Estimation of elements

The nitrogen content of leaves was estimated by adopting Kjeldhal method (Loomis and Shull, 1937). Phosphorus was estimated by sulphonic acid method and potash by Flame Photometer (Chapman and Pratt, 1961).

3.12. Experiment III

This study was conducted to find out the influence of different growth regulators and pinching on bud take in trifoliate orange and Rangpur lime seedlings.

The trifoliate orange and Rangpur lime seedlings were budded by 'Forkert' method when they attained suitable size (0.5 to 0.6 cm girth). The design, treatments and replications were the same as in Experiment II.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

The observations and data recorded on various characters as influenced by different treatments were subjected to statistical analyses and the results are presented under the following headings.

4.1. Experiment I

Effects of photoperiod and gibberellic acid on the growth of trifoliate orange and Rangpur lime seedlings

4.1.1. Plant height

From the statistical analysis of the data presented in Table 1, it is evident that plant height significantly increased with 16 hours photoperiod while it decreased significantly with 20 hours photoperiod. At 60 days after treatment the decrease in height with 20 hours photoperiod was considerable as compared to normal day length. At 120 days after treatment, the height significantly increased with 16 hours photoperiod as compared to normal day length and 20 hours photoperiod. There was no significant difference with 20 hours photoperiod as compared to normal day length.

The height of trifoliate orange seedlings at 60 days and 120 days after treatment was significantly less than that of Rangpur lime seedlings. Treatment with gibberellic acid

Table 1. Effect of photoperiod and gibberellic acid on height (cm) of trifoliate orange and Rangpur lime seedlings at 60 days and 120 days after treatment

Light		L_0			L_1			L_2			Mean values for varieties		Average G	S.E. for main treatment and interaction S.E.		C.D. at 5%
Variety		V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2				
60 days after treatment																
Growth regulator	G_0	10.1850	10.6250	10.4050	10.9475	13.7025	12.3250	13.5550	11.7450	12.0242	11.5626	12.0242	11.7933	L	0.2147	0.7428
	G_1	19.1375	19.2000	19.1688	19.1688	17.8225	18.4500	12.3900	12.4400	12.4150	16.4500	16.9058	16.6779	G	0.2267	0.6430
	G_2	12.1600	16.1250	14.1425	18.8125	18.5175	18.6650	11.7725	14.0750	12.9238	14.2483	16.2392	15.2437	V	0.2021	0.6463
	G_3	17.2275	17.9450	17.5863	17.1125	17.6025	17.3575	10.4750	11.8750	11.1750	14.9375	15.8075	15.3729	LV	0.3500	1.1194
														LG	0.3926	1.4839
														VG	0.3205	0.9093
														LVG	0.5552	1.5750
Mean		14.6775	15.9738		16.1738	17.2250		12.0481	12.5338							
Average L		15.3256			16.6994			12.2909								
Average V		V_1= 14.2997			V_2= 15.2441											
120 days after treatment																
	G_0	37.9375	44.1825	41.0600	47.3125	47.9325	47.6225	54.4375	46.0525	50.2450	46.5625	46.0558	46.3108	L	0.3901	1.3500
	G_1	54.7500	62.8750	58.8125	61.3125	63.7500	62.5313	50.0625	49.6875	49.8750	55.3750	58.7708	57.0729	G	0.6305	1.7889
	G_2	37.6250	58.5000	48.0625	64.0000	58.6875	61.3438	48.4375	55.2500	51.8438	50.0208	57.4792	53.7500	V	0.5716	1.8282
	G_3	46.1250	54.5000	50.3125	62.9250	59.6250	61.2750	47.0000	53.8750	50.4375	52.0167	56.0000	54.0083	LV	0.9900	3.1666
														LG	1.0922	3.0985
														VG	0.8918	2.5300
														LVG	1.5446	4.3820
Mean		44.1094	55.0144		58.8875	57.4988		49.9844	51.2163							
Average L		49.5625			58.1937			50.6003								
Average V		V_1 = 50.9937			V_2= 54.5772											

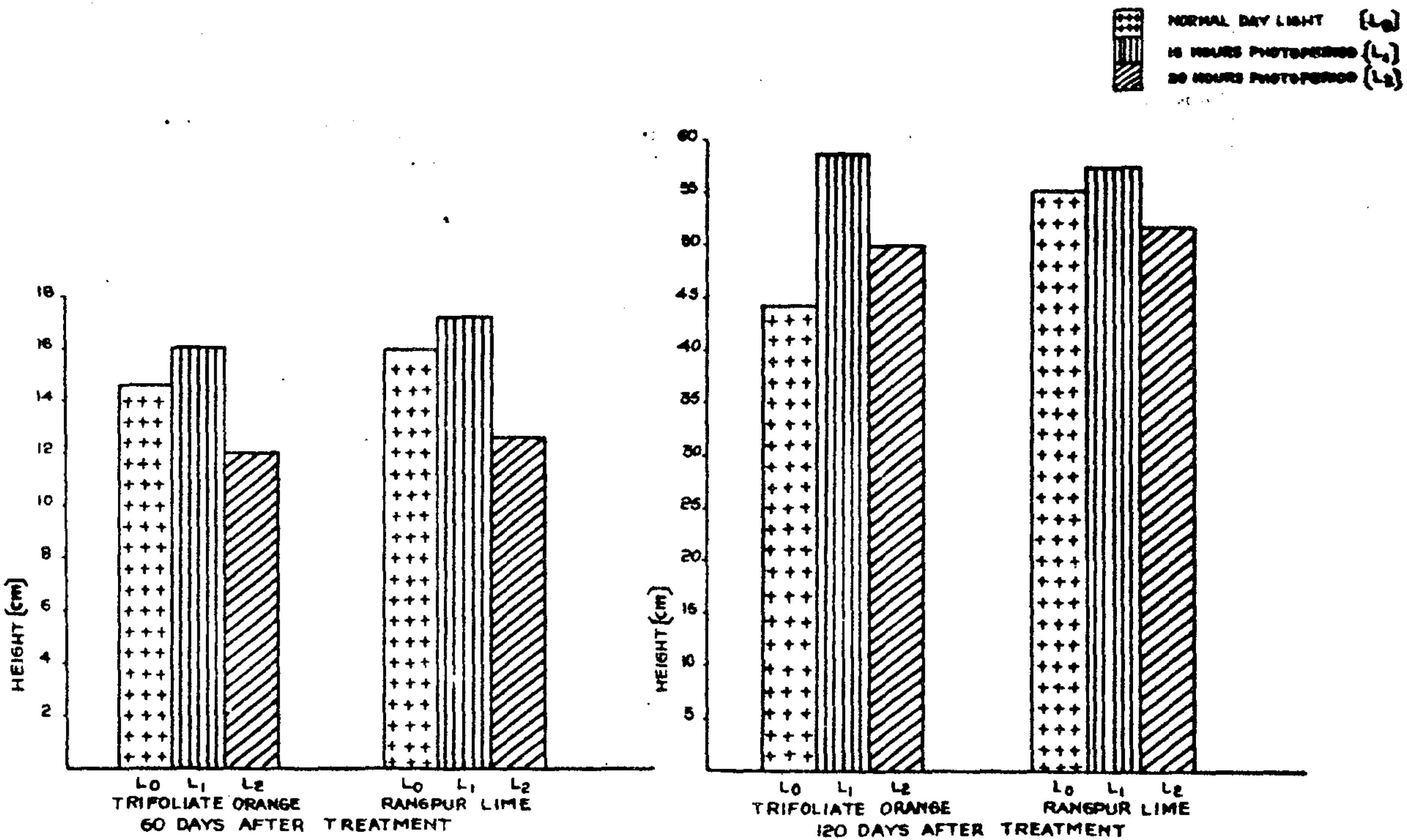

Fig 1. EFFECT OF PHOTOPERIOD ON GROWTH (Height) OF TRIFOLIATE ORANGE & RANGPUR LIME SEEDLINGS

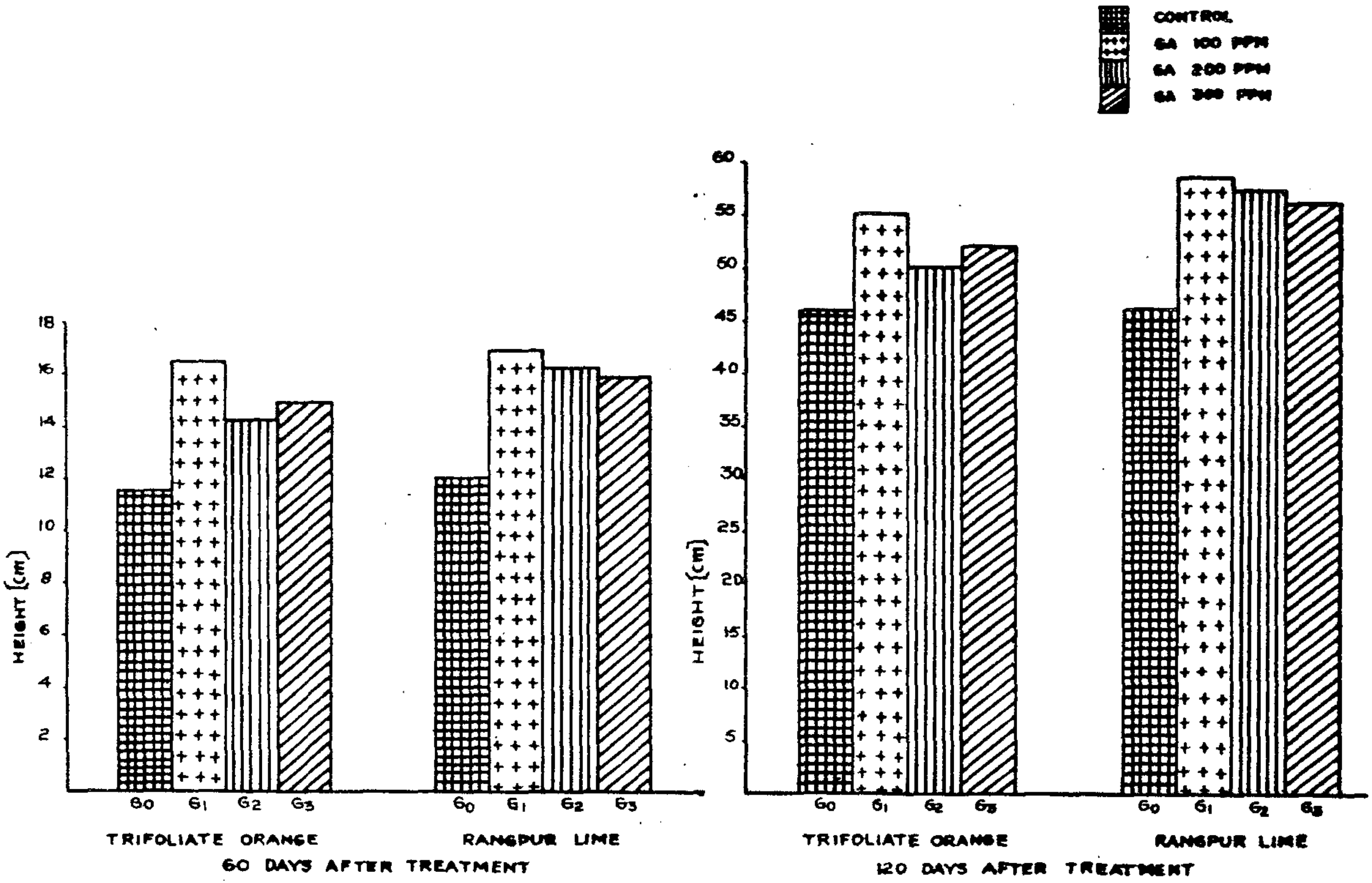

Fig 2. EFFECT OF GIBBERELLIC ACID ON GROWTH (Height) OF TRIFOLIATE ORANGE AND RANGPUR LIME SEEDLINGS

Plate 1. Growth of Trifoliate orange seedlings as influenced by gibberellic acid and photoperiod (16 hours light and 8 hours dark)

1. GA at 0 ppm
2. GA at 100 ppm
3. GA at 200 ppm
4. GA at 300 ppm

60 days after treatment

120 days after treatment

Plate 1

Plate 2. Growth of Rangpur lime seedlings as influenced by gibberellic acid and photoperiod (16 hours light and 8 hours dark)

1. GA at 0 ppm

2. GA at 100 ppm

3. GA at 200 ppm

4. GA at 300 ppm

60 days after treatment

120 days after treatment

Plate 2

Plate 3. Lighting arrangements for providing different photoperiods.

at 100 ppm resulted in significantly more height than at all the other concentrations as well as control both at 60 and 120 days after treatment. The height tended to increase at 100 ppm and decrease at higher concentrations. In general, treatment with GA resulted in increased height as compared to no treatment (control).

The effects due to interactions of light treatment and gibberellic acid treatment on height were highly significant at both 60 days and 120 days periods, whereas there was no significant interaction between the two rootstock varieties and gibberellic acid treatment, after 60 days. Also interaction effects of all the three factors (light, gibberellic acid and varieties) were highly significant at 60 days and 120 days after treatment.

4.1.2. Girth of seedling

It is evident from Table 2 that with 16 hours photoperiod there was no significant effect on girth but at longer photoperiod (20 hours) the girth was significantly less at 60 days after treatment. Similar trend was noticed at 120 days after treatment.

The stem thickness of Rangpur lime seedlings was significantly more than that of trifoliate orange at both 60 and 120 days after treatment. There was not much difference in diameter of the two rootstocks after 120 days of treatment.

Table 2. Effect of photoperiod and gibberellic acid on the girth (cm) of trifoliate orange and Rangpur lime seedlings at 60 days and 120 days after treatment

Light		L_0			L_1			L_2			Mean values for varieties		Average G	S.E. for main treatment and interaction		C.D. at 5%
Variety		V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	G		S.E.	
								60 days after treatment								
Growth regulator	G_0	0.2400	0.3000	0.2700	0.2650	0.2800	0.2725	0.2450	0.2475	0.2463	0.2500	0.2758	0.2629	L	0.005504	0.01917
	G_1	0.3075	0.3175	0.3125	0.2950	0.3025	0.2988	0.2225	0.2500	0.2363	0.2750	0.2900	0.2825	G	0.006196	0.01757
	G_2	0.2250	0.2875	0.2563	0.2875	0.3050	0.2963	0.2200	0.2750	0.2475	0.2442	0.2892	0.2666	V	0.004846	0.15500
	G_3	0.2850	0.2975	0.2913	0.2675	0.3050	0.2863	0.2050	0.2600	0.2325	0.2525	0.2875	0.2866	LV	0.008394	0.02684
														LG	0.010732	0.03044
														VG	0.008762	0.02486
														LVG	0.015177	0.04306
Mean		0.2644	0.3006		0.2788	0.2981		0.2231	0.2581							
Average L		0.2825			0.3009			0.2406								
Average V		V_1 = 0.2637			V_2 = 0.2856											
								120 days after treatment								
	G_0	0.5200	0.6450	0.5825	0.4725	0.6025	0.5375	0.4900	0.5275	0.5088	0.4942	0.5917	0.5429	L	0.004190	0.01450
	G_1	0.5925	0.7125	0.6525	0.5275	0.7025	0.6150	0.4750	0.5575	0.5163	0.5317	0.6575	0.5946	G	0.005660	0.0160
	G_2	0.4600	0.6850	0.5725	0.5450	0.6800	0.6125	0.4550	0.6050	0.5300	0.4867	0.6567	0.5716	V	0.003550	0.0113
	G_3	0.5600	0.6400	0.6000	0.5475	0.6950	0.6213	0.4400	0.5850	0.5125	0.5125	0.6400	0.5779	LV	0.006164	0.0197
														LG	0.009806	0.0278
														VG	0.008007	0.0227
														LVG	0.013868	0.0392
Mean		0.5331	0.6706		0.5231	0.6700		0.4650	0.5688							
Average L		0.6019			0.5966			0.5169								
Average V		V_1 = 0.5071			V_2 = 0.6365											

While there was no notable increase in thickness with gibberellic acid treatments at 60 days after treatment, at 120 days after gibberellic acid treatment the increase in thickness was significantly more. The highest significant increase was with gibberellic acid at 100 ppm. At higher concentrations, the increase in diameter was comparatively less.

There was no response to two factor and three factor interactions at 60 days after treatment (Table 2). However, highly significant differences were noticed due to two factor and three factor interactions at 120 days after the treatment. The combination L_0G_1 (normal day light and 100 ppm GA) and L_1G_1 (16 hours photoperiod and 100 ppm GA) resulted in significantly increased thickness than L_0G_2 (normal day light and 200 ppm GA) and L_2 (20 hours photoperiod) at all the concentration of GA, at both 60 and 120 days after treatment. The results showed beneficial effect of gibberellic acid at 100 ppm on girth of seedlings with normal day light and 16 hours photoperiod. Irrespective of gibberellic acid treatments, with longer photoperiod the thickness of stem was significantly less than that due to the interaction of standard day length and 16 hours photoperiod with gibberellic acid treatments at 120 days after treatment. Also, both the varieties recorded less diameter with longer photoperiod (20 hours). In Rangpur lime seedlings all the gibberellic acid concentrations significantly increased the stem thickness as compared to no gibberellic acid at 120 days after treatment. With trifoliate orange seedlings significant increase in diameter was recorded with gibberellic acid at 100 ppm.

4.1.3. Number of leaves per plant

Data on the number of leaves as influenced by different photoperiods and gibberellic acid treatments are furnished in Table 3. It is seen that at 120 days after treatment, photoperiod of 16 hours resulted in significantly more number of leaves than control and longer photoperiod (20 hours). Also it is seen that 20 hour photoperiod reduced significantly the number of leaves as compared to no light treatment and photoperiod of 16 hours duration. The total number of leaves recorded in Rangpur lime was significantly more than that recorded in trifoliate orange seedlings at both 60 days and 120 days after treatment.

At 60 days after treatment, gibberellic acid treatments resulted in significantly higher number of leaves than seedlings with no gibberellic acid treatment. At 120 days after treatment, gibberellic acid at 100 ppm gave significantly more number of leaves than in plants not treated. There were no significant differences among treatments with gibberellic acid at other concentrations.

Table 3. Effect of photoperiod and gibberellic acid on leaf number in trifoliate orange and Rangpur lime seedlings at 60 days and 120 days after treatment

Light / Variety		L0 V1	L0 V2	L0 Mean	L1 V1	L1 V2	L1 Mean	L2 V1	L2 V2	L2 Mean	Mean values for varieties V1	Mean values for varieties V2	Average G	S.E. for main treatment and interaction	S.E.	C.D. at 5%
60 days after treatment																
Growth regulator	G_0	13.25	16.00	14.63	13.75	15.25	14.50	13.00	12.75	12.88	13.33	14.66	14.00	L	0.20063	0.6942
	G_1	16.75	18.00	17.38	15.25	15.75	15.50	12.00	13.25	12.63	14.66	15.67	15.17	G	0.17416	0.4941
	G_2	12.75	15.25	14.00	16.75	18.00	17.38	12.25	14.25	13.25	13.92	15.83	14.88	V	0.06073	0.1943
	G_3	15.00	16.50	15.75	16.00	15.75	16.38	11.50	12.75	12.13	14.17	15.33	14.75	LV	0.10520	0.3865
														LG	0.30166	0.8558
														VG	0.24630	0.6988
														LVG	0.42661	1.2103
Mean		14.44	16.44		15.44	16.44		12.19	13.25							
Average L		15.4375			15.9375			12.7188								
Average V		V_1=14.0208			V_2=15.3750											
120 days after treatment																
	G_0	29.00	38.50	33.75	31.75	31.50	31.63	31.00	28.25	29.63	30.58	32.75	31.67	L	0.28470	0.9851
	G_1	33.25	36.50	34.88	37.75	37.50	37.63	28.00	28.25	28.13	33.00	34.08	33.54	G	0.40820	1.1582
	G_2	26.00	33.75	29.88	38.00	36.25	37.13	30.50	31.25	30.88	31.50	33.75	32.63	V	0.26100	0.8349
	G_3	29.50	34.00	31.75	36.00	35.50	35.75	27.75	29.25	28.50	31.08	32.92	32.00	LV	0.45210	1.4462
														LG	0.70710	2.0059
														VG	0.57740	1.6379
														LVG	0.99990	2.836
Mean		29.44	35.68		35.88	35.18		29.31	29.25							
Average L		32.5625			35.5313			29.2813								
Average V		V_1=31.5417			V_2=33.3750											

The two factor interactions LV (light and variety) and LG (light and gibberellic acid) gave significant differences at both the periods of observations while the three factor interactions LVG (photoperiod, variety, gibberellic acid) brought about significant differences at 120 days after treatment. Significantly more number of leaves were obtained with the treatments L_0V_2 (normal day length and rootstock Rangpur lime) and L_1V_2 (16 hours photoperiod and Rangpur lime) than with L_2V_2 (20 hours photoperiod and Rangpur lime). The interaction L_1V_1 (16 hours photoperiod and trifoliate orange) and L_0V_1 (normal day light and trifoliate orange) gave significantly more number of leaves than L_2V_1 (20 hours photoperiod and trifoliate orange). It is seen that with exposure to longer photoperiod of both the varieties less number of leaves were recorded at both the periods of observation. At 120 days, the interaction L_1V_1 (16 hours photoperiod and trifoliate orange) recorded significantly more leaf number than L_0V_1 (normal day length and trifoliate orange) and L_2V_1 (20 hours photoperiod and trifoliate orange). The treatment L_0V_2 (normal day length and Rangpur lime) and L_1V_2 (16 hours photoperiod and Rangpur lime) recorded significantly more leaf number than the interaction L_2V_2 (20 hours photoperiod and Rangpur lime) at 120 days. Due to interaction between photoperiod and gibberellic treatment the number of leaves were not much affected by longer light exposure combined with different gibberellic acid treatments. With 16 hour photoperiod (L_1) the trend was towards increased number of leaves with increasing concentrations of gibberellic acid except at 300 ppm, at both the periods. In L_0 (normal day length) no regular trend was manifested due to gibberellic acid at all concentrations.

4.1.4. Internodal length

In Table 4, observations on the influence of photoperiod and gibberellic acid treatments on internodal length are presented. The 16 hour photoperiod resulted in significantly increased internodal length than other treatments at both the periods of observations. While trifoliate orange recorded longer internodes than Rangpur lime under the influence of longer photoperiod, exposure to longer durations of light tended to reduce internodal length in both the rootstocks.

The internodal length in Rangpur lime seedling was significantly less than that in trifoliate orange seedlings at 120 days interval while at 60 days interval no significant differences were seen.

Due to treatment with gibberellic acid no significant effect on internodal length was noticed at 60 days after treatment while at 120 days after treatment all the gibberellic acid concentrations resulted in significantly longer

Table 5. [illegible] in trifoliate orange and Rangpur lime seedlings

Light intensity	L_0 V_1	L_0 V_2	L_0 Mean	L_1 V_1	L_1 V_2	L_1 Mean	L_2 V_1	L_2 V_2	L_2 Mean	Mean values for varieties V_1	V_2	G		S.E. for main treatment and interaction	S.D. at 5%
							30 days after treatment								
G_0	0,9250	1,0650	0,9950	1,0750	1,0750	1,0750	0,8500	0,7750	0,7900	0,9083	0,9250	0,9167	L	0,01155	0,03597
G_1	1,1000	1,0500	1,0750	1,0000	1,0000	1,0000	0,8500	0,7250	0,7750	0,9750	0,9250	0,9500	G	0,01785	0,05057
G_2	0,7000	0,7000	0,7000	1,1250	1,1250	1,1250	0,8500	0,7750	0,8825	0,9083	0,9166	0,9125	V	0,01247	0,03989
G_3	0,8750	1,0250	1,0000	1,1000	0,9750	1,0375	0,7750	0,8500	0,8125	0,9500	0,9500	0,9500	LV	0,02160	0,06909
													LG	0,03097	0,08760
													VG	0,02551	0,07158
													LVG	0,04367	0,12397
Mean	0,9162	0,9625		1,0750	1,0438		0,8188	0,7813							
Average L	0,9375			1,0594			0,8000								
Average V	V_1= 0,9454			V_2= 0,9292											
							120 days after treatment								
G_0	1,5250	1,2750	1,4001	2,1250	1,9500	2,0375	1,8000	1,4750	1,6375	1,8167	1,6666	1,7666	L	0,02338	0,06651
G_1	1,9000	1,7000	1,8000	2,2750	1,9750	2,1250	1,8750	1,5750	1,7250	2,0000	1,7667	1,8833	G	0,02694	0,07444
G_2	1,6750	1,7750	1,7250	2,2000	2,0250	2,1875	1,8250	1,8500	1,8375	1,9500	1,8833	1,5167	V	0,02569	0,08197
G_3	1,8000	1,8000	1,8000	2,0000	1,9500	1,9750	1,6500	1,7000	1,6750	1,8167	1,8167	1,8167	LV	0,04435	0,14156
													LG	0,04545	0,12954
													VG	0,03711	0,16528
													LVG	0,06428	0,19235
Mean	1,7125	1,6750		2,1875	1,9750		1,7875	1,6500							
Average L	1,6938			2,0813			1,7188								
Average V	V_1= 1,8556			V_2= 1,7667											

internodes as compared to no gibberellic acid treatment. Only the interaction LG (photoperiod and gibberellic acid) gave significant increase at both 60 days and 120 days after treatment and VG (variety and gibberellic acid) at 120 days after treatment. There were no marked differences observed between different combinations except L_0G_1 (normal day length and gibberellic acid 100 ppm) and L_1G_2 (16 hours photoperiod and gibberellic acid 200 ppm) which caused significantly more internodal elongation than L_0G_0 (normal day length and no gibberellic acid), L_0G_2 (normal day length and gibberellic acid 200 ppm), L_2G_0 (20 hours photoperiod and no gibberellic acid), L_2G_1 (20 hours photoperiod and gibberellic acid 100 ppm), L_2G_2 (20 hours photoperiod and gibberellic acid 200 ppm) and L_2G_3 (20 hours photoperiod and gibberellic acid 300 ppm) at 60 days after treatment. At 120 days after treatment, the interaction of L_1 (16 hours photoperiod) with all gibberellic acid treatment caused significantly longer internode than L_0 (normal day light) and L_2 (20 hours photoperiod with various gibberellic acid) concentrations. The interaction V_1G_1 (trifoliate orange and gibberellic acid 100 ppm) recorded significantly more internodal length than all other interactions. The three factor interactions (light, variety and gibberellic acid) did not give significant effects.

4.1.5. Number of internodes

In Table 5, data on the effect of photoperiod and gibberellic acid on number of internodes per plant are given.

At 60 days after treatment, the number of internodes which was significantly more with 16 hours photoperiod, showed significant decrease at 20 hours photoperiod which again was significantly less than that with L_0 (normal day length). At 120 days after treatment, the 16 hours photoperiod recorded significantly more number of internodes than L_0 (normal day length) and L_2 (20 hours photoperiod).

The internodal number was significantly higher in Rangpur lime that in trifoliate orange at both 60 days and 120 days after treatments.

Treatment with gibberellic acid at 100 ppm (G_1) recorded significantly higher number of internodes than control and other treatments, at both the observations, except gibberellic acid at 300 ppm (G_3) at 60 days after treatment. All the gibberellic acid treatments recorded significantly more number of internodes than with no gibberellic acid treatment at both 60 and 120 days after treatment.

Effects due to all the interactions were significant at 120 days, whereas effects due to the interactions of LG (light and gibberellic acid) and LVG (light, variety and gibberellic acid) were significant only at 60 days after treatment.

Table 5. [illegible] gibberellic acid on [illegible] number [illegible] trifoliate orange and Rangpur lime seedlings at 60 days and 120 days after treatment

Light / Variety		L_0 V_1	L_0 V_2	L_0 Mean	L_1 V_1	L_1 V_2	L_1 Mean	L_2 V_1	L_2 V_2	L_2 Mean	Mean values for varieties V_1	Mean values for varieties V_2	Average G	S.E. for main treatment and interaction S.E.		C.D. at 5%
60 days after treatment																
Growth regulators	G_0	7.00	6.75	6.88	6.75	8.25	7.50	8.00	8.00	8.00	7.25	7.67	7.6666	L	0.1572	0.5442
	G_1	13.50	14.00	13.75	12.75	14.00	13.88	8.75	8.00	8.38	11.67	12.00	11.8333	G	0.1630	0.4624
	G_2	8.00	10.50	9.25	14.50	15.00	14.75	9.25	8.50	8.88	10.58	11.33	10.9583	V	0.1736	0.5555
	G_3	12.75	12.75	12.75	13.50	14.50	14.00	7.00	8.25	7.63	11.08	11.83	11.4583	LV	0.3008	0.9621
														LG	0.2823	0.8009
														VG	0.2305	0.6539
														LVG	0.3992	1.1327
Mean		10.31	11.00		11.88	12.94		8.25	8.19							
average L		10.6265			12.4063			8.2188								
average V		V_1=10.1458			V_2=10.7083											
120 days after treatment																
	G_0	20.75	21.50	21.13	23.00	24.00	23.50	25.75	22.75	24.25	23.17	22.75	22.9583	L	0.30812	1.0661
	G_1	30.25	31.50	30.58	30.50	31.75	31.13	24.00	24.75	24.38	28.25	29.33	28.7916	G	0.34791	0.9870
	G_2	19.25	27.75	23.50	32.00	29.25	30.63	24.25	27.50	24.50	25.17	28.17	26.6666	V	0.31982	1.0229
	G_3	22.50	27.25	24.88	31.50	30.00	30.75	23.25	26.50	24.88	25.75	27.91	26.8333	LV	0.55394	1.7718
														LG	0.60260	1.3958
														VG	0.49202	1.3958
														LVG	0.85221	2.4176
Mean		23.19	27.00		29.25	28.75		24.31	25.38							
average L		25.0937			29.0000			24.8438								
average V		V_1=25.5833			V_2=27.0417											

The interactions L_1G_1 (16 hours photoperiod and gibberellic acid 100 ppm), L_1G_2 (16 hours photoperiod and gibberellic acid 200 ppm) and L_1G_3 (16 hours photoperiod and gibberellic acid 300 ppm) resulted in significantly more number of internodes than all other interactions except L_0G_1 (Normal day length and gibberellic acid 100 ppm) at 60 days and 120 days after treatment. Evidently 16 hours photoperiod combined with gibberellic acid treatments gave significant increase in internodal number. With 20 hours photoperiod, however, there was a general decrease in the number of internodes with gibberellic acid treatments as compared to L_1 (light 16 hours photoperiod) or L_0 (normal day light) treatments.

The interactions L_1V_1 (16 hours photoperiod and variety trifoliate orange) and L_1V_2 (16 hours photoperiod and variety Rangpur lime) recorded significantly higher number of internodes than all the other combinations except L_0V_1 (normal day length and trifoliate orange) at 120 days after treatment. Among the interactions, VG (variety and gibberellic acid), it was observed that V_2G_1 (Rangpur lime and gibberellic acid 100 ppm) and V_1G_1 (trifoliate orange and gibberellic acid 100 ppm) recorded significantly higher number of internodes than others except V_2G_3 (Rangpur lime and gibberellic acid 300 ppm) at 120 days after treatment. Gibberellic acid treatment at 100 ppm increased the number of internodes in both the rootstocks.

4.1.6. Leaf nutrient content

In Table 6, the data relating to the effect of photoperiod and gibberellic acid on leaf nitrogen, phosphorus and potassium contents in trifoliate orange and Rangpur lime are furnished.

1. Nitrogen

In respect of leaf nitrogen, the main effects of light and variety and the interaction LV (light and variety) showed significant differences.

The treatment L_1 (16 hours photoperiod) significantly increased the leaf nitrogen content as compared to L_2 (20 hours photoperiod).

Trifoliate orange (V_1) recorded significantly higher leaf nitrogen content than Rangpur lime (V_2).

Among gibberellic acid treatments there were no significant differences. However, G_0 (control) recorded significantly higher nitrogen than others.

In the interaction LV (light and variety), L_1V_1(16 hours photoperiod and trifoliate orange) and L_0V_1 (normal day length and trifoliate orange) recorded significantly higher leaf nitrogen content than L_0V_2 (normal day length and Rangpur lime), L_1V_2 (16 hours photoperiod and Rangpur lime), L_2V_1 (20 hours photoperiod and trifoliate orange), L_2V_2 (20 hours photoperiod and Rangpur lime).

Table 6. Effect of photoperiod and gibberellic acid on leaf nitrogen, phosphorus and potassium content of trifoliate orange and Rangpur lime seedlings

(Mean values on oven dry basis)

Treatments	Nitrogen N	Phosphorus P_2O_5	Potassium K_2O
	(Per cent content on oven dry basis)		
L_0	2.4400	0.2372	1.3084
L_1	2.5556	0.2419	1.3491
L_2	2.3506	0.2388	1.3253
S.E.M.	0.0378		0.0280
C.D. at 5%	0.1306		0.0969
V_1	2.6033	0.2329	1.2623
V_2	2.2942	0.2456	1.3929
S.E.M.	0.0371	0.0022	0.0284
C.D. at 5%	0.1186	0.0072	0.0909
G_0	2.6488	0.2608	1.6592
G_1	2.4329	0.2421	1.2542
G_2	2.4079	0.2550	1.1204
G_3	2.3054	0.1992	1.2767
S.E.M.	0.0589	0.0042	0.0455
C.D. at 5%	0.1670	0.0121	0.1291

Interaction LV for leaf nitrogen (Mean values on oven dry basis)

	V_1	V_2
L_0	2.7088	2.2213
L_1	2.8194	2.2919
L_2	2.3319	2.3694
S.E.M.	0.0642	
C.D. at 5%	0.2055	

ii. Phosphorus

The main effects of variety and gibberellic acid (VG) recorded significant differences. Rangpur lime (V_2), gibberellic acid 100 ppm (G_1) and control (G_0) recorded significantly higher leaf phosphorus content as compared to trifoliate orange and other gibberellic acid treatments.

iii. Potash

Rangpur lime (V_2) recorded significantly higher potash content than trifoliate orange (V_1). Leaf potash content was significantly higher with gibberellic acid at 300 ppm and control as compared to gibberellic acid at 200 ppm.

It is evident that the leaf nitrogen, phosphorus and potash content were influenced by gibberellic acid treatment.

4.2. Experiment II

Effects of alar, cycocel and pinching on growth of trifoliate orange and Rangpur lime seedlings

The data on growth of trifoliate orange and Rangpur lime seedlings as influenced by Alar, Cycocel and pinching were analysed as R.C.B.D. and furnished in Table 7.

4.2.1. Plant height

Both trifoliate orange and Rangpur lime seedling at 30 days and 60 days after treatment recorded significant decrease in height under the influence of Alar and Cycocel at all the concentrations.

Table 7. Effects of Alar, Cycocel and pinching on height, girth of trifoliate orange and Rangpur lime seedlings at 30 days and 60 days after treatment

Treatments	Trifoliate orange seedlings				Rangpur lime seedlings			
	Height (cm) at		Girth (cm) at		Height (cm) at		Girth (cm) at	
	30 days	60 days	30 days	60 days	30 days	60 days	30 days	60 days
Alar - 1000 ppm	45.15	49.22	0.69	0.84	74.65	88.95	0.94	1.14
500 ppm	49.28	56.25	0.73	0.82	78.55	85.05	0.92	1.10
250 ppm	49.85	57.50	0.72	0.82	82.40	91.10	0.91	1.07
Cycocel - 1000 ppm	50.38	55.95	0.72	0.85	82.25	91.80	0.93	1.15
500 ppm	49.65	57.00	0.72	0.82	83.10	93.90	0.93	1.14
250 ppm	47.63	58.10	0.71	0.81	86.70	94.12	0.94	1.10
Pinching	-	-	0.73	0.84	-	-	0.94	1.16
Control	53.78	63.65	0.67	0.76	90.30	99.90	0.85	0.96
S.E.M.	1.04	1.05	-	0.012	1.01	0.63	0.01	0.02
C.D. at 5%	3.09	3.42	-	0.040	3.00	1.87	0.02	0.06

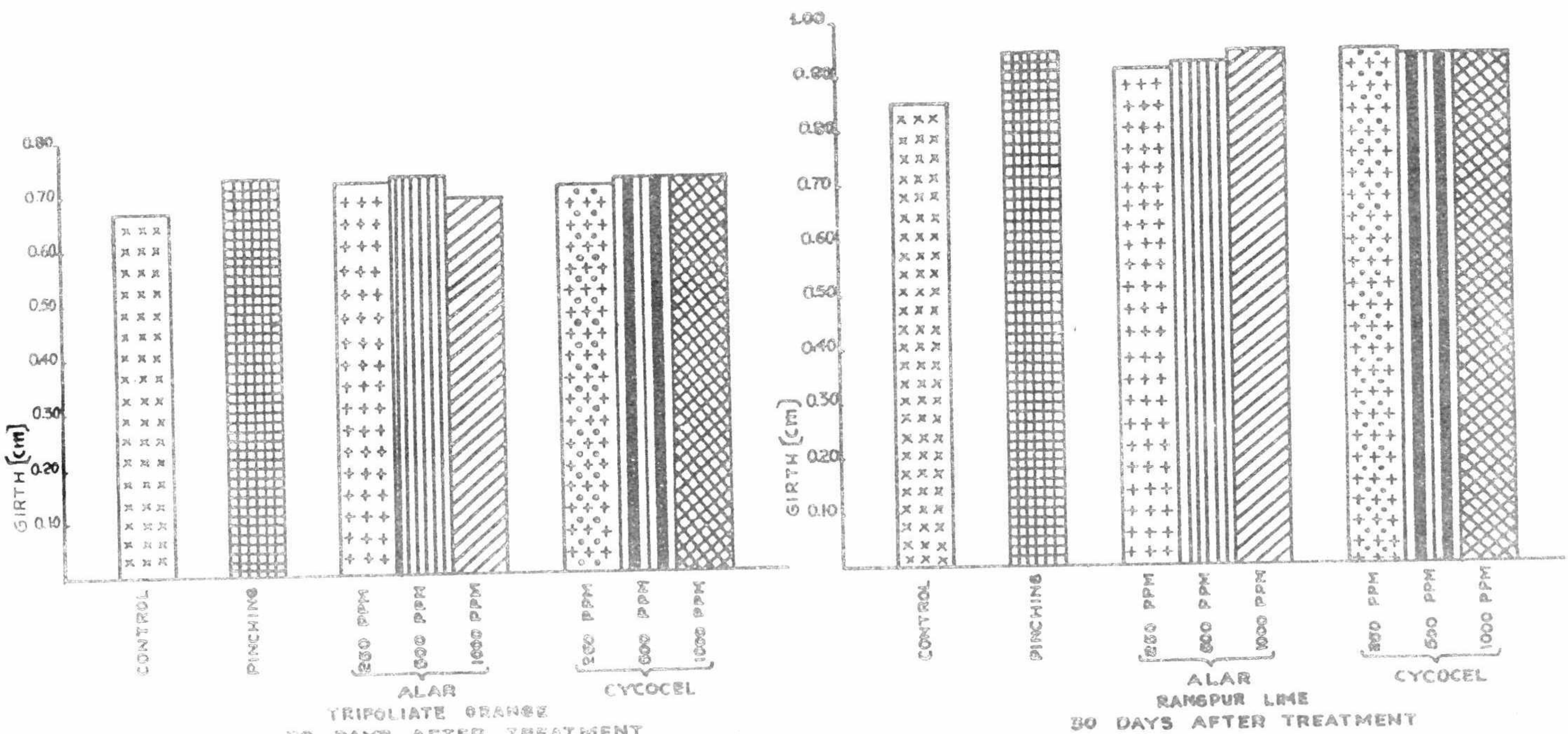

Fig 3. EFFECT OF ALAR, CYCOCEL AND PINCHING ON GIRTH OF TRIFOLIATE ORANGE AND RANGPUR LIME SEEDLINGS

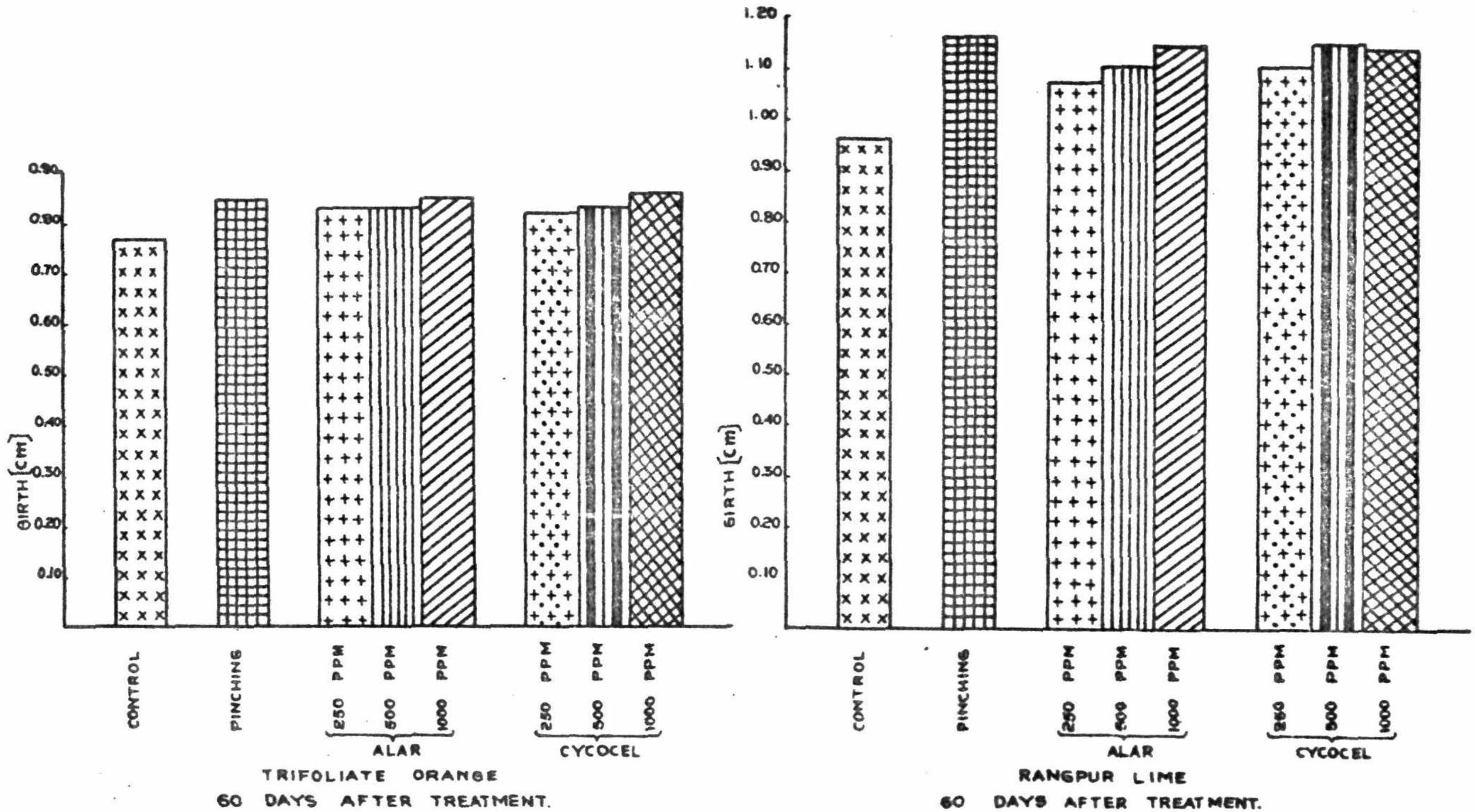

Fig 4. EFFECT OF ALAR, CYCOCEL AND PINCHING ON GIRTH OF TRIFOLIATE ORANGE AND RANGPUR LIME

Rangpur lime seedlings showed significant decrease in height under the influence of Alar at 1000 ppm and 500 ppm as compared to Alar at 250 ppm and control at both 30 days and 60 days after treatment. The growth retardant Alar at 1000 ppm significantly reduced the height of trifoliate orange seedlings as compared to its other concentrations (500 and 250 ppm), Cycocel (1000, 500, 250 ppm) and control. There were no significant differences among treatments with Cycocel at different concentrations, which recorded significantly less height than control at both 30 days and 60 days after treatment.

4.2.2. Girth

Rangpur lime recorded significantly increased girth at both 30 days and 60days interval, while trifoliate orange recorded significantly increased girth only at 30 days after treatment.

In both Rangpur lime and trifoliate orange seedlings, pinching, Alar and Cyclcel treatments at different concentrations significantly increased the girth as compared to control.

4.3. Experiment III

Bud take in trifoliate orange and Rangpur lime seedlings as influenced by different treatments

4.3.1. Trifoliate orange

In trifoliate orange, pinching resulted in significantly higher percentage of bud take as compared to all other treatments except control, which in turn recorded significantly higher percentage of success than Alar at 1000 ppm and Cycocel at 1000 ppm (Table 8).

4.3.2. Rangpur lime

In Rangpur lime also pinching resulted in significantly higher percentage of bud take as compared to all other treatments except control, which recorded significantly higher percentage of bud take than Alar at 250ppm and Cycocel at 1000 ppm. Alar at 1000 ppm gave significantly lowest percentage of bud take than all other treatments (Table 8).

Table 8. Effect of Alar, Cycocel and pinching on bud take in trifoliate orange and Rangpur lime seedlings

Treatments		Bud take (per cent)	
		Trifoliate orange	Rangpur lime
Alar	- 1000 ppm	30	25
	500 ppm	50	70
	250 ppm	55	50
Cycocel	- 1000 ppm	25	65
	500 ppm	45	75
	250 ppm	55	75
Pinching		75	95
Control		65	85
S.E.M.		5.00	5.35
C.D. at 5%		14.71	15.74

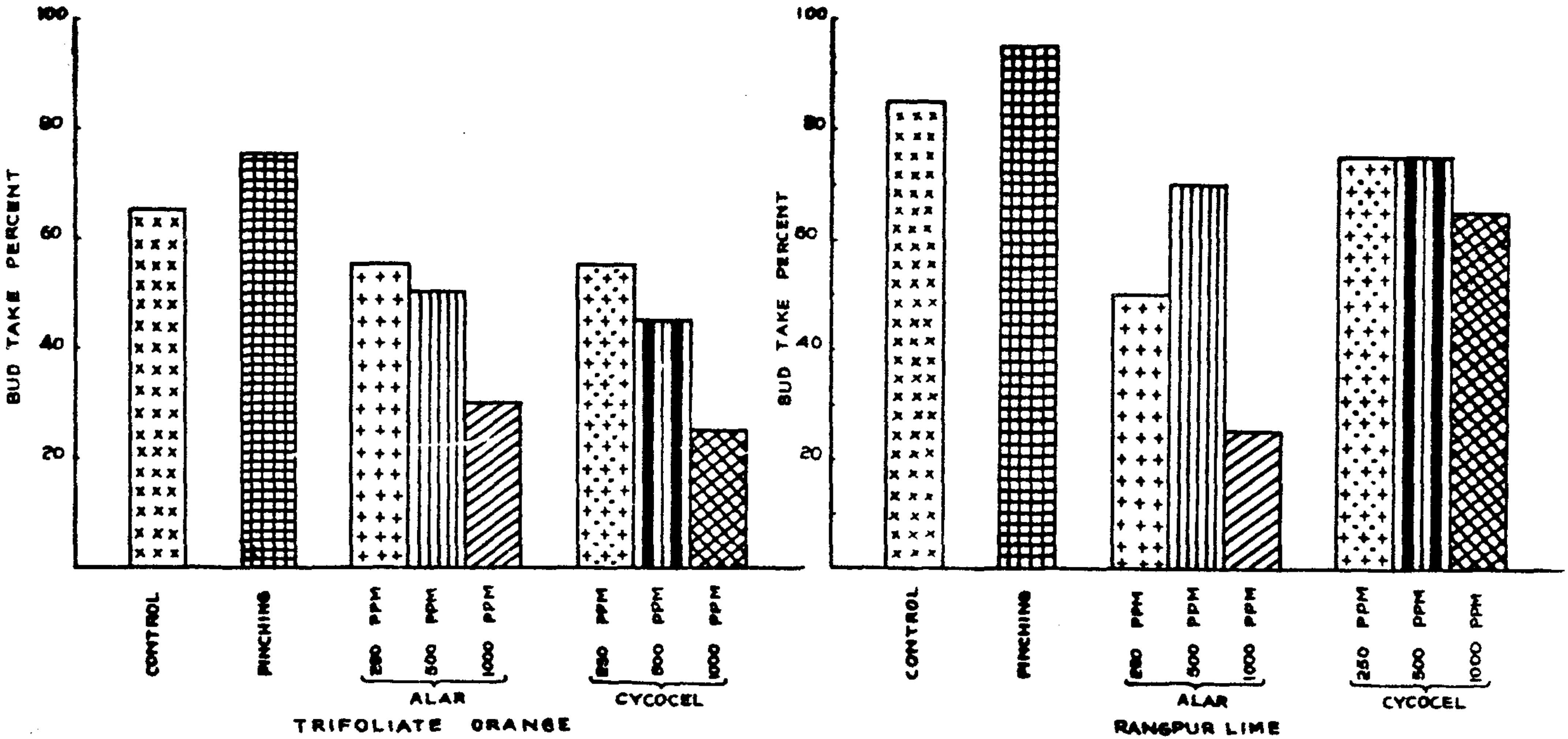

Fig 5. EFFECT OF GROWTH REGULATORS AND PINCHING ON BUD TAKE IN TRIFOLIATE ORANGE AND RANGPUR LIME

DISCUSSION

CHAPTER V

DISCUSSION

Trifoliate orange is regarded as one of the very promising rootstocks but the slow growth of seedlings in the nursery has been the main limitation for its large scale use as a rootstock. The trifoliate orange seedlings require about 24 months for attaining suitable size for budding as against 9-12 months required for Rangpur lime seedlings. Attempts made to force the growth of trifoliate orange seedlings for budding within 9-12 months period have not yielded encouraging results. Hence, the present study was undertaken and the results are discussed hereunder.

5.1. Photoperiod and plant growth

Increase in photoperiod over normal day length increased the plant height in seedlings of Rangpur lime as well as trifoliate orange. Similar increase in height of seedlings under increased photoperiod has been reported in grape fruit (Khol, 1960), peach (Vardanija, 1960) and trifoliate orange (Stathakopoulos and Erickson, 1966; Warner and Worku, 1966; Warner, 1971). In the present study, sixteen hour photoperiod was found to be more effective in increasing plant height of seedlings as compared to twenty hours photoperiod. It is possible that this photoperiod was optimal for causing increase in the length of parenchyma and epidermal cells, cell number and number of xylem rows thus resulting in elongation of seedlings (Pathak and Ranjit Singh, 1978).

5.2. Gibberellic acid and plant height

Gibberellic acid at 100 ppm was found to be very effective in increasing the height of the rootstock seedlings. Similar increase in height of seedlings due to gibberellic acid treatment has been reported by several other workers (Singh *et al.*, 1959; Randhawa and Singh, 1959; Ahmed and Khan, 1964; Srivastava and Singh, 1969; Shant and Rao, 1973).

5.3. Gibberellic acid and stem girth

Foliar application of 100 ppm gibberellic acid increased the diameter of both Rangpur lime and trifoliate orange seedlings at 120 days. This is in conformity with the findings of Bhambota and Kaul (1966) who recorded increased stem girth in rough lemon seedlings treated with 100 ppm gibberellic acid. In this study, gibberellic acid treatment failed to record increase in girth at 60 days. Kumar (1971), however, recorded an increase in stem girth of Kagzi lime seedlings in the beginning but not in the final observations. It seems that gibberellic acid can increase the girth by enlargement of cells only after repeated applications. Chrispeels and Varner (1967) have established that the hormone must be present continuously for the regulatory actions to proceed and this implies that the hormone may become attached to some site of action through a relatively facile attachment-detachment mechanism. Apparently, the quantity of hormone present may not have been adequate so as to cause the increase in girth within 60 days of the treatment.

5.4. <u>Gibberellic acid and internodal length</u>

One of the important formative effects of gibberellic acid is cell elongation. The effect is more pronounced in seedlings (Nanda and Purohit, 1964). In the present study, gibberellic acid treatment increased the internodal length in seedlings at 120 days but not at 60 days period. Similar response due to gibberellic acid was also recorded in Kagzi lime (Kumar, 1971) and forest plants (Nanda and Purohit, 1964). In the presence of gibberellic acid large amounts of new proteins are synthesised (Filner and Varner, 1967). Such newly synthesized proteins bring about increase in height and girth.

Interaction between photoperiod and gibberellic acid resulted in increased internodal length of seedlings both at 60 days as well as 120 days period. This indicates that photoperiod or gibberellic acid when applied individually is slow in its action. Together they appear to have synergistic effect causing quicker enlargement.

5.5. Gibberellic acid and leaf number

Maximum number of leaves per plant was recorded in seedlings exposed to 16 hours photoperiod. Exposure of seedlings to longer photoperiod results in increased photosynthates which in turn promote production of greater number of leaves. Foliar application of gibberellic acid was also found to increase the leaf number to a great extent and such an increase in leaf number per seedling due to foliar application of gibberellic acid was reported by Randhawa and Iwata (1963), Bhambota and Kaul (1966). However, at concentrations of more than 100 ppm, reduction in number of leaves per plant was recorded. Similar reduction in number of leaves due to foliar application of gibberellic acid at more than 100 ppm concentration has been reported by Bhambota and Kaul (1966).

Interaction between photoperiod and gibberellic acid brought about an increase in number of leaves at both the periods of observation. Apparently longer photoperiod enabled building up of reserve carbohydrates and higher level of gibberellic acid induced cell enlargement. Thus, with the availability of more food material, more number of leaves are produced (Leopold and Kriedemann, 1975).

5.6. Growth retardants and plant growth

Foliar application of Alar and Cycocel to trifoliate orange and Rangpur lime seedlings significantly reduced the height both at 30 days and 60 days after treatment at all the concentrations as compared to control. Similar dwarfing effect of Cycocel and Alar on shoot growth was recorded by Husabo (1972). Increase in stem girth was recorded in both the rootstocks at 30 days as well as 60 days after treatment as compared to control.

Such an increase in stem girth of seedlings due to application of growth retardants conform to the findings of Ryugo and Sansavini (1972) in peach seedlings, Garg and Singh (1976) in cape gooseberry, Grauslund (1976) in apple, and Teskey and Rajput (1977) in pear. The study further revealed that pinching is as effective as Cycocel and Alar, and sometimes even more effective in increasing the stem thickness of rootstock seedlings of trifoliate orange as well as Rangpur lime. Application of growth retardants evidently alter the balance of growth promoters in the plant which may retard cell elongation, whereas pinching may not bring about any hormonal imbalance. In a plant without the rapidly growing tip, which is a strong mobilisation centre, the nutrients and photosynthates may be directed towards other cells.

5.7. Leaf nutrient content

Analysis of leaves of the seedlings did not show any significant difference in nitrogen content of leaves. Gibberellic acid treatment reduced the nitrogen content of the seedlings. Similar effect has also been noted in strawberry plant by Kaul and Singh (1967). In contrast, Lewis and Hull (1960) recorded significant increase in the nitrogen content in cherry plant due to gibberellic acid treatment.

The percentage of nitrogen tended to decrease owing to gibberellic acid application. Apparently, rapid vegetative growth on account of increased expansion and division of cells caused utilization and dilution of nitrogen content leading to decrease in the content.

Increase in photopariod also increased the nitrogen content of leaves over control, which is in agreement with earlier established findings.

Gibberellic acid application did not alter the phosphorous and potash content of the leaves. However, Kaul and Singh (1967) recorded variations in phosphorus and potash level as a result of application of gibberellic acid in strawbberry.

5.8. Percentage of bud take

It is interesting to note that the foliar application of Cycocel and Alar to the gibberellic acid treated rootstock seedlings resulted in poor percentage of bud take. It was observed that success of bud take in growth retardant treated plants was even less than that of the control. Maximum success of bud take was recorded in plants subjected to pinching of main stem.

The growth retardants such as Cycocel and Alar suppress the vegetative growth. For successful bud take rapid bud union is essential. But growth retardants are known to suppress the bud growth and result in poor vegetative growth of seedlings (Grauslund, 1976; Seth and Singh, 1976; Bist and Kaul, 1977; Teskey and Rajput, 1977). Maximum success in bud take was obtained in plants which were pinched. Pinching to remove the growth point promotes growth of lateral buds. It is possible that pinching does not adversely alter the hormonal balance of the plant. Instead, it diverts the food materials and hormones to the dormant bud ensuring higher bud take.

SUMMARY

CHAPTER VI

SUMMARY

The slow growth of trifoliate orange seedling in the nursery seems to be the main drawback for its use as a commercial rootstock for citrus fruits. A study on acceleration of growth in the nursery stage of seedlings of rootstocks trifoliate orange and Rangpur lime was conducted during the year 1977-78 at the Citrus Experiment Station, Gonicoppal, Kodagu, Karnataka.

The effects of photoperiod and gibberellic acid, Alar and Cycocel at different concentrations and pinching were studied in order to promote the desired growth within as short time as possible.

6.1. Plant height

The increase in height of trifoliate orange seedlings was highest when exposed to 16 hour photoperiod at 120 days after treatment with gibberellic acid. However, the response of Rangpur lime seedlings to this photoperiod was more pronounced than that of trifoliate orange.

Application of gibberellic acid at 100 ppm caused maximum increase in plant height as compared to all other treatments both at 60 and 120 days after treatment.

Interaction among photoperiod, gibberellic acid and varieties resulted in increased height.

6.2. Girth of seedlings

There was no increase in stem girth of rootstock seedlings due to increase in photoperiod.

Gibberellic acid treatment failed to increase the stem girth at 60 days. However, there was slight increase at 120 days after treatment. Rangpur lime recorded greater diameter than trifoliate orange.

Interaction between photoperiod and gibberellic acid did not bring about increase in diameter at 60 days, but considerable increase in diameter was recorded at 120 days after treatment with gibberellic acid.

6.3. Number of leaves per plant

Trifoliate orange and Rangpur lime seedlings exposed to sixteen hour photoperiod recorded maximum number of leaves per plant at 60 days as compared to control and 20 hour photoperiod. Exposure of seedlings to longer duration of light reduced the number of leaves per plant.

Application of gibberellic acid increased the number of leaves and maximum was recorded at 100 ppm.

Interaction between photoperiod and gibberellic acid caused increase in leaf number both at 60 and 120 days after treatment, whereas three factor interaction increased leaf number at 120 days only.

6.4. Internodal length

Internodal length of rootstock seedlings was maximum at 16 hour photoperiod both at 60 and 120 days after treatment with gibberellic acid. Exposure of seedlings to longer duration of light tended to reduce the internodal length.

Internodal length increased due to gibberellic acid application at all concentrations at 120 days, but not so at 60 days.

Interaction among photoperiod, gibberellic acid and variety did not influence the internodal length of seedlings.

6.5. Internodal number

Maximum number of internodes was recorded under the influence of 16 hour photoperiod both at 60 and 120 days after treatment with gibberellic acid. Rangpur lime recorded more number of internodes as compared to trifoliate orange.

Seedlings treated with gibberellic acid at 100 ppm recorded more number of internodes than the seedlings treated with higher concentrations of gibberellic acid.

Interaction between photoperiod and gibberellic acid caused an increase in number of internodes.

Interaction among varieties, photoperiod and gibberellic acid treatments brought about increase in number of internodes.

6.6. Leaf nutrient content

6.6.1. Nitrogen

Trifoliate orange recorded higher nitrogen content than Rangpur lime.

Foliar nitrogen content increased under the influence of 16 hours photoperiod as compared to normal day length and 20 hours photoperiod.

Higher leaf nitrogen content was recorded owing to interaction of photoperiod and gibberellic acid.

6.6.2. Phosphorus

The leaf phosphorus content of Rangpur lime was significantly higher than that of trifoliate orange.

The phosphorus content of leaf was unaffected by photoperiod.

The phosphorus content was highest in leaves of seedlings not treated with gibberellic acid. Treatment with gibberellic acid at 200 ppm resulted in significantly higher leaf content as compared to the other two concentrations.

6.6.3. Potassium

The leaf potassium content of Rangpur lime was significantly higher than that of trifoliate orange.

The potassium content was highest in the 16 hours photoperiod.

The potassium content was highest in seedlings not treated with gibberellic acid.

6.7. Effect of growth retardants and pinching

6.7.1. Height of plant

Alar and Cycocel at 1000 ppm significantly reduced the height of trifoliate orange seedlings at 60 days after treatment. In Rangpur lime seedlings, the height was significantly reduced by Alar and Cycocel at all concentrations, the reduction being maximum due to Alar at 1000 ppm.

6.7.2. Stem thickness of plant

The girth of trifoliate orange seedlings was significantly increased due to treatment with Alar and Cycocel at 1000 ppm.

The girth of Rangpur lime seedlings was also significantly increased due to treatment with all the concentration of Alar and Cycocel. The increase was highest due to Alar and Cycocel at 1000 ppm.

6.7.3. Per cent bud take

In both trifoliate orange and Rangpur lime pinching of seedlings resulted in highest bud take followed by plants which were treated with gibberellic acid at 100 ppm.

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CHAPTER VII

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APPENDIX

Appendix 1

Mean meteorological data for the year 1977 and 1978 as recorded at the Citrus Experiment Station, Gonicoppal, Kodagu, Karnataka

Months Mean of 1977 and 1978	Rainfall (mm)	Temperature		Humidity	
		Maximum (°C)	Minimum (°C)	Morning	Evening
January	0.0	28.3	16.3	82.6	77.3
February	2.0	32.2	15.8	83.8	75.8
March	17.3	33.6	16.8	83.9	74.3
April	61.1	34.5	17.1	86.4	81.5
May	173.8	33.0	16.8	89.4	92.9
June	433.9	26.2	17.1	95.2	95.3
July	459.0	26.9	17.3	94.6	94.2
August	293.0	24.9	18.0	93.1	89.9
September	217.0	27.6	17.6	92.2	89.1
October	154.8	29.6	17.5	90.1	87.0
November	111.8	31.4	17.8	88.7	83.8
December	24.0	33.9	18.0	84.0	86.2