CROP REGULATION STUDIES IN KINNOW MANDARIN

Thesis

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
in
POMOLOGY
(Minor Subject : Botany)

By

Jaspreet Kaur
(L-2006-A-57-M)

Department of Horticulture
College of Agriculture
PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA – 141 004

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2009

Dedicated

to

My Loving Parents

CERTIFICATE-I

This is to certify that the thesis entitled **"Crop Regulation Studies in Kinnow Mandarin"** submitted for the degree of **Master of Science**, in the subject of **Pomology** (Minor subject: **Botany**) of Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Jaspreet Kaur** (L-2006-A-57-M) under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

Major Advisor
(Dr. H.S. Rattanpal)
Horticulturist
Deptt. of Horticulture
Punjab Agricultural University
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CERTIFICATE-II

This is to certify that the thesis entitled **"Crop Regulation Studies in Kinnow Mandarin"** submitted by **Jaspreet Kaur** (L-2006-A-57-M) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science**, in the subject of **Pomology** (Minor subject: **Botany**) has been approved by the Student's Advisory Committee along with Head of the Department after an oral examination on the same.

Head of the Department
(Dr. P.S. Aulakh)

Major Advisor
(Dr. H.S. Rattanpal)

Dean, Postgraduate studies
[Dr. (Mrs.) S.K. Mann]

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ABSTRACT

The present investigation entitled "Crop regulation studies in Kinnow mandarin" was carried out in the 10-year-old Kinnow plantation of Department of Horticulture, Punjab Agricultural University, Ludhiana during the cropping season 2007-08. The fruits were hand thinned 60 days after full bloom to different levels expressed as leaf:fruit ratio, which varied from 15:1 to 45:1. Fruit thinning was also undertaken by spraying Naphthalene Acetic Acid (NAA) at different concentrations varying from 200-300 ppm, 40 days after full bloom. The maximum fruit weight and volume among the hand thinning treatments was recorded with leaf:fruit ratio of 45:1 and 300 ppm among different concentrations of NAA. Some increase in size was observed with all the hand thinning levels and NAA treatments. However, significant increase in fruit size was noted with heavy thinning. Severe thinning treatments caused significant reduction in yield as compared to control. The maximum yield was recorded in non-treated trees, which was significantly higher as compared to all the hand thinning and NAA treatments. Fruit quality parameters viz. TSS, acidity, TSS:acid ratio and palatability rating were not significantly influenced by any of the thinning treatment. The starch content of root bark and return bloom improved with all the hand thinning and NAA treatments, 131.6 per cent return bloom was noted with leaf:fruit ratio of 45:1.

Key words: Kinnow, NAA Spray and Leaf:Fruit Ratio

15-7-09

Signature of the major advisor

Jaspreet Kaur

Signature of the student

CONTENTS

CHAPTER - I

INTRODUCTION

Citrus is the leading sub-tropical fruit crop of the world. It has total production of 115 million metric tonnes (FAO 2007). In India, citriculture is the third largest fruit industry and occupies a place of significant importance in the economy of the country. It occupies an area of 6.91 lakh hectare with an estimated fruit production of 6.29 million tonnes (FAO 2007).

The citrus industry of Punjab is unique as it is mainly concentrated on a single mandarin cultivar 'Kinnow' (a hybrid of *Citrus nobilis* and *Citrus deliciosa*). It is cultivated on an area of 31,788 ha with an annual production 5,91,319 tonnes (Anon 2008). The sub-montane districts of Hoshiarpur, Ropar and South Western districts of Ferozepur, Mukatsar and Bathinda have emerged as the predominant citrus production centers.

The area and production of Kinnow is increasing because of its wider adaptability to different agro-climatic conditions, precocious bearing, high yield potential and better fruit quality, which ensures higher economic returns to the growers. However, the superior traits like precocious and prolific bearing accentuate the tendency for alternate bearing and decline. The maiden overbearing results in slow decline of tree in subsequent years or tree collapse. The tree decline, at early stage is becoming a major problem in Kinnow. The symptoms includes retardation of growth, chlorotic foliage, premature defoliation, twig dieback and unhealthy appearance. The excessive crop load seems to disturb the normal partitioning of photosynthates as a major part of these is stored. The suboptimal availability of carbohydrates impairs the root metabolism and their capacity to absorb sufficient nutrients and water. The devitalized root system is which infected by the soil borne fungi like, *Phytophthora, Fusarium, Diplodia,* etc. which aggravate the problem of decline.

The heavily loaded young trees of 'Murcott' tangerine were found to decline because of starch depletion of roots by Smith (1976). He further observed leaves of such trees to be deficient in one or more minerals such as N, P and K. The overbearing results in the production of undersized and poor quality fruits in 'on' year and poor crop in 'off' year, thus disrupting the orderly marketing of crop. The fruit thinners have been tried to mitigate this complex problem. Application of ethephon (200 ppm) or NAA (300 ppm) reduced alternate bearing in Wilking mandarin. An increase of 64 per cent in fruit size over the control was observed with ethephon and 48 per cent with NAA treatment by Galliani *et al* (1975).

In view of the above information it seems desirable to test the efficiency of growth regulators in reducing crop load, quality improvement and tree physiology in Kinnow. The crop regulation may help to check alternate bearing and tree decline besides, improvement in fruit size.

Therefore, the present study was conducted with the following objectives:

1. To study the effect of different concentrations of NAA on fruit thinning in Kinnow mandarin.

2. To study the effect of thinning levels on quality, productivity and return of the crop.

3. To determine the effect of thinning treatments on carbohydrates levels.

CHAPTER - II

REVIEW OF LITERATURE

Flowering and fruit production are the exhaustive processes in the life cycle of a fruit tree. A heavy fruit set results in competition for photosynthates and other nutrients among the developing fruits and the growing shoots resulting in loss of vitality of the trees. The most striking effect of this competition is small unprofitable fruit size as well as inferior fruit colour and quality along with deterioration of the tree health and subsequent poor cropping.

For fresh fruit use the size, shape, colour and appearance are prominent marketing traits and the fruit thinning may be required to meet the market demand. However, if the intended fruit utilization is processing, the thinning may be dispensed with. Some species of citrus, mandarins in particular (Kinnow and Wilking) are prone to alternate bearing, which results in heavy crop of small fruits in one season, but light crops with oversized and rough skinned fruits in the next season. In early years of Kinnow tree, an extremely heavy crop of fruit is set, which deprives the roots of photosynthates. The starved roots are attacked by many soil pathogens. The trees may collapse as in Murcott or start declining in general health as in Kinnow and go out of production in next 2-3 years.

Auchter and Roberts (l935) were the first to demonstrate that chemical sprays could be used effectively to thin apple flowers, which was cheaper than the manual thinning. Consequently many substances like phenols, cresols, NAA, 2,4-D, MCPA, ethephon, carbamate, MH, etc. were used to defoliate the flowers or the fruitlets in different fruit crops.

The effect of fruit thinning has been reviewed under the following subheads:

1. Effect on the extent of fruit thinning
2. Effect on fruit quality
3. Effect on physiology of the tree
4. Effect on subsequent cropping and alternate bearing

2.1 EFFECT ON THE EXTENT OF FRUIT THINNING

Hirose (1970) reported that NAA at 200-300 ppm concentration applied in June drop stage on Satsuma mandarin, resulted in adequate thinning and increased fruit size. Sprays of MH (1000 to 1500 ppm) given 30-40 days after full bloom reduced fruit size but 2,4,5-T (10-20 ppm) sprays increased fruit size, caused granulation and defoliation in Satsuma mandarin (Hirose *et al* 1974). In an another experiment these workers further reported that NAA at 200 or 300 ppm doses caused satisfactory thinning but reduced the fruit size without affecting the juice quality. Sometime, defoliation, leaf burn, leaf curling and growth retardation of the shoots followed the chemical thinning of Satsumas. Spiegol-Roy (1974), reported that application of I- alpha-napthalene acetyl, 3, 5-dimethyl pyrozole (TH 656) at 160 ppm concentration increased fruit size without affecting yield of Wilking mandarin.

Yasui *et al* (1974) observed that efficiency of 200-300 ppm NAA sprays one month after full bloom for thinning Satsuma mandarins varied greatly with location, season, environmental conditions (temperature, relative humidity) time, age and stage of fruitlet development. The fruit thinning effects of NAA were variable and dependent upon nutritional factors as determined by size and position of fruit, shoot size, number of leaves per fruit and C/N ratio in shoot and leaves. The absorption of NAA by leaves was increased with increase in temperature and humidity. Sprays of Ethephon (200 ppm) and NAA (300 ppm) on fruitlets of 1 cm diameter, resulted in satisfactory fruit thinning without significant reduction in yield of Wilking mandarin. Ethephon also reduced alternate bearing. The fruit size was increased by 64 per cent with Ethephon and by 48 per cent with NAA treatment (Galliani *et al* 1975). NAA (400-500 ppm) sprayed after two weeks of fruit-set during on-year, caused crop thinning and regulated biennial bearing in Kinnow mandarin, but 2,3,5-triidobenzoic acid (25-100 ppm) applied at same time had no effect on thinning (Ali *et al* 1975). Noma (1976) reported that NAA (300 ppm) applied 30 days after full bloom in Satsuma gave the best thinning effect. He further observed that NAA induced the formation of abscission layer between peduncle and disk of the fruit, where the cells enlarge and cell membranes disappear leaving large intercellular spaces, as a result fruit readily fall in response to mechanical forces like its own weight or wind disturbance.

Tomita and Natsumi (1977) reported that trees with thinning treatment had 83 or 92 leaves per fruit as compared to 62 or 69 leaves on unthinned trees of Kawano natsudaidai. The proportion of small fruits was only 13 per cent on thinned trees as compared to 48 per cent on unthinned ones.

Tsertsvadze (1978) recommended that for regular bearing of Satsuma mandarin 50 per cent of the flowers should be removed. However, fruit weight, juice and sugar content were the highest in trees in which 75 per cent flowers were removed. In Satsuma mandarin, 200-300 ppm NAA, applied 25 days after full bloom caused 30 per cent increase in fruit drop which was considered ideal by Hirose *et al* (1978).

Application of NAA (500 ppm) to Valencia, 30 days after anthesis, during the on year successfully thinned the crop and produced even cropping (Gallasch, 1978).

Application of Ethephon (250 ppm) at the end of the natural fruit drop period effectively thinned the Beauty of Glen Retreat mandarin cultivar (Chapman 1980). Ethephon (200-250 ppm) applied near the end of the natural drop period effectively thinned Dancy mandarin and increased alternate bearing (Jahn 1981). Noma (1981) reported that the application of

5-chloro-1H-3-indazolacetic acid (OS-455) (IZAA) at 100-200 ppm, given 50 days after full bloom was effective in thinning smaller and younger Satsuma fruits. No phytotoxicity occurred on fruits or leaves, fruit size remained unaffected, but fruit sugar content increased in the treated trees. Wheaton (1982) tried various chemical thinning agents, such as NAA (200-800 ppm), CPA (250-1000 ppm), 2,4-D (25-100 ppm), 2,4, 5-T (20-500 ppm), Ethephon (50-250 ppm), IZAA (100-200 ppm), spray oil (0.5-1.0%) and Cycloheximide (2.5 to 12.5 ppm) on Dancy and Murcott mandarins. He observed that NAA (200-500 ppm) was the most effective and consistent thinning agent in both the cultivars.

Satsuma tree, whose flowers had been thinned heavily showed much less fruit drop than those whose flowers had been lightly thinned (Manabe *et al* 1982). Sugiyama and Miyagawa wase, at 40-50 days after full bloom, thinned the fruits much better than the later application was reported by (Noma 1983).

The thinning percentage, with the application of Ethephon at 150-300 mg/litre during natural fruit drop was higher, when the tree bears heavy crop load as compared to those bearing light crop (Chapman 1984). Satisfactory fruit thinning of Kawano natsudaidai was obtained by spraying the trees with ethychlozate (100 ppm) or 2,4-dichloro phenoxy-2-propionic acid triethamine salt (100 ppm), when fruits were 30-35 mm in diameter, by Hirose *et al* (1984). TUR (Chloromeguat) at 3 g/litre, Alar (Diaminozide) at 2 g/litre, Camposa (Ethephon) at 0.3 ml/litre applied to Satsuma lemon during active shoot growth, moderated the irregular bearing (Rosnadze *et al* 1986).

In order to reduce the fruit set, Josan and Sharma (1987) applied MH (1000 and 2000 ppm), Carbamate (5000 to 10000 ppm) at full bloom stage and NAA (300 ppm to 600 ppm) to marble sized fruits of Wilking mandarin. They observed that NAA (600 ppm) to be the most effective, as it reduce the fruit set without- altering the fruit quality.

Sharma and Awasthi (1988) reported that 350 ppm NAA spray or hand thinning induced sufficient fruit thinning in Kinnow when applied 35 days after full bloom. They further, reported in 1990, that NAA (350 ppm) and Ethrel (200 ppm) regulated crop in the subsequent year. Various combinations of Ethychlozate (50 or 100 ppm) and Ethephon (0-50 ppm) were applied to Satsuma 30 days after full bloom. Addition of 25-30 ppm Ethephon to 100 ppm Ethychlozate gave satisfactory fruit thinning without increasing defoliation and also combination of Ethychlozate (100 ppm) with Ethephon (5-10 ppm) gave effective results (Suzuki *et al* 1990). Maximum blossom/fruitlet thinning was recorded in 600 ppm Ethrel treatment followed by 400 ppm NAA at Abohar (Sharma *et al* 1993). However, the fruit size and internal quality was not affected.

Ethephon (200 ppm) applied at natural fruit fall stage on Montenegrina mandarin, reduced crop load and regulated overbearing in the following year (Souza *et al* 1993). Brar *et al* (1993) reported that the spray of NAA (400 ppm) applied at full bloom stage in Kinnow mandarin resulted in sufficient fruit thinning. Harty and Sutton (1994) demonstrated that hand thinning in Satsuma mandarin regulated leaf : fruit ratio, reduced alternate bearing and increased fruit size.

Yang and Changpeng (1997) demonstrated that fruit thinning can be used to control biennial bearing. In mandarin, leaf:fruit ratio of 25-30 and in large fruited Navel orange, leaf:fruit ratio of 80-100 were found optimum in reducing biennial bearing.

Singh *et al* (2000) recorded the highest fruitlet thinning, leaf:fruit ratio, return bloom, and minimum June drop and September drop with 400 ppm ethephon treatment. The maximum fruit yield was recorded in untreated trees. Whereas, the maximum fruit size was recorded with ethephon 400 ppm treatment.

Okuda *et al* (2002) demonstrated new crop management method called "syntemized alternate bearing method"(SABM) for mature Satsuma mandarin trees. This method aims at achieving alternate bearing by picking off all the fruits in the first year, followed by the absence of thinning in the second year. The yield per tree, number of fruits per tree, mean fruit weight, fruit quality increased with SABM as compared to control. The SABM could be applied for stable production in Satsuma mandarin.

Malfa *et al* (2004) reported the effect of manual and chemical fruit thinning on fruit size of Simeto mandarin. Manual thinning and NAA at 350, 500, 800 ppm were performed at the end of June. In all the thinning treatments, fruits were larger in size than those of Control. Although no significant differences were observed among the treatments, it seemed to authors that NAA at 500 ppm would be suitable for fruit thinning.

Cai *et al* (2005) reported the effect of fruit thinning on fruit size of mandarin cultivar Xiangshanhong. Fruit thinning was carried out on 14 June, 20 July, 18 August and 17 September. Thinning treatment increased fruit weight to over 200g as compared to around 100g in control. Likewise, pruning and hand fruit thinning were carried out to control the alternate bearing and fruit quality of Monteneqrina mandarins by Satori *et al* (2006). It was concluded that thinning of 33 per cent of the fruits on heavily loaded trees enhanced growers income and reduced alternate bearing.

2.2 EFFECT ON FRUIT QUALITY

The fruit thinning has been reported to effect the external and internal quality of the citrus fruits. NAA sprays (300 to 500 ppm) applied near June drop resulted in fruit thinning. Fruit was found to increase with severe thinning along with increased yield in the following year. Kinnow, Wilking, Satsuma mandarins, Dancy tangerine, Washington Navel, Valencia and Diller oranges all have shown increased fruit size due to thinning (Hield *et al* 1962, 1964, 1966; Hilgeman *et al* 1964).

Application of NAA (200 ppm) 30 days after full bloom on Unshiu orange resulted in increased citric acid, total sugars, fruit size, and proportion of large fruits. The ratio of large fruit (about 120 g) to medium (100 g) to small fruit (80 g) was 15:10:1 in trees sprayed with 300 ppm NAA, but proportion of small fruits on control trees was significantly higher (Nakajima *et al* l969). Significant increase in fruit weight and juice content of Kinnow mandarin was observed with application of NAA at 250 and 300 ppm, two weeks after fruit set, in Pakistan (Asi and Ali, l970). NAA sprays on Wilking mandarin during June drop resulted in heavier fruits but with less acid and juice content (Cassin 1970).

Application of NAA (1000 ppm) in June or early July resulted in production of the large and high quality fruits of Avana mandarin (Cutuli l973). Marked increase in juice content and amino acids (aspartic acid, threonine, serine, proline and arginines) was observed by spraying Satsuma trees with 250 ppm NAA. Thinning treatments tended to raise the reducing sugars level and lower that of citric acid, but total sugars were not affected (Hirose *et al* 1975). NAA (400, 500 ppm) applied to on year Kinnow mandarin tree, two weeks after fruit set resulted in heavier fruits with higher juice and sugar content (Ali *et al* l975). Sprays of Ethephon or 2,4,5-T at 200 ppm, during the period of fruit drop in Imperial mandarin resulted in increased fruit size. Pigment levels were unaffected by 2,4,5-T, but Ethephon increased carotenoids and reduced chlorophyll 'a' and 'b' levels. Treated trees showed reduced tendency towards biennial bearing (El-Zeftawi, 1976). Lavon and Bar-Akiva (1976) observed that foliar sprays of ammonium phosphate in combination with potassium nitrate applied at June drop to Wilking mandarin trees, thinned the fruitlets, fruit size was increased, the fruit quality was slightly reduced and the total soluble solids:acid ratio was improved.

The average acid content of thinned Kawano natsudaidai fruits was reduced to 1.78 per cent as compared to 2.19 per cent of the unthinned fruits (Tomita and Natsumi 1977). A new thinning compound Figaron (IZAA or ethyl-5-chloro-H-3-indazolyl-acetate), when applied 50 days after full bloom, on Satsuma at concentration of 100 to 200 ppm, resulted in increased Brix° (sugar content) and improved fruit colour without causing any phytotoxicity (Hirose *et al* 1978).

Application of Ethychlozate (100 or 200 ppm) 40 days after full bloom on "Satsuma trees resulted in uniform fruit size at harvest. It enhanced fruit colour and soluble solids content when applied 70 days after full bloom. Ethyclozate rapidly translocated to the roots, promoting their growth for 2-3 weeks after application, increased water and mineral metabolism and improved fruit quality (Kamuro and Hirari 1983).

Rensburg (1985) reported that spraying GA_3 on trees of loose-skinned Clementine with NAA for fruit thinning or with Cycloheximide to stimulate fruit growth, markedly improved fruit size at harvest. Ethephon

(200 ppm) or its combination with urea (4%) applied to Montenegrina mandarin trees at the natural fruit drop stage resulted in increased juice, T.S.S. and percentage of the larger fruits (Koller *et al* 1986).

NAA 600 ppm applied to Wilking mandarin trees at June drop, produced best results with regard to fruit size and fruit quality (Josan and Sharma, 1987). Hutton (1989) applied various concentrations of Ethephon on Valencia Late during the period of natural fruit drop and observed that Ethephon at 300 ppm reduced the crop load by 15 per cent and significantly increased the fruit size. The TSS:acid ratio increased from 9.75 to 10.91, the citric acid was lower, while the T.S.S and juice were relatively unaffected by Ethephon treatments. NAA at 300 ppm increased the large fruits by 20% but did not effect yield. The application of NAA (300 ppm) on natural fruit drop stage resulted in increased percentage of larger fruits by 11 per cent and yield by 7 per cent in Star Ruby grapefruit (Greenberg *et al* 1994). The effect of thinning methods on the production and quality of Satsuma mandarin was demonstrated by Ting and Xiaoping (1988). During 1995-1996, 5 methods were used to thin Satsuma mandarin fruits (1) traditional thinning to leave 30 leaves/fruit, uniformly distributed within the crown. (2) branches with thickness of 1.5 cm thinned, other branches unthinned to leave 30 leaves/fruit; (3) thinning all fruits in the inner crown; (4) half the crown thinned and the other half unthinned and (5) control. The best treatment for increasing production was method 2

(47% more than control) followed by method 3 (23% more than control). All thinned trees produced larger fruits with higher soluble solids content. Similarly, the effect of hand thinning and plant growth regulators i.e. NAA and ethephon, on fruit quality in Nagpur mandarin trees budded on Rangpur lime rootstock was investigated by Sawale *et al* (2001). Among the different treatments, fruit quality parameters were significantly improved with 350 ppm NAA.

The effects of fruit thinning with NAA (300, 400 and 500 ppm), ethephon (200, 300 and 400 ppm) and hexawin (500, 1000 and 1500 ppm) on the fruit quality of Kinnow mandarin was studied by Singh and Dhatt (2002). Thinning with ethephon (400 ppm) resulted in the highest fruit size and weight, total soluble solids, TSS:acid ratio and carotenoid content of the peel. The percentage of large sized fruits increased with 400 ppm ethephon treatment and acidity was the lowest with 300 ppm ethephon treatment. Similarly, Rufini and Remos (2002) studied the effect of manual fruit thinning (50, 60, 70 and 80%) on the fruit quality of tangerine c.v. Ponkan trees. Thinning increased fruit size, average fruit weight and juice content.

2.3 EFFECT ON PHYSIOLOGY OF THE TREE

The production cycle in Wilking mandarin, as related to carbohydrate level was studied by Lewis *et al* (1964). The mechanism controlling alternate bearing in Wilking mandarin trees appears to be related to NAA sensitive regulatory mechanism within the trees. Carbohydrate level was affected by alternate bearing but carbohydrate do not seem to be the factors limiting production. NAA (300 ppm) treated trees of Satsuma showed reduction in losses of carbohydrates and nitrogen up to 47 per cent from those of untreated trees (Noma 1970). The starch content of Kinnow roots was low during on year (when average crop load was 300 kg/tree) as compared with that of off year, (crop load 0-l kg/tree) (Jones *et al* 1975).

Heavily loaded trees of Murcott tangerine showed deficiencies of one or more minerals such as N, P, K or Mn. They also showed starch depletion of roots resulting in collapse of trees (Smith, l976).

Monselise *et al* (l982) showed that, in Wilking mandarin ratio of total starch in 'off year' to 'on year' trees was 3.4 (l7.2 for roots, 2.3 for aerial parts including fruits and 2.l for trunk). These workers also emphasized nutritional and hormonal factors responsible for the collapse of Wilking mandarins. Goldschmidt and Golomb (1982) reported that starch concentration was 3.6 (leaves) to 17.4. (medium roots) times higher in 'off year' trees than 'on year' trees. The 'off year' trees contained 13.26 kg starch and 10.66 kg soluble sugars, as against 2.95 kg starch and 6.75 kg soluble sugars in on tree. Application of Ethephon (300 ppm) to Murcott mandarin at natural fruit drop stage resulted in increased level of carbohydrates over control (Chapman l984). Mineral content of leaves like

N, P, K and carbohydrate content of roots was not significantly affected by Ethephon sprays on mandarins (Souza *et al* 1993). Similarly, the sugar level in the leaves was found not to be influenced by the use of different thinning treatments in mandarin, thereby indicating the allocation of photosynthates to alternate sinks (Santos *et al*, 2001).

2.4 EFFECT ON SUBSEQUENT CROPPING AND RETURN BLOOM

The principle aim of flower/fruitlet thinning was to avoid exhaustion of the tree and to promote regular bearing. It has been observed that in most of the fruits over cropping exhausts the tree of its photosynthetic and mineral resources leading to low crop in the next season. In crops like mango, apple and certain seeded varieties in citrus, the excessive 'on year' crop results in negligible subsequent cropping and the on 'off year' cycle is repeated. In apple, judicious fruit thinning in 'on year', has helped to regulate to cropping in 'off year' but the success of fruit thinning is variable in other crops. Parker (1934) observed that hand thinning in Valencia orange resulted in increased fruit size in the year of thinning and an increase in number of fruits for the following crop. Trees of Wilking mandarin, which had produced a heavy crop did not bloom or set a crop in following year. However, application of NAA to 'on year' successfully thinned the excessive years crop and improved the production in the following year (Lewis *et al* 1964). It was demonstrated by Hield *et al* (1962, 1966) that removal of 30 to 60 per cent of young fruits in Wilking mandarin can successfully induced a crop in the following 'off year' cycle.

Kleg and Minessy (1964) reported that 2,4-D caused fruit thinning and was effective in overcoming alternate bearing on Balady mandarin. The removal of more than 50 per cent fruitlets was effective in breaking the alternate bearing cycle in young Kinnow trees (Hilgeman *et al* 1964). The biennial bearing in sweet orange is caused by fruits inhibiting flower formation on wood on which they are borne, and this is brought about by a flower-inhibiting substance (possibly gibberellin-like) diffusing from the fruit (Moss 1971). Application of Ethephon (200 ppm) and NAA (350 ppm) on Wilking mandarin trees at 1 cm fruitlet diameter stage, reduced alternate bearing and resulted in satisfactory yields the following year (Galliani *et al* 1975).

Ethephon (250 ppm) applied to 'on year' Imperial mandarin trees at fruit drop stage resulted in reversing and regulating the cropping (El-Zeftawi 1976). Sprays of Ethephon (400 ppm) and NAA (500 ppm) reduced the alternate bearing cycle in Ellendale and Dancy mandarins (Gallasch 1988). Sharma and Awasthi (1988) demonstrated that the application of NAA at 950 ppm 35 days after full bloom regulated the crop in the subsequent year. The thinned trees, with low fruit loads had more flowers in the following year than those with heavy load trees (Morioka 1990). Similarly, in mandarin cv. Silverhill, leaf:fruit ratio between 15:1 to 20:1 was found optimum to reduce biennial bearing by Harty and Sutton

(1994). In 9 year-old trees of tangor budded on rangpur lime rootstock reduction in yield was observed due to thinning in 'on-year' with improved productivity in the following year. However, no significant effect of thinning in the 'off-year' was observed on the productivity in the following year (Marinho and Souza 1997). The spray of ethephon and figaron was found to increase fruit number in the following year by Castro *et al* (1998). Likewise, the effect of thinning on return bloom was studied by Singh (2000). The maximum return bloom was observed with 400 ppm ethephon treatment.

In Simeto mandarin manual thinning and NAA spray was found effective in overcoming alternate bearing (Malfa *et al* 2004). The leaf:fruit ratio of 35:1 was found effective in overcoming alternate bearing in Wase Satsuma mandarin by Tachibana and Yahata (2004). Similarly, Satori et al (2006) found that pruning and removal of 33 per cent of fruits on heavily loaded trees reduced alternate bearing.

CHAPTER - III

MATERIALS AND METHODS

The present investigations on the "Crop regulation studies in Kinnow mandarin" were carried out in the experimental orchard of the Department of Horticulture, Punjab Agricultural University, Ludhiana. These trees were grown under uniform conditions of soil and orchard management practices.

EXPERIMENT - I

Effect of different hand thinning levels on Kinnow mandarin

Treatment (Leaf:Fruit ratio)		Time of application
T_1	15:1 (Control)	60 days after full bloom
T_2	20:1	60 days after full bloom
T_3	25:1	60 days after full bloom
T_4	30:1	60 days after full bloom
T_5	35:1	60 days after full bloom
T_6	40:1	60 days after full bloom
T_7	45:1	60 days after full bloom

Effect of different concentrations of NAA on Kinnow mandarin

EXPERIMENT II

	Treatment	Dose (ppm)	Time of application
N_1	NAA (Napthalene acetic acid)	200	40 days after full bloom
N_2	NAA	250	40 days after full bloom
N_3	NAA	300	40 days after full bloom
N_4	Control (water spray)	--	40 days after full bloom

EXPERIMENTAL DESIGN

Single tree served as treatment unit and each treatment was replicated thrice. The data were analysed using Randomized Block Design.

SPRAYS OF CHEMICALS

Randomly selected trees were sprayed uniformly to slight run-off and the control trees were sprayed with tap water only. Before every spray treatment application, the knapsack sprayer used for spraying was washed thoroughly with water and rinsed with solution to be sprayed. Tween-20 was added in all the spray treatments.

3.1 PHYSICO-CHEMICAL CHARACTERISTICS OF FRUITS

3.1.l Fruit size : The length and diameter of ten randomly selected fruits were recorded with the help of a scale in centimeters.

3.1.2 Fruit weight: Twenty fruits from each tree were taken at random at the harvesting time and mean fruit weight was worked in grams per fruit.

3.1.3 Fruit volume: The volume of fruits was determined by water displacement method. A graduated cylinder was used for the purpose. The volume of ten fruits selected at random from each treatment was determined and mean volume per fruit was calculated in cubic cms.

3.1.4 Fruit colour : The rind colour was described with the help of Horticultural Colour Charts (Wilson, l938).

3.1.5 Juice content: A random sample of ten fruits was cut into halves and their juice was extracted with the help of a juice extractor. The juice was strained through a muslin cloth and weighed and was expressed as percentage of the total fruit weight.

$$\text{Juice percentage} = \frac{\text{Juice weight}}{\text{Weight of fruit}} \times 100$$

3.1.6 Seed number: For the purpose of seed content in Kinnow fruits a random sample of ten fruits was taken and average number of seed per fruit was calculated.

3.1.7 Peel percentage : Peel of fruits was removed and weighed. The percentage of peel was calculated on fresh weight basis.

$$\text{Peel percentage} = \frac{\text{Peel weight}}{\text{Weight of fruit}} \times 100$$

3.1.8 Peel thickness : The fruits were hand peeled and peel thickness was recorded with the help of Vernier's calliper in millimeters.

3.1.9 Rag percentage : Juice was extracted from peeled fruits and rag thus obtained was weighted. The percentage of rag was calculated on fresh weight basis.

$$\text{Rag percentage} = \frac{\text{Rag weight}}{\text{Weight of fruit}} \times 100$$

3.1.10 Carotenoid Content of Peel: The total carotenoids (β-carotene) were estimated by the method described by Booth (1945). Ten grams of mixed peel was placed in an oven at 40-45°C for 3-4 hrs to remove moisture. The dried peel was transferred to a mortar and approximately two gram anhydrous sodium sulphate was added to absorb remaining moisture. As the grinding proceeded, 10-15 ml of three per cent acetone in petroleum either (3 ml acetone + 97 petroleum ether) was added to extract the yellow pigments. The process was repeated 3-4 times. After total extraction, a final volume was made with solvent and its absorbance was read at 452 nm on the spectrophotometer. The solvent (3 per cent acetone in petroleum ether) was used as blank. The results were expressed in terms of β-carotene as mg/gm of peel.

$$\text{Carotenoid content of peel} = \frac{3.857 \times OD \times \text{Volume made}}{\text{Weight of the sample}} \times 100$$

3.1.11 Total soluble solids (T.S.S.): Freshly strained and thoroughly stirred juice was used for determining the total soluble solids with the help of hand refractometer and temperature correction made.

3.1.12 Total titrable acidity : The juice acidity was determined by titrating five ml juice aliquot against 0.1 N sodium hydroxide, using phenolphthalein as an indicator. The total acids were expressed as percentage of citric acid.

$$\text{Per cent acidity} = \frac{0.0064 \times N/10\ NaOH\ \text{used (ml)}}{\text{Juice taken (ml)}} \times 100$$

3.1.13 TSS / acid ratio : The ratio was calculated by dividing the value of TSS with that of the corresponding value to titrable juice acidity.

3.1.14 Palatability rating : The fruits were evaluated by a five members panel on Hidonic Scale (1-9) based on taste and flavour. The fruits were rated excellent (8-9), very good (6-7), good (5-6) fair (4-5) and poor (below 4).

3.2 FLOWERING AND FRUITING CHARACTERS

3.2.1 Fruit yield (kg per tree): The fruit yield in terms of number of fruits per tree and fruit weight per tree was calculated in each treatment unit.

3.2.2 Leaf:fruit Ratio: The leaf:fruit ratio was calculated by counting number of leaves per fruit 60 days after full bloom.

3.2.3 June drop : The fruit drop was recorded in June from already marked shoots on each side of plant and per cent drop worked out.

3.2.4 Return bloom: The flower number was counted on four representative tagged branches during the flowering season of 2007 and 2008 in order to determine the extent of return bloom under all the treatments. Per cent change in number of flowers in the year 2008 with respect to year 2007 was given as return bloom.

3.3 PHYSIOLOGICAL STATUS OF TREE

3.3.1 Starch content of twigs and roots

The starch content of bearing and non-bearing twigs and root bark was estimated using the procedure of Mcready *et al* (1950).

Extraction: 500 mg of powdered dry material was taken in centrifugal tubes and was homogenised with hot 80 per cent ethanol. The extract was centrifuged at 4500 rpm for 20 minutes. The alcoholic solution was decanted. The process was repeated and total of four washing treatment or until a test of anthrone is negative were given.

The sugar free residue was air dried. To this residue 5 ml of distilled water and 6.5 ml of 52% perchloric acid was added and reaction mixture was kept at 0°C for 20 minutes. After centrifugation at 5000 rpm for 10 minutes, the extract was strained. This step was repeated 2-3 times and supernatants were pooled and the volume was made to 100 ml with distilled water.

Estimation: Anthrone-sulphuric acid reagent was prepared by dissolving:

(a) 200 mg anthrone

(b) 100 ml of cold H_2SO_4 (95%)

In 0.5 ml of aliquot of above extract, 5 ml of cold anthrone reagent was added with constant stirring. The mixture was later heated for 8 minutes in a boiling water bath and cooled rapidly to room temperature. Absorption of greenish brown colour was recorded at 630 nm.

Calculation: Starch content in the sample was calculated from the standard curve prepared by using glucose and multiplying the values by conversion factor 0.9.

Statistical Analysis

The experiment was laid in Randomized Block Design using software CPCS1.

CHAPTER - IV

RESULT AND DISCUSSION

The present investigations entitled "Crop regulation studies in Kinnow mandarin" was conducted during 2007-2008 at New orchard, PAU, Ludhiana. The salient findings have been discussed in the light of scientific information available on the subject under the following headings.

4.1 PHYSICO-CHEMICAL CHARACTERISTICS OF FRUIT

4.1.1 Fruit Size

a) Fruit Length

The data on fruit length presented in table 1 and 2 indicated that there was no significant difference between different hand thinning levels as well as between different concentrations of NAA.

The data on fruit length indicated that maximum fruit length (5.63 cm) was observed in leaf:fruit ratio of 45:1. While on the other hand minimum fruit length (5.42 cm) was observed in leaf:fruit ratio of 15:1. Increase in fruit length was observed with increased leaf:fruit ratio. The increase in fruit size might be due to thinning of fruits and consequently less competition between the fruits for available photosynthates. Moreover, thinning at early stage stimulates cell division resulting in increased fruit size. Similarly, Augsti *et al* (1995) also observed that final fruit size was only partially related to fruit competition and only when fruit thinning was higher than 40 per cent that fruit size was affected.

Table 1 Effect of different hand thinning levels on fruit size, fruit weight and fruit volume in Kinnow mandarin

Treatment No.	Thinning level (leaf:fruit ratio)	Fruit size (cm)		Fruit weight (g)	Fruit volume (cc)
		Length	Diameter		
T_1	15:1 (Control)	5.42	6.65	123.4	124.41
T_2	20:1	5.45	6.69	125.6	126.74
T_3	25:1	5.47	6.72	127.3	128.60
T_4	30:1	5.50	6.76	129.6	131.12
T_5	35:1	5.54	6.81	132.8	134.62
T_6	40:1	5.59	6.87	136.4	138.56
T_7	45:1	5.63	6.93	139.7	142.17
	CD at 5%	NS	NS	7.23	7.35

Table 2 Effect of different concentrations of NAA on fruit size, fruit weight and fruit volume in Kinnow mandarin

Treatment No.	Treatment	Fruit size (cm)		Fruit weight (g)	Fruit volume (CC)
		Length	Diameter		
N_1	NAA 200 ppm	5.67	6.98	143.2	145.99
N_2	NAA 250 ppm	5.72	7.05	146.8	149.93
N_3	NAA 300 ppm	5.74	7.08	148.7	152.01
N_4	Control	5.43	6.66	123.7	124.67
	CD at 5%	NS	NS	6.32	6.67

The perusal of data on fruit length revealed maximum fruit length (5.74 cm) in case of NAA 300 ppm application and minimum (5.43 cm) in case of untreated trees. The present findings are also in line with earlier workers who reported that NAA (300-600 ppm) increased fruit size in Wilking mandarin (Josan and Sharma, 1987). The present findings corroborate the earlier findings of Brar *et al* (1993) who studied the effect of NAA on the fruit size on Kinnow mandarin. The improvement in fruit size might be due to reduced crop load with the increase in concentration of NAA.

b) Fruit Diameter

The effect of different concentration of NAA and different hand thinning levels on fruit diameter are presented in table 1 and 2, respectively.

The perusal of data indicated that the different leaf:fruit ratio did not have any significant effect on the fruit diameter. However, the maximum fruit diameter was recorded in leaf:fruit ratio of 45:1 (6.93 cm) and the minimum fruit diameter was observed in leaf:fruit ratio of 15:1 (6.65 cm). The present findings get support from the findings of Harty and Sutton (1994) who studied the effect of different leaf:fruit ratio on the fruit size in Satsuma mandarin in New Zealand. Similarly present findings corroborate with Zaragoza *et al* (1994) who studied the effect of hand thinning on the fruit diameter in Satsuma Clausellina.

Different concentrations of NAA did not significantly influence fruit diameter. However, the maximum fruit diameter (7.08 cm) was observed with the application of 300 ppm NAA, while the minimum fruit diameter (6.66 cm) was observed in untreated trees. The present findings corroborates the earlier findings of Brar *et al* (1993) who studied the effect of different chemical thinning agents on fruit size. The improvement in fruit size might be due to thinning of fruits and consequently less competition between the developing fruits.

4.1.2 Fruit weight

The data presented in table 1 and 2 showed that effect of leaf:fruit ratio and NAA application on the fruit weight.

The maximum fruit weight was observed in case of leaf:fruit ratio of 45:1 (139.7 g) which was at par with 40:1 and 35:1. However the minimum fruit weight was observed in leaf:fruit ratio of 15:1 (123.4 g) which was at par with 20:1, 25:1 and 30:1. The increase in fruit weight might be due to the reduction in the number of fruits per tree there by increasing leaf:fruit ratio which resulted in increased availability of the photosynthates and nutrients to the remaining fruits thus improving the fruit weight.

Similar, to our results increased fruit size was observed by Harty and Sutton (1994) in Satsuma mandarin at leaf:fruit ratio of 15:1 and 20:1. Also Ting and Xiaoping (1998) obtained large sized fruits at leaf:fruit ratio of 30:1 in Satsuma mandarin.

The maximum fruit weight (148.7 g) was obtained with NAA 300 ppm and it was at par with other two NAA treatments i.e. NAA 200 ppm and 250 ppm. Minimum fruit weight was observed in case of control (123.7 g) and it was significantly lower than all the NAA treatments. Thus it can be inferred from the data that fruit weight increased as the concentration of applied NAA increased. These results are in accordance with findings of Galliani *et al* (1975) who reported the NAA 350 ppm increased fruit weight in Wilking mandarin. Kaur *et al* (2005) also observed that NAA 400 ppm was the most effective thinning agent responsible for increased fruit weight in Kinnow mandarin. The improvement of fruit weight might be due to reduced crop load with thinning agent NAA thus increasing the availability of photosynthates and nutrients to the remaining fruits there by increasing the individual fruit weight.

4.1.3 Fruit volume

The data presented in table 1 and 2 showed the effect of different hand thinning levels and concentrations of NAA on fruit volume.

The maximum fruit volume (142.17 cc) was recorded in trees with leaf:fruit ratio 45:1 which was followed by leaf:fruit ratio of 40:1 (138.56 cc) and 35:1 (134.62 cc). However, the minimum fruit volume (124.41 cc) was recorded in trees with leaf:fruit ratio

Table 3 Effect of different hand thinning levels on juice content, seed number, carotenoid content of peel in Kinnow mandarin

Treatment No.	Thinning level (leaf:fruit ratio)	Juice content (%)	Seed number per fruit	Carotenoid content of peel (mg/g)
T_1	15:1 (Control)	52.79	22.8	1.06
T_2	20:1	52.87	22.7	1.10
T_3	25:1	52.60	23.4	1.07
T_4	30:1	52.23	23.0	1.08
T_5	35:1	51.72	22.5	1.08
T_6	40:1	51.15	20.7	1.08
T_7	45:1	50.52	20.4	1.09
	CD at 5%	NS	NS	NS

Table 4 Effect of different concentrations of NAA on juice content, seed number, carotenoid content of peel in Kinnow mandarin

Treatment No.	Treatments	Juice content (%)	Seed number per fruit	Carotenoid content of peel (mg/g)
N_1	NAA 200 ppm	50.07	24.0	1.06
N_2	NAA 250 ppm	40.49	24.2	1.07
N_3	NAA 300 ppm	49.19	25.3	1.07
N_4	Control	53.17	24.5	1.05
	CD at 5%	2.50	NS	NS

15:1 which was at par with trees having leaf:fruit ratio adjusted to 20:1 (126.74 cc) 25:1 (128.60 cc) and 30:1 (131.12 cc). The increase in fruit volume might be due to increased availability of carbohydrates due to lowering of fruit load and consequently increased fruit size and volume. The present findings corroborates the earlier findings of Marioka and Yahata (1989) who studied the affect of different leaf:fruit ratio on fruit size.

Fruit volume was significantly higher with the application of NAA 300 ppm (152.01 cc) as compared to control and NAA 200 ppm (145.99 cc). The latter treatment was at par with NAA 250 ppm (149.93 cc) for fruit volume. Wheaton and Stewart (1974) also observed that NAA (100-800 ppm) was effective thinning agent responsible for increased fruit volume in tangerine. The present findings are in conformity with the results reported by Sidhu (1990) who also observed increased fruit volume with increased concentrations of NAA in case of Kinnow mandarin. The improvement in fruit volume might be due to increase in concentration of NAA, because NAA reduce crop load and increased availability of carbohydrates and nutrients to the remaining fruits which enhanced fruit size and volume.

4.1.4 Juice Content (%)

The data regarding juice percentage are presented in table 3 and 4 as effected by different hand thinning levels as well as different concentrations of NAA.

Juice content of fruits was not influenced significantly by different leaf:fruit ratio. The minimum juice content (52.87%) was recorded in trees adjusted to leaf:fruit ratio of 20:1 followed by 40:1 (51.15%) and 35:1 (51.72%) in ascending order. The maximum juice content (52.87%) was recorded in trees adjusted to leaf:fruit ratio of 20:1 followed by 15:1 (52.79%) and 25:1 (52.60%). The possible reason for reduction in juice content under various treatments might be due to increase in peel proportion of fruits with increase in leaf:fruit ratio. Similarly, in Satsuma mandarin Sutton and Harty (1990) recorded decreased juice content with different treatments of hand thinning.

The different concentrations of NAA significantly influenced the juice content of fruits. The maximum juice content (53.17%) was obtained in control. However, the minimum juice content (49.19%) was recorded in plants sprayed with 300 ppm NAA. The juice content under this treatment was significantly lower than control, except NAA 250 ppm and NAA 200 ppm. The present findings are contrary to the reports of Das and Narayana (1974), who reported significant increase juice content in Mosambi with NAA treatments. The present studies corroborates with findings of Sinha *et al* (1977), who reported that increase in concentration of NAA resulted in increased juice content.

4.1.5 Seed number

The data presented in table 3 and 4 revealed that different treatments did not have significant effect on the number of seeds per fruit. The minimum seed number (20.4) was recorded in plants having leaf:fruit ratio of 45:1 which was at par with leaf:fruit ratio of 40:1 (20.7). The maximum seed number (23.4) was observed in plants having leaf:fruit ratio of 25:1 which was at par with the plants having leaf:fruit ratio of 30:1 (23.0).

The data on seed number per fruit indicated that it did not differ significantly with different concentrations of NAA. However, the minimum seed number (24.0) was obtained in plants sprayed with 200 ppm NAA. The maximum seed number (25.3) was recorded in plants sprayed with 300 ppm NAA. Lewin and Monselise (1970) also reported that number of developed seeds in Temple and Ortanque mandarin cultivars was reduced with 150 ppm NAA application at very early fruitlet development stage. However, Singh (1994) reported decrease in seed number per fruit with NAA application.

4.1.6 Carotenoid content of peel

The data for carotenoid content of peel under different treatments are presented in table 3 and 4.

The carotenoid content of peel was not significantly influenced by different leaf:fruit ratio. The maximum peel carotenoid content (1.10 mg/g) was recorded in plants adjusted to leaf:fruit ratio of 20:1

Table 5 Effect of different hand thinning levels on rag content, peel content and peel thickness in Kinnow mandarin

Treatment no.	Treatments	Rag (%)	Peel (%)	Peel thickness
T_1	15:1 (Control)	24.24	22.98	2.52
T_2	20:1	24.21	22.92	2.52
T_3	25:1	24.29	23.11	2.59
T_4	30:1	24.40	23.37	2.68
T_5	35:1	24.55	23.73	2.82
T_6	40:1	24.72	24.13	2.97
T_7	45:1	24.82	24.50	3.10
	CD at 5%	NS	NS	0.16

Table 6 Effect of different concentrations of NAA on rag content, peel content and peel thickness in Kinnow mandarin

Treatment no.	Treatments	Rag (%)	Peel (%)	Peel thickness
N_1	NAA 200 ppm	25.04	24.90	3.25
N_2	NAA 250 ppm	25.20	25.30	3.40
N_3	NAA 300 ppm	25.29	25.52	3.48
N_4	Control	24.12	22.71	2.44
	CD at 5%	NS	1.17	0.14

and it was at par with 45:1, 30:1, 35:1 and 40:1. On the other hand the minimum carotenoid content of peel (1.06 mg/g) was observed in plants adjusted to leaf:fruit ratio 15:1 which was at par with leaf:fruit ratio 25:1 (1.07 mg/g).

The carotenoid content at peel was also not significantly affected by different concentrations of NAA, however, various treatments resulted in increased carotenoid content of peel with increase in NAA concentration. The maximum carotenoid content of peel (1.07 mg/g) was obtained in plants sprayed with 300 ppm NAA and it was at par with 250 ppm and 200 ppm NAA. However, the mean minimum carotenoid content of peel (1.05 mg/g) was recorded in untreated trees. El-Zeftawi (1976) also reported increase in carotenoids of Imperial mandarin with NAA treatments.

4.1.7 Rag Content (%)

The data given in table 5 and 6 revealed that different hand thinning levels and different concentrations of NAA had no-significant influence on rag percentage.

Different leaf:fruit ratio did not have any significant effect on rag content. The maximum rag content (24.82%) was obtained in plants having leaf:fruit ratio of 45:1 followed by 40:1 (24.72%) and 35:1 (24.55%). The minimum rag content (24.21%) was obtained in plants having leaf:fruit ratio of 20:1. The present findings corroborate with the findings of Rufini and Remos (2002) they also observed that hand thinning did not have any significant effect on rag content in Ponkan tangerine.

The maximum rag content (25.29%) was recorded in plants sprayed with 300 ppm NAA followed by 250 ppm NAA (25.20%) and 200 ppm NAA (25.04%). The minimum rag content (24.12%) was recorded in untreated trees. The increase in rag content might be due to reduction in crop load by thinning agent NAA and thus production of heavier fruits. The present findings are also in line with earlier workers who reported that NAA increased rag content in Kinnow mandarin (Asi and Ali 1970).

4.1.8 Peel Content (%)

The data on peel percentage as effected by different hand thinning levels and different concentrations of NAA are presented in tables 5 and 6.

It is obvious from the data that different treatment did not significantly affect the peel percentage. However, the maximum peel percentage (24.50%) was observed with leaf:fruit ratio of (45:1) followed by 40:1 (24.13%), 35:1(23.73%), 30:1 (23.37%), 25:1 (23.11%), 15:1 (22.98%) and the minimum (22.92%) case of leaf:fruit ratio 20:1. The later treatment was at par with 15:1. The present findings are in line with the findings of earlier workers, Rufini and Remos (2002) who reported that different hand thinning treatments did not have any significant effect on peel content in Ponkan tangerine.

From the perusal of data of table 5 and 6 it is evident that peel percentage was significantly influenced by different NAA treatments and peel percentage was significantly higher in all NAA treatments as compared to control. The highest peel percentage (25.52%) was recorded in case of NAA 300 ppm, which was at par with NAA 250 ppm (25.30%) and NAA 200 ppm (24.90%), while the lowest peel percentage (22.71%) was observed in case of untreated trees. Similar results were obtained by Josan and Sharma (1987) in thinning experiments in Wilking mandarin and by Bajwa *et al* (1971) in sweet orange. Both workers recorded increased peel percentage with NAA treatments.

4.1.9 Peel Thickness

The data in table 5 and 6 showed that different hand thinning levels and different concentrations of NAA increased the peel thickness over the control. The maximum peel thickness (3.10 mm) was observed in trees adjusted to leaf:fruit ratio 45:1 which was significantly different from all other treatments. The minimum peel thickness was observed in leaf:fruit ratio of 15:1 and 20:1 followed by 25:1, 30:1, 35:1, 40: 1 and 45:1. Increase in peel thickness can be attributed to increased fruit size as a result of hand thinning. The present studies corroborate with the earlier findings of Sutton and Harty (1990) who reported that hand thinning treatments affected the peel thickness in Satsuma mandarins.

Table 7 Effect of different hand thinning levels in rind colour in Kinnow mandarin

Treatment No.	Thinning level (leaf : fruit ratio)	Rind colour
T_1	15:1 (Control)	25D (Dull orange)
T_2	20:1	25C (Light orange)
T_3	25:1	25C (Light orange)
T_4	30:1	25C (Light orange)
T_5	35:1	25B (Orange)
T_6	40:1	25A (Dark orange)
T_7	45:1	25A (Dark orange)

Table 8 Effect of different concentrations of NAA on rind colour in Kinnow mandarin

Treatment No.	Treatment	Rind colour
N_1	NAA 200 ppm	25B (Orange)
N_2	NAA 250 ppm	25B (Orange)
N_3	NAA 300 ppm	25A (Dark orange)
N_4	Control	25D (Dull orange)

The data Table 5 and 6 on peel thickness revealed that peel thickness (3.48 mm) was significantly higher with the application of NAA 300 ppm as compared to control. However, the significantly lower peel thickness (2.44 mm) was observed in control as compared to all the other treatments. The increased peel thickness can be attributed to increased fruit weight. These results were in agreement with the findings of Malaka and Bondok (1997) who reported that NAA affected the peel thickness in Balady mandarin.

4.1.10 Rind Colour

The data presented in Table 7 and 8 revealed that the rind colour was significantly influenced by the different hand thinning levels and concentrations of NAA.

The maximum colour development (25A) was observed in plants having leaf:fruit ratio of 40:1 and 45:1 minimum colour development (25D) was recorded in plants having leaf:fruit ratio 15:1. All other treatments enhanced colour development of the rind as compared with control. Similarly, to our results enhanced rind colour was observed by Singh (1994) in Kinnow mandarin.

The maximum colour development (25A) was found in plants sprayed with 300 ppm NAA. However, minimum colour development was recorded in untreated trees. All the NAA treatments enhanced colour development of the rind as compared with control. El-Zeftawi (1976) also observed change in fruit colour with different treatments of NAA in Imperial mandarin.

Table 9 Effect of different hand thinning level on TSS, acidity, TSS:acid ratio and palatability rating in Kinnow mandarin

Treatment no.	Thinning level (leaf:fruit ratio)	TSS (%)	Acidity (%)	TSS:acid ratio	Palatability rating
T_1	15:1 (Control)	11.2	0.972	11.52	7.16
T_2	20:1	11.4	0.976	11.68	7.28
T_3	25:1	11.1	0.961	11.55	7.31
T_4	30:1	11.5	0.932	12.33	7.30
T_5	35:1	11.8	0.956	12.34	7.36
T_6	40:1	11.8	0.963	12.25	7.13
T_7	45:1	11.9	0.958	12.42	7.27
	CD at 5%	NS	NS	NS	NS

Table 10 Effect of different concentrations of NAA on TSS, acidity, TSS:acid ratio and palatability rating in Kinnow mandarin

Treatment no.	Treatments	TSS (%)	Acidity (%)	TSS:acid ratio	Palatability rating
N_1	NAA 200 ppm	11.6	0.974	11.90	7.42
N_2	NAA 250 ppm	11.8	0.967	12.20	7.77
N_3	NAA 300 ppm	11.8	0.957	12.33	7.94
N_4	Control	11.3	0.968	11.67	6.77
	CD at 5%	NS	NS	NS	NS

4.1.11 Total Soluble Solids

The data regarding total soluble solids (TSS) are presented in table 9 and 10. It is evident from the data that total soluble solids were not significantly influenced by different treatments.

The maximum TSS (11.9%) was recorded in trees with leaf:fruit ratio adjusted to 45:1, which was closely followed by leaf:fruit ratio of 40:1 (11.8%) and 35:1 (11.8%). However, the minimum TSS (11.1%) was obtained in trees having leaf:fruit ratio 25:1 followed by 15:1 (11.2%) and 20:1 (11.4%). Improvement in total soluble solids might be attributed to reduce crop load due to thinning of fruits. Consequently increasing the leaf:fruit ratio thus improve the quality of fruits. Though difference between treatments was non significant, yet it was observed that TSS increased with increase in leaf:fruit ratio. The present studies corroborates with the findings of Yang and Changpeng (1997), who observed improved fruit quality with hand thinning.

Total soluble solids were also not significantly influenced by different concentrations of NAA. The maximum TSS (11.8%) was recorded with the application of 300 ppm NAA and the minimum TSS (11.3%) was recorded in untreated tress (control) as compared to all the NAA treatments.

Similarly, increased TSS was observed with NAA application in Kinnow (Sharma and Awasthi 1990) and Nagpur mandarin (Sawale *et al* 2001).

4.1.12 Acidity (%)

The data on per cent acid content under different treatments are presented in table 9 & 10. Acidity was not significantly influenced by different leaf:fruit ratio and different concentrations of NAA.

No specific trend for total acids was observed the minimum acidity (0.932%) was observed in plants having leaf:fruit ratio (30:1). However, the maximum acidity (0.976%) was found in plants having leaf:fruit ratio. However, the present studies are contrary to the earlier findings of Okuda *et al* (2002) who observed hand thinning treatments reduced the acidity Satsuma mandarin.

Non-significant differences were observed for acidity in Kinnow fruits with different NAA treatments. The maximum acidity (0.974%) was recorded in plants sprayed with 200 ppm NAA and minimum acidity (0.957%) was observed with NAA 300 ppm. No specific trend for total acids was noted. The present studies are contrary to the earlier findings of Sharma *et al* (1994) who reported NAA treatments reduced the acidity in in Kinnow mandarin and Malfa *et al* (2004) in Simeto mandarin.

4.1.13 TSS:Acid ratio

The data on TSS:acid ratio as affected by different hand thinning levels and spray of different concentrations of NAA are presented in Table 9 and 10, respectively.

TSS:acid ratio was not significantly affected by different to leaf:fruit ratios. The maximum TSS:acid ratio 12.42 was recorded in plants adjusted to leaf:fruit ratio of 45:1 followed by 35:1 (12.34), 30:1 (12.33). On the other hand the minimum TSS:acid ratio (11.52) was observed in plants adjusted with leaf:fruit ratio 15:1 which was at par with 25:1 (11.55). Similarly, to our results increased TSS:acid ratio was observed by Sawale *et al* (2001) in Nagpur mandarin.

Similarly the TSS:acid ratio was not significantly affected by different concentrations of NAA. The maximum TSS:acid ratio (12:33) was observed in plants sprayed by 300 ppm NAA followed by NAA 250 ppm (12.20). However, the minimum TSS:acid ratio (11.67) was recorded in untreated trees. In general various treatments resulted in increased TSS:acid ratio with increase in concentrations of NAA. Similarly increased TSS:acid ratio was observed with NAA application in Kinnow (Kaur *et al* 2005).

4.1.14 Palatability rating

The data on the effect of different leaf:fruit ratio and different concentrations of NAA on palatability ratio are presented in Table 9 and 10.

The data indicate that different leaf:fruit ratio did not differ significantly for palatability rating. The maximum palatability (7.36) was observed in plants having leaf:fruit ratio of 35:1 followed by 25:1 (7.31) and 30:1 (7.30). On the other hand minimum palatability rating (7.16) was observed in plants having leaf:fruit ratio 15:1.

Table 11 Effect of different hand thinning levels on fruit drop and yield in Kinnow mandarin

Treatment No.	Thinning level (leaf:fruit ratio)	June drop %	Yield (kg)
T_1	15:1 (Control)	14.6	68.50
T_2	20:1	13.2	52.78
T_3	25:1	10.2	39.31
T_4	30:1	7.1	35.58
T_5	35:1	5.6	33.35
T_6	40:1	5.2	29.96
T_7	45:1	6.6	26.11
	CD at 5%	0.5	3.10

Table 12 Effect of different concentrations of NAA on fruit drop and yield in Kinnow mandarin

Treatment No.	Treatments	June drop %	Yield (kg)
N_1	NAA 200 ppm	6.2	39.04
N_2	NAA 250 ppm	5.6	31.00
N_3	NAA 300 ppm	4.3	24.36
N_4	Control	14.3	72.09
	CD at 5%	0.48	2.52

The data on palatability rating was significantly affected by different concentrations of NAA. The maximum palatability rating (7.94) was recorded in plants sprayed with NAA 300 ppm. However, the minimum palatability rating (6.77) was recorded in untreated trees. Better TSS/TA might have resulted in improved palatability rating.

4.2 FLOWERING AND FRUITING CHARACTERS

4.2.1 June Drop

The perusal of data in Table 11 and 12 reveals that June drop was reduced with different leaf:fruit ratio and different concentrations of NAA.

Among the different leaf:fruit ratio, the lowest June drop (5.2%) was recorded in plants having leaf:fruit ratio of 40:1, which was at par with leaf:fruit ratio of 35:1 (5.6%). However, the highest June drop (14.6%) was obtained in plants having leaf:fruit ratio 15:1 and it was significantly higher as compared to all other treatments. In general, fruit drop decreased with the increase in leaf:fruit ratio, probably higher number of leaves per tree resulted in lower fruit drop or it might be due to altered physiology caused by lower fruit number per tree. The present findings corroborate with the earlier findings of Sun (1998) who observed that fruit drop is determined by crop load in Navel orange.

The lowest June drop (4.3%) was recorded in NAA 300 ppm treatment, followed NAA 250 ppm (5.6%) and NAA 200 ppm (6.2%). The highest June drop (14.3%) was recorded in untreated trees. The lowered fruit drop with hand thinning and NAA treatments can be assigned to reduced crop load. Chapman (1984) also observed that fruit drop is determined by crop load. Reduction in fruit drop with NAA application might be due elevated levels of auxins retained in plant tissue after causing initial drop and thus preventing further fruit drop. In Satsuma mandarin Ortola *et al* (1991) also recorded lower fruit drop with NAA application.

4.2.2 Fruit yield (kg)

The data regarding fruit yield are presented in table 11 and 12. Fruit yield was significantly influenced by different hand thinning levels as well as different concentrations of NAA.

All the treatments decreased the yield as compared to control and significant decrease in fruit yield was observed with increasing leaf:fruit ratio. The maximum yield (68.50 kg) was observed in plants having leaf:fruit ratio of 15:1 followed by 20:1 (52.78 kg) and minimum yield (26.11 kg) was recorded in plants adjusted to leaf:fruit ratio of 45:1 was followed by 40:1 (29.96 kg), 35:1 (33.35 kg) and 25:1 (39.31 kg) in ascending order. The present findings are contrary to the findings of Tachiban and Yahata (2004) who reported significant decrease in fruit yield with increase in leaf:fruit ratio in Wase Satsuma mandarin.

Table 13 Effect of different hand thinning levels on fruit thinning and return bloom in Kinnow mandarin

Treatment No.	Thinning level (leaf:fruit ratio)	Fruit thinning (%)	Return bloom (%)
T_1	15:1 (Control)	0.0	86.8
T_2	20:1	25.0	102.2
T_3	25:1	40.0	108.3
T_4	30:1	50.0	113.4
T_5	35:1	57.2	119.7
T_6	40:1	62.6	129.9
T_7	45:1	66.7	131.6
	CD at 5%		6.5

Table 14 Effect of different concentrations of NAA on fruit thinning and return bloom in Kinnow mandarin

Treatment No.	Treatments	Fruit thinning (%)	Return bloom (%)
N_1	NAA 200 ppm	51.2	112.3
N_2	NAA 250 ppm	62.4	125.3
N_3	NAA 300 ppm	69.7	135.6
N_4	Control	0.0	90.2
	CD at 5%		5.3

Foliar application of NAA at different concentration significantly influenced the yield. The maximum yield (72.09 kg) was obtained in untreated trees and it was significantly higher as compared to all the NAA treatments. The minimum yield (24.36 kg) was observed in plants sprayed with NAA 300 ppm followed by NAA 250 ppm (31.00 kg) and NAA 200 ppm (39.04 kg) in ascending order. Chemical thinning was found most effective in reducing the number of fruits per tree. There was a negative relationship between increasing concentration of NAA and number of fruits per tree. This may be attributed to higher percentage of fruit abscission and lower fruit set which reduced the number of fruits per tree.

Lower fruit yield with NAA application was observed in Kinnow mandarin (Sidhu *et al* 1990 and Singh *et al* 2000). The present findings are in contrary to the findings of Stover *et al* (2006), who reported the significant decrease in fruit yield in mandarins with application of NAA.

4.2.3 Return Bloom

The observations were also recorded on the extent of return bloom on the trees treated differentially in the proceeding season. The data presented in table 13 and 14 reveal that all the thinning treatments significantly enhanced the return bloom over the control.

Table 15 Effect of different hand thinning level on starch content of non-bearing shoots, bearing shoots and starch content of root bark in Kinnow mandarin

Treatment No.	Thinning level (leaf:fruit ratio)	Starch content in non-bearing shoots (mg/g)	Starch content in bearing shoots (mg/g)	Starch content in root bark (mg/g)
T_1	15:1 (Control)	27.0	20.4	19.8
T_2	20:1	28.6	21.5	23.7
T_3	25:1	28.5	21.7	24.3
T_4	30:1	28.7	21.8	25.1
T_5	35:1	28.6	21.8	25.9
T_6	40:1	28.8	21.7	26.8
T_7	45:1	28.8	21.9	28.4
	CD at 5%	NS	NS	1.4

Table 16 Effect of different concentration of NAA on starch content of non-bearing shoots, bearing shoots and starch content of root bark in Kinnow mandarin

Treatment No.	Treatments	Starch content in non-bearing shoots (mg/g)	Starch content in bearing shoots (mg/g)	Starch content in root bark (mg/g)
N_1	NAA 200 ppm	28.4	21.6	25.6
N_2	NAA 250 ppm	28.7	21.7	26.5
N_3	NAA 300 ppm	28.9	21.1	28.2
N_4	Control	27.3	20.5	20.5
	CD at 5%	NS	NS	1.15

The maximum (131.6%) return bloom was recorded in those plants thinned to leaf:fruit ratio of 45:1 and it was par with 40:1 (129.9%) and 35:1 (119.7%). The minimum (86.8%) return bloom was recorded in plants thinned to leaf:fruit ratio of 15:1 followed by 20:1 (102.2%) and 25:1 (108.3) in ascending order. The excessive crop in one year cause production of less crop in the next year because of possible drain on the stored resources of carbohydrates, minerals and other metabolites. The trees which matured less number of fruits produced good crop in the following year as they have higher tree reserves compared to unthinned trees, as is evident from starch content of roots Table 15 and 16. The present studies corroborate with the earlier findings of Yang and Changpeng (1997) who also reported significant increase in return bloom with increase in leaf:fruit ratio in citrus trees.

Among the different concentration of NAA the maximum return bloom (135.6%) was recorded with the application of 300 ppm NAA followed by the application of 250 ppm (125.3%). On the other hand minimum return bloom was observed in case of untreated trees (90.2 %). These results also get support from the research findings of Singh *et al* (2000) who reported increase in return bloom with NAA application.

4.3 PHYSIOLOGICAL STATUS OF TREE

4.3.1 Starch content of non-bearing shoots

The data on starch content of non-bearing shoots by different hand thinning levels and different concentrations of NAA are presented in Table 15 and 16.

The data reveal that different hand thinning levels did not differ significantly in terms of starch content of non-bearing shoots. However, the maximum starch content (28.8 mg/g) was recorded in 45:1 which was at par with 40:1 and 30:1, the minimum starch content (27.0 mg/g) was recorded in 15:1. In general, increased starch content in non-bearing shoots increased with increase in leaf:fruit ratio.

Similarly, data on starch content of non-bearing shoots indicated that it did not differ significantly with different concentrations of NAA sprayed. However, the maximum starch content of non-bearing shoots (28.9 mg/g) was recorded with the application of 300 ppm NAA followed by 250 ppm and 200 ppm NAA. On the other hand minimum starch content of non-bearing shoots (27.3 mg/g) was recorded in untreated trees. In general starch content in non-bearing shoots increased with the increase in concentration of NAA. These results are in line with Goldschmidt and Golomb (1982), who reported that removal of fruits in mid-summer resulted in build up of the starch reserve levels.

4.3.2 Starch content in bearing shoots

The data recorded on starch content in bearing shoots indicated that there was non-significant difference between treatments of NAA and different hand thinning levels, as is evident from table 15 and 16.

The maximum starch content in bearing shoots (21.9 mg/g) was observed in trees adjusted to leaf:fruit ratio of 45:1 followed by leaf:fruit ratio of 35:1, 30:1 and 40:1. However, the minimum starch content in bearing shoots (20.4 mg/g) was recorded in plants adjusted to leaf:fruit ratio 15:1 followed by 20:1 and 25:1. This increase in starch content of bearing shoots might be due to reduction in number of fruits with increasing leaf:fruit ratio.

From the perusal of data it is evident that starch content in bearing shoots did not different significantly with different treatments of NAA. The maximum starch content in bearing shoots (21.13) was in case of NAA 300 ppm, which was at par with 250 ppm and 200 ppm NAA. However, the minimum starch content in bearing shoots (20.5 mg/g) was in case of untreated trees. Improvement in starch content of bearing shoots might be due to reduction in crop load with the increase in concentration of NAA. These results are in line with Goldschmidt and Golomb (1982) who reported that removal of fruit in mid summer resulted in build up of the starch reserve levels. Similarly, Singh (1994) observed the level of starch content in bearing shoots increased with increase in application of NAA.

4.3.3 Starch in roots

The data on effect of different hand thinning level and NAA treatments on starch content of root bark are given table 15 and 16. The starch content of root bark was significantly influenced by different leaf:fruit ratio and different concentrations of NAA.

Starch content of root bark was the highest in plants thinned to leaf:fruit ratio of 45:1 (28.4 mg/g) and it was at par with leaf:fruit ratios of 40:1 (26.8 mg/g) and 35:1 (25.9 mg/g). The lowest (19.8 mg/g) starch content of root bark was recorded in plants having leaf:fruit ratio of 15:1 and it was significantly lower as compared to all other treatments.

Among the different NAA treatments, maximum starch content in root bark (28.2 mg/g) was observed in NAA 300 ppm and it was significant by higher as compared to all other treatments and control. NAA 250 ppm (26.5 mg/g) and NAA 200 ppm (25.6 mg/g) were at par for starch content of root bark. Minimum starch content of root bark was observed in case of control (20.5 mg/g) and it was significantly lower as compared to all the NAA treatments. This increase in starch content of root bark may be attributed to less number of fruits on the trees due to thinning, as fruits are major sink organs for carbohydrates. Likewise, Smith (1976) also observed root starvation in heavily loaded trees of Murcott tangerines.

CHAPTER - V

SUMMARY AND CONCLUSION

The present investigation entitled "Crop regulation studies in Kinnow mandarin" were carried out in the Kinnow Orchard, Department of Horticulture, Punjab Agricultural University, Ludhiana during 2007-2008. The young Kinnow trees have a tendency for overbearing which results in tree decline, low crop next year and poor quality fruits. The effect of hand thinning and NAA was studied on 10 year old Kinnow plants. The salient findings of the investigation are given below.

- The fruit size increased with all the hand thinning treatments as compared to control. However, the maximum fruit size viz. length (5.63 cm) and diameter (6.93 cm) was recorded in plants having leaf:fruit ratio of 45:1 and this was followed by 40:1. Among NAA treatments, the maximum fruit length (5.74 cm) and diameter (7.08 cm) was recorded with NAA 300 ppm.
- Fruit weight increased in all the hand thinning and NAA treatments as compared to control. The maximum fruit weight (139.7 g) was observed in plants having leaf:fruit ratio of 45:1 followed by 40:1. Among different concentrations of NAA, the maximum fruit weight (148.7g) was recorded with NAA 300 ppm.
- The maximum fruit volume (142.17 cc) was recorded in leaf:fruit

ratio of 45:1, among hand thinning treatments and NAA 300 ppm (152.01 cc) among different concentrations of NAA.

- Juice content was increased by all the hand thinning treatments, but all the treatments were at par. The maximum juice content (52.87%) was recorded in trees having leaf:fruit ratio 20:1. Among different NAA concentration, the maximum juice content (53.17%) was recorded in control.
- All the hand thinning and NAA treatments were at par for seed number per fruit.
- Peel carotinoid content increased with all the hand thinning and NAA treatments. The maximum peel carotenoid content (1.09 mg/g) was recorded in leaf:fruit ratio 45:1 among hand thinning treatments. Maximum carotenoid content of peel (1.07 mg/g) was recorded in NAA 300 ppm among different NAA treatments.
- Rag content was increased by all the hand thinning and NAA treatments. The maximum rag content (24.87%) was recorded in plants having leaf:fruit ratio 45:1 and among NAA treatments, the maximum rag content (25.29%) was recorded in NAA 300 ppm.
- Peel percentage was increased by all the hand thinning treatments but difference was non- significant. With NAA application the maximum peel content (25.52%) was obtained by application of NAA 300 ppm.

- Peel thickness increased with all the hand thinning treatments, but the maximum peel thickness (3.10 mm) was recorded in plants having leaf:fruit ratio 45:1. Peel thickness also increased with different concentrations of NAA and maximum peel thickness (3.48 mm) was recorded in NAA 300 ppm.
- There was no significant effect of different hand thinning levels and NAA treatments on rind colour.
- TSS content of fruits was improved by all the hand thinning and NAA treatments. The maximum TSS content was recorded with leaf:fruit ratio of 45:1 (11.9%) among hand thinning treatments and NAA 300 ppm (11.8%) with among NAA treatments.
- Acidity was not significantly influenced by different hand thinning levels or NAA concentrations.
- The highest TSS:acid ratio was recorded with leaf:fruit ratio 45:1 (12.42) and with NAA 300 ppm (12.33).
- Palatability rating was not significantly influenced with different hand thinning levels. Maximum palatability rating was observed in leaf:fruit ratio of 35:1 among hand thinning levels and NAA 300 ppm, among different NAA concentrations.
- All the thinning treatments were effective in controlling fruit drop. The June drop was minimum in trees having leaf:fruit ratio of 40:1 and those sprayed with 300 ppm NAA.

- The highest fruit yield was recorded in control and it was significantly higher as compared to both hand thinning and chemical thinning levels.
- All the thinning treatments increased return bloom as compared to control. The maximum return bloom (135.6%) was observed with NAA 300 ppm.
- The starch content of bearing and non-bearing shoots increased with different thinning treatments. However, different among difference treatments was non-significant.
- The starch content of root bark was increased with all the thinning treatments. The maximum starch content was observed in plants having leaf:fruit ratio 45:1 (28.4 mg/g) and NAA 300 ppm (28.2mg/g) among different concentrations of NAA.

CONCLUSION

All the thinning treatments resulted in increased fruit weight as compared to control, significant increase in fruit weight was recorded only with very severe thinning treatments, which resulted the significantly lowering of fruit yield as compared to control. However, return bloom improved with all the thinning treatments.

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