Effect of Plant Growth Regulators on Growth, Yield and Quality of Mandarin (*Citrus reticulata* Blanco) cv. 'Nagpur'

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HARI DAYAL CHOUDHARY

Thesis

Master of Science in Horticulture
(Fruit Science)

2013

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF HORTICULTURE AND FORESTRY, JHALAWAR

Maharana Pratap University of Agriculture and Technology,

Udaipur - 313001 (RAJ.)

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Thesis

Submitted to the

Maharana Pratap University of Agriculture and Technology, Udaipur

in partial fulfillment of the requirements for

the degree of

Master of Science in Horticulture
(Fruit Science)

By

HARI DAYAL CHOUDHARY

2013

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Place : Jhalawar

Date : **(Hari Dayal Choudhary)**

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ACRONYMS

%	:	Per cent
/	:	Per
@	:	At the rate of
a.i.:	Active ingredients	
C.D.	:	Critical difference
^{0}C	:	Degree celsius
cc	:	Cubic centimetre
cm	:	Centimeter
cv.	:	Cultivar
DAT	:	Days after treatment
2,4-D	:	2,4- Di-chlorophenoxy aceticacid
d.f.	:	Degree of freedom
et al.	:	(*et albiti*), and elsewhere
etc.	:	Etcetera
Fig.	:	Figure
g.	:	Gram
GA_3	:	Gibberellic acid
ha	:	Hectare
i.e.	:	*id est*), that is
Lit	:	Litre
Max.	:	Maximum
Mg	:	Milligram
Min.	:	Minimum
MSS	:	Mean sum of square
RDF	:	Recommended dose of fertilizers
No.	:	Number
NAA	:	Naphthalene acetic acid
NaOH	:	Sodium Hydroxide
1 N	:	One normality
NS	:	Non significant
PPM	:	Parts per million
Rh	:	Relative humidity
S.Em	:	Standard error of mean
TSS	:	Total soluble solids
Viz.	:	(*Videlicet*), namely

CHAPTER - 1

INTRODUCTION

1. INTRODUCTION

In India citrus fruits have a prominent place among popular fruit and being extensively grown under tropical and subtropical conditions. Among the various citrus species, mandarin, sweet orange and lime are the common fruits having 50, 21 and 15 per cent of total area under cultivation, respectively.

Mandarin (*Citrus reticulata* Blanco) is considered to be one of the most important cultivated species among citrus and is being commercially grown in specific region of the country, like 'Nagpur mandarin' in Central India, 'Khasi mandarin' in North Eastern regions and 'Coorg mandarin' in Southern States of Karnataka (Coorg, Chikmangaloor, Hassan), Kerala (Wyanad) and Tamil Nadu (Shevray Hills, Lower Palani Hills). Mandarin juice is refreshing and nutritious due to its ascorbic acid content, sweet acid taste and appealing colour.

"Nagpur Mandarin" is a highly polyembryonic species of Chinese origin (ponkan), having medium sized, upright trees with evergreen growth habit and relatively few thorns. Leaves are medium in size, lanceolate in form having prominent midrib and long narrowly winged petioles. Flowers are small, medium, fruit depressed, globose or sub-globose with thin, loose peel easily separating from the segments. Seeds are small, pointed with green cotyledons. Its single fruit contains 10-15 segments.The fruit size big, subglobose, average weight 110-125 gm, rind medium thick, fairly loosely adherent, surface is also relatively smooth but, segment found in 10-15 number and number of seeds 1-2 per segment, colour of peel pale orange yellow. Fruit have mild flavor, excellent quality, juicy, TSS 10-12^0 brix, and acidity 0.50-0.70%. Fully grown up tree bears 125 kg fruits.

The total production of oranges in India is 3255.0 thousand MT from an area of 324.0 thousand hectares with the productivity of 10 MT/ha. In Rajasthan, mandarin covers 15.2 thousand hectares area and the productivity of 17.9 MT/ha (NHB, Database, 2011). In Jhalawar district of Rajasthan mandarin is grown in on area of 22,500 ha, out of which 13,000 ha in the bearing stage and the production is 2 lac tonnes (Anon., 2012).

A lot of research has been done on the use of PGR to improve fruit size, delay in fruit maturity and over come rind staining in citrus. However, limited studies have been conducted to evaluate the complete profile of fruit quality in response to growth regulators application to citrus during fruit development. The use of growth regulators has become an important component of agro-technical procedures for most of the cultivated plants and especially for fruit plants (Monselise, 1979). So far, in citrus fruits, excessive fruit drop can be controlled by the exogenous application of plant growth regulators. The auxins and gibberellins are widely used to control the fruit drop in citrus and to improve the quality of fruit (Almeida *et al*., 2004). Although, some references are available in the literature and efforts have been made to control the fruit drop by exogenous application of growth regulators, but, there is no precise recommendation as and when to the control of fruit drop in 'Nagpur' mandarin. Moreover, it has also been reported that the pre-harvest drop of 'Valencia orange' in Florida was not reduced by the application of plant growth regulators, stressing the importance of climatic conditions on the effectiveness of growth regulators treatment (Greenberg et al., 1975).

Application of plant growth regulators has proven effective for increasing fruit size and delay fruit maturity (Coggins Jr and Hield, 1968). Fruit development is thought to be triggered by hormones (Talon *et al*., 1990) and it has been reported that the endogenous gibberellin status of the developing citrus ovaries is the limiting factor for the initiation of fruit development. Application of gibberellic acid (GA_3) before or at full bloom increased fruit size and pedicel length. Foliar application of different levels of GA_3 (5, 50, 100 and 500 mg L-1) to young fruitlets just after fruit set have been reported for gain in fruit weight, reduction in peel thickness and better recovery percentage with improved taste of grapefruit (Berhow,2000).

In 'Balady' mandarin fruit weight, diameter, volume, juice percentage, TSS, acidity, TSS:Acid ratio and ascorbic acid in juice were found to be affected by mid November spray treatments of GA_3 and $CaCl_2$ (El-Hammady *et al*., 2000).

Ontogenic development from fruit set to fruit ripening and final reach to customer, several agents are responsible for elimination of some fruits from fruit set to final maturity. These factors can include: abscission of flowers, dropping off of fruit-lets and ripe fruits, pests and diseases, unfavourable environmental conditions,

mechanical damages, nutritional disorders, peel puffing, low fruit shelf life, small fruit size, etc. For example, in some citrus varieties, pre harvest drop decreases fruit yield. In some citrus species, like mandarin, fruit peel puffing makes high losses and low fruit storage life. On the other hand, in some alternate bearing citrus varieties, small fruit size in "on" years, reduces selling price. Reports have shown that application of synthetic auxins after flowering until before ending June drop caused severe thinning of fruits (Brar, et al., 1992; Ortola, et al., 1991). Spraying just after June drop, causes abscission in some small and weak fruits (Ortola, et al., 1991). Several reports have shown that sprays of synthetic auxins after summer physiological drop (June drop), reduces young fruit-lets sensitivity to auxins thinning effect (Guardiola and Garcia-Luis, 1997), enlarged fruits, increased rind strength and decreased fruit peel puffing in some citrus cultivars (Greenberg, *et al*., 1992; El-Otmani, *et al*., 1993; Agusti, *et al*., 1995; Greenberg, *et al*., 1995). Late sprays of auxins on fruit-lets do not affect fruit size and do not thin fruit-lets any more (Greenberg *et al*., 2006). Application of auxin after June drop stimulates cell expansion. This cell expansion increases vesicle capacity for juice accumulation and therefore, the fruit grows faster. Delayed application of treatments, until cell expansion diminishes or ceases and makes treatment less effective (Agusti *et al*., 1994; 2002; Guardiola and Lazaro, 1987). Nawaz *et al.* (2008) reported that 2,4-D, NAA and GA_3 treatments reduced pre harvest drop of Kinnow mandarin compare to control, significantly. The lowest fruit drop of 12.95 per cent was observed in 20 ppm 2, 4-D, followed by 10 ppm 2, 4-D and 20 ppm GA_3 with a fruit drop of whereas, maximum fruit drop (49.03%) was found in control. It is also clear from the results that 2, 4-D treatments proved better compared to GA_3 and NAA but when the concentration of 2,4-D was increased up to 30ppm, fruit drop was also increased.

Keeping in view the role of PGRs in reducing the fruit drop as well as improving fruit quality, this study has been attempted to evaluate the effect of exogenous application of PGRs at fruitlet stage under Jhalawar agro-climatic conditions of Rajasthan (Zone-V) in 'Nagpur' mandarin.

The research entitled "Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco) cv. 'Nagpur" was conducted with the following objectives.

1. To study the effect of different plant growth regulators on growth and yield of mandarin.

2. To study the effect of different plant growth regulators on fruit quality.

3. To work out economics of treatment used.

CHAPTER – 2

REVIEW

OF LITRETURE

2. REVIEW OF LITERATURE

The literature pertaining to the studies carried out on "Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco) cv. Nagpur" is documented under following head and sub heads.

2.1 Effect of NAA on Growth, Yield and Quality Attributes

Boswell *et al*. (1976) found that application of naphthalene acetic acid (NAA) (Tre- Hold A-112) found effective for controlling the vegetative vigour of 'Hass' avocado following tree stumping, tree topping and shoot tip pruning.

Mohammed *et al.* (1984) reported that application of NAA, speciallyhigher concentration in guava reduced the height of the plants under UHDP system. However, their interaction effect under UHDP on number of branches / plants and length of longest branch/plant were non-significant.

Prakash *et al.* (1990) reported that foliar spray of NAA (20 to 80ppm) improved fruit retention and fruit weight in 'Tesia Samisto' peach.

Sharma and Awasthi (1990) studied in Kinnow observed that sprayed of NAA at 350 ppm improved fruit set (48.8 %).

Ortola *et al*. (1991) found that when NAA applied shortly after the end of the June drop, increases the fruit growth rate of Satsuma mandarin (*Citrus unshiu* Marc.), which resulted in bigger fruit size at harvest without any reduction in yield.

In lemon, application of NAA (10 to 40 ppm) had significantly increased size, weight and juice content of fruits. The TSS, acidity and ascorbic acid content were also higher in the fruits treated with growth regulators than in the control (Josan *et al*., 1998).

In pineapple application of NAA (50 ppm) significantly increases the number of leaves and leaf area over control(Ao and Sarma, 1999).

Greenberg *et al.* (2000) sprayed NAA (300 ppm) in June on fruit-lets of mandarins which reduces fruit numbers but increased fruit size without affecting total yield.

Holtzman *et al*. (2000) found that application of NAA (300ppm) spray at the early date (22 mm), thinned fruit, increased fruit size and decreases yield by 12%; whereas spraying at the second date (30 mm) did not effected on yield or fruit size in 'Valencia' orange.

Maibangra and Ahmed (2000) treated pineapple plant with 100 ppm NAA and it was found increased yield as compared to control.

Choi and Minsoon (2001) reported that application of NAA in “Fuji” apple significantly decreased shoot growth and regrowth rate. In addition 2 or 3 application of NAA (60-70 days after full flowering) at the concentration of 10 to 40 mg / l can control the canopy size in high density orchard system.

Ingle *et al*. (2001) revealed that foliar application of NAA (30 ppm) increases the fruit weight, acidity, juice per cent, peel and yield over control in ‘Nagpur’ mandarin.

Spray of 350 ppm NAA in ‘Nagpur’ mandarin significant improves the quality of fruits with respect to TSS, acidity and ascorbic acid content of juice(Sawale *et al.* 2001).

Yadav *et al.* (2001) concluded that in guava fruit weight, organoleptic rating, TSS, ascorbic acid and total sugar content increased significantly by the application of NAA @ 20 to 60 ppm.

Yeshayahu *et al.* (2001) stated that spray of 300 ppm NAA increased fruit size in ‘Myovaze Satsuma’ mandarin.

Hanzaii and Tafazoli (2002) found that spray of NAA at 0, 100, 200, 300 and 400 ppm on ‘Kinnow’ mandarin was observed that it is effective in thinning of fruits and control of fruiting.

Baghel and Tiwari (2003) concluded that spray of 6 per cent urea and 150 ppm NAA in mango found superior for increasing the total number of flowers/panicle and percentage of hermaphrodite flowers. However, maximum flowering and fruiting and number of fruits/tree was recorded under combined application of 4 per cent urea and 150ppm NAA.

Malfa *et al*. (2004) found that spray of NAA (500 ppm) in ‘Slimeto’ mandarin found that effective in fruit thinning.

Spray of`Clausellina' satsuma (*Citrus unshiu* Marc.) with reported that 25 ppm NAA and 50 ppm 2,4-DP at the end of fruilet abscission was reported that it has given improved fruit size and quality(Duarte *et al*. 2006).

Greenberg *et al*. (2006)observed the effect of spray of NAA 300 ppm on yield, fruit size, fruit quality, fruit splitting and the incidence of creasing in ‘Nova’ mandarin. The early NAA spray, thinned fruit lets, increased fruit size, decreased splitting to 30 per cent, decreased the incidence of creasing to 28 per cent compared to 36 per cent in the control, and had no effect on the yield.

Stover *et al.* (2006) observed that application of NAA during physiological drop when fruitlets averaged 8 to 16 mm in diameter that NAA application reduced fruit per tree, increased fruit size and decreased production of smallest size fruit in mandarin hybrids.

Stern *et al*. (2007) reported that the application with 25 ppm 2,4-dichlorophenoxyacetic acid (2,4-D) plus 30 ppm naphthaleneacetic acid (NAA; 0.3% AmigoTM), at the beginning of pit-hardening when fruitlet diameter was ca. 13 mm caused appreciable and significant increases in fruit size and total yield, except when the crop load was heavy.

Nawaz *et al.* (2008) studied the effect of foliar sprays of NAA at 10, 15 and 20 ppm in ‘Kinnow’ mandarin and maximum vitamin-C contents (45.30 mg/100g) was found in 15 ppm NAA.

Iqbal *et al.* (2009) reported that NAA (45ppm) spray reduces pre-harvest fruit drop, increased yield, pulp/acid ratio (11.31), TSS (11%), total sugar (7.45%), acidity and ascorbic acid in guava.

Jain *et al*. (2009) reported improving fruit quality and shelf life of mandarin fruit with the foliar application of NAA.

Asin *et al*. (2010) observed that application of NAA at 40 ppm in pear cv. ‘Conference’ and ‘Blanquilla’ and improved fruit retention per cent and fruit yield.

Greenberg *et al*. (2010) reported increased fruit size, fruit quality and the incidence of creasing in 'Washington' navel orange with the foliar application of NAA at 300 ppm.

Hasami and Abdi (2010) found that of NAA at 100 ppm increased bunch weight, improved physical properties (fruit weight, height, diameter and size), decreased TSS, total and reducing sugar in date palm.

Kassem *et al*. (2010) found that application of NAA at pea stage and marble stage in“Costata” persimmon significantly increased vegetative growth, fruit retention and fruit yield in both the seasons.

Amiri *et al*. (2012) applied with 0, 300, 400 and 500 ppm NAA through foliar spray and found that 400 ppm NAA spray reduces pre-harvest fruit in ‘Satsuma’ mandarin drop compare to control.

Ghosh *et al*. (2012) observed that application of spray of NAA (15ppm) was the most effective in reducing the fruit drop at different months after fruit set which resulted in doubling of fruit production as compared to control and improved fruit size in sweet orange.

Kacha *et al.* (2012) studied that application of NAA in phalsa and recorded that spray of 200 ppm NAA resulted maximum height of bush (177.33 cm) and length of shoot (99.17 cm).

Khankandani *et al.* (2013) observed that application of NAA @ 200 ppm in 'Siahoo' mandarin at 50 days after flowering regulate alternate bearing and decreases fluctuation of yield during different years.

2.2 Effect of GA_3 on Growth, Yield and Quality Attributes

Agusti *et al*. (1982) reported that a single spray of GA_3 at 5 ppm concentration at petal-fall to the entire tree enhanced initial set in the 'Navelate' sweet orange, but this effect was transient and in most cases final yield was not increased. But when followed by girdling, final yield was increased even in the most productive orchards, this effect being due to an increase in fruit number while fruit size was unaffected.

El-Hammady *et al*. (1990) spray in mandarin cv. Balady with GA_3 at 50, 100 or 200 ppm on 15 Dec., 1 Jan. or 15 Jan. before an expected heavy crop reduced the flowering percentage and yield for that season and also increased the yield in the following season.

Gregoriou *et al.* (1993) reported improvement in yield, tree vigour and fruit quality in'Carrizo' citrange with the foliar application of GA_3.

Thukral *et al*. (1993) reported that foliar application of GA_3 @ 25ppm increases shoot emergenc, fruit set, reduced the number of flowers/tree and percentage fruit drop compared with water-sprayed controls.

Soto-Oryiz *et al.* (1994) reported that application of GA_3 @ 25 or 40 ppm in 'Washington' Navel orange trees was observed that reduced the number of flowers (recorded in Feb.) by more than half and more than trebled percentage fruit set (recorded at the end of Apr.) compared with untreated controls.

Davies *et al.* (1999) the experiment was to determine the optimal time to apply gibberellic acid for increasing juice, yield and improving peel quality in ‘Hamlin’ sweet orange.

Nath and Baruah (1999) reported that application of GA_3 at 50 or 100 ppm was observed that delayed flowering, improved growth and yield in Assam lemon.

HuaXin and RongLin (2000) spray citron with 10 mg GA_3/kg 10 days before flowering could increase fruit set by 69.1 per cent, and it was especially effective on flowering branches without leaves.

Medeiros *et al.* (2000) found that GA_3 @ 20 ppm provided the best pre-harvest fruit drop control in 'Hamlin' orange.

Arzani and Akhlaghi-Amiri (2001) experiment was conducted to increase fruit size and quality in Satsuma mandarin sprayed with GA_3 at 0, 300, 400 and 500 ppm was observed that spray of 400 ppm GA_3 increase juice per cent, size, weight and diameter of fruit.

Ingle et al. (2001) revealed that foliar application of GA_3 at 25 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control in ‘Nagpur’ mandarin.

Menegucci *et al.* (2001) found that application of GA_3 @ 0, 10, 20, 40, and 120 mg/dm3 and spray of 120 mg/dm3 GA_3, at the time the color of the fruits began to change, and 45 days later and provided a 70 days delay of fruit harvest in 'Lima Sorocaba' orange.

Sanches *et al.* (2001) reported that reduced the number of flowers formed by 81per cent and increased production of out-of-season fruits (by 59.77%) in 'Tahiti' acid lime with GA_3 @ 20, 40 and 80 ppm.

Hanzaii and Tafazoli (2002) found that spray with GA_3 at 0, 25, 50, 75 and 100 ppm were applied 3 times during the late autumn and early winter seasons of 1993 on off trees. Flower numbers were reduced as a result of GA_3 application in the following spring but increased in the second spring in ‘Kinnow’ mandarin.

EelKim *et al.* (2003) application in Satsuma mandarin with GA_3 at 0, 25, 50 and 100 ppm and reported considerably decreased the number of flowers and increased the number of vegetative shoots. Fruit set rate showed an increasing tendency as the GA_3 level increased and increase fruit size.

El-Sabagh and Ahmed (2004) reported that application of GA_3 at 90 ppm in ‘Anna’ apple was found in the highest total soluble solid percentage and yield.

Huang and Huang (2005) reported that spraying a solution of GA_3 at 50 mg/kg (1 g of GA_3 + 20 kg water) at the 3/4 flower fall stage and again 10 days later, increased fruit set by 100 per cent in citrus.

Tumminelli *et al.* (2005) obserwed that application with gibberellic acid (GA_3) at 9.4 ppm in 'Tarocco' blood orangeswas found to delay changes in rind colour.

Zhang *et al.* (2005) studied in citrus fruit plant spray with 100 ppm GA_3 was found delayed chlorophyll degradation, inhibited carotenoid beta-cryptoxanthin biosynthesis and accumulation, which inhibited the development of fruit colour and lustre.

Chao and Lovatt (2006) found that application of 10 ppm GA_3 at 60 per cent full bloom, 75 per cent petal fall and in early July or 25 ppm at 60 per cent and 90 per cent full bloom, 75 per cent petal fall and 10 days after 75 per cent petal fall reduced total yield relative to the untreated control and application of GA_3 (15 or 25 ppm) at 60 per cent and 90 per cent full bloom, 75 per cent petal fall and 10 days after 75 per cent petal fall resulted in retention of significantly more fruit and increased yield.

Duarte *et al.* (2006) observed that application of gibberellic acid (GA_3) consistently reduced flower formation, but had a variable effect on the amount of first-grade fruit in the early harvest in `Clausellina' satsuma (*Citrus unshiu* Marc.).

Modesto *et al.* (2006) studied the effect of foliar sprays of GA_3 at 0, 5, 10, 15 and 20 ppm in ‘Ponkan’ mandarin and reported, delay in fruit harvesting, which was induced by the physiological effect of GA_3.

Saleem *et al.* (2007) reported that application of gibberellic acid (GA_3) was in different concentrations in Blood Red sweet orange trees two months after fruit set.

June fruit drop and different fruit quality parameters were studied to evaluate the optimum concentration of the growth regulators and increased growth, yield and quality of sweet orange fruits at all the concentrations.

Thirugnanavel *et al*. (2007) fount that application with 50 ppm GA_3 in June has given better performance in delaying of flowering, number of flower shoot, initial fruit -1 set, fruit retention, number of fruits and yield in acid lime.

Saleem *et al.* (2008) observed that application of GA_3 in 'Blood Red' sweet orange has reduced fruit weight, diameter, peel thickness and peel quality, improved juice content (%), pulp (%), reducing sugar, non-reducing sugar, total sugar, TSS (%) and vitamine C.

Sharma and Singh (2008) observed that application of GA_3 at 10 ppm in plum, proved more effective in promoting tree growth and fruit weight and volume and increased yield.

Nawaz *et al*. (2008) studied the effect of foliar sprays of GA_3 in Kinnow mandarin andresulted maximum fruit size (71.20 mm) at 10 ppm $GA_{3,}$ maximum fruit weight (155.53g) and juice percentage (52.16%) at 100ppm $GA_{3.}$

Greenberg *et al*. (2010) reported that increased fruit size and fruit quality in 'Washington' navel orange was obtained with the foliar application of GA_3 @ 20 ppm.

Roux and Barry (2010) found that repeated (4) foliar applications of GA_3 (at 64ppm) increased growth in 'Eureka' lemon (Citrus limon) shoots by 63 per cent, with no significant effect on rootstock and scion diameters. Vegetative growth of 'Eureka' lemon nursery trees was retarded following the repeated (4) foliar application of gibberellin-biosynthesis inhibitors.

Chao *et al.* (2011) showed that application GA_3 at 15 or 25 ppm at 60 per cent bloom, 90 per cent bloom, 75 per cent petal fall and 10 days after 75per cent petal fall and found significant increase in the number of fruit per tree and yield and improved fruit set or fruit size in mandarin.

Garner *et al*. (2011) working in ‘Hass’ avocado reported that foliar application of GA_3 at 25 ppm increased yield and fruit size.

Moneruzzaman et al. (2011) found that application of GA_3 in red jambu air madufruits (*Syzygium samarangense*) increased fruit length and diameter. Furthermore, it enhanced faster fruit growth and color development in addition to increasing fruit number, weight and yield. It also decreased premature fruit dropping. However, spraying with 20 ppm GA_3 increased the number of buds and fruit setting and reduced bud dropping before anthesis. With regard to fruit quality, the application of GA_3 at 50 ppm increased total soluble solids (TSS), total sugar, total biomass and total flavonoids content in the fruits by 112, 97, 45 and 92 per cent compared with the control treatment.

Bhujbal *et al*. (2012) found that application of GA_3 at 50, 100 and 150 ppm was showed that spray of 150 ppm GA_3 earliness in sprouting of new shoot, increased shoot length and maximum number of leaves per shoot in sapota.

Galvan *et al.* (2012) reported that application of GA_3 @ 32.2 ppm in ‘Washington’ Navel orange hasresulted maximum increase in fruit set.

Khalid *et al*. (2012) working in young 'Kinnow' mandarin found that the spray of gibberellic acid 10 ppm at fruit setting stage and their effect on fruit quality was evaluated immediately after harvest. The PGRs alone had significant influence on juice mass (%), rag mass (%), ascorbic acid (mg 100 mL-1) and reducing sugars (%) whereas, rind mass (%), TSS, titratable acidity (TA), TSS:TA and total sugars (%) were not affected by PGRs applications.

Kacha *et al.* (2012) reported that application of 150 ppm GA_3 significantly increased number of flower per shoot (151.21), number of fruit per shoot (60.74), fruits weight (49.80 g), juice content (57.78%) and minimum seed per cent (30.44%) and maximum yield (1.71 kg/plant) and (5800 kg/ha).

Kumar *et al.* (2012) observed that the application of GA_3 in strawberry at 80 ppm improved vegetative growth, runner production, ascorbic acid and acidity.

Reddy and Prasad (2012) reported that the spray with GA_3 75 ppm has increased fruit size and yield in pomegranate cv. Ganesh.

2.3 Effect of 2,4-D on Growth, Yield and Quality Attributes

Lima and Davies (1984) observed that spray of 2,4-D in navel orange with 10 or 20 ppm after midbloom, reduced summer fruit drop in all seasons.

Prakash *et al.* (1990) reported that application of 2,4-D at 10 to 40 ppm has improved fruit retention, fruit weight and TSS in 'Tesia samisto' peach.

Gregoriou *et al.* (1993) observed reduced percentage of fruits drop in trees on all rootstocks except those in Carrizo citrange with the foliar application of 2,4-D.

Chattha *et al.* (1999) found that the application of 2,4-D at concentration with 20, 30, 40 ppm after fruit set to the control of fruit drop in mango cv. Samer Behisht Chausa. In a trial, application of 2,4-D at 40 ppm resulted in maximum fruit retention and minimum fruit drop.

Medeiros *et al.* (2000) found that application of 2,4-D at 10 ppm has given the best pre-harvest fruit drop control in 'Hamlin' orange.

Arzani and Akhlaghi-Amiri (2001) experiment was conducted to increase fruit size and quality in Satsuma mandarin with 60 ppm 2,4-D sprayand found increased juice per cent and fruit size.

Ingle et al. (2001) revealed that foliar application of 2,4-D at 10 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control in Nagpur mandarin

Menegucci *et al*. (2001) found that application of 2,4-D at the time the color of the fruits began to change and 45 days later and provided a 70 days delay of fruit harvest in 'Lima Sorocaba' orange.

Hanzaii and Tafazoli (2002) found that spray of 2,4-D at 0, 100, 200, 300 and 400 ppm in 'Kinnow' mandarin and observed that number of flowerswere reduced as a result of GA_3 application in the following spring but increased in the second spring.

Tumminelli *et al*. (2005) observed that application of 2,4-D is effective in delaying and reducing the undesired fruit abscission and senescence in 'Tarocco' blood oranges.

Duarte *et al*. (2006) reported that application with 20 ppm 2,4-D at flowering in `Clausellina' satsuma (*Citrus unshiu* Marc.) has given improved fruit size and quality.

Greenberg *et al*. (2006) observed the effect of spray with 2,4-D, 40 ppm on yield, fruit size, fruit quality, fruit splitting and the incidence of creasing in 'Nova' mandarin and found that early spray of 2,4-D decreased fruit splitting to 25 per cent, increased yield to 50 kg/tree compared to 37 kg/tree in the control, increased fruit size and had no effect on the incidence of creasing.

Saleem *et al*. (2007) found that application of 2,4-D in different concentrations on Blood Red sweet orange trees two months after fruit set. Different fruit quality parameters were studied to evaluate the optimum concentration of the growth regulators. Juice quantity, TSS, total sugars and reducing sugars were improved by most of the treatments compared with control but in case of acidity and Vit. C, there was not any clear cut trend of treatment effect.

Stern *et al.* (2007) observed that application of 25 ppm 2,4-D plus 30 ppm NAA at the beginning of pit-hardening in cherry caused appreciable and significant increases in fruit size, total yield and fruit quality.

Amiri *et al.* (2008) found that spray of 2,4-D in Italian orange is effective and economical way to reduce citrus pre harvest fruit drop.

Nawaz *et al*. (2008) studied the effect of foliar sprays of 2,4-D at 10, 20 and 30 ppm in Kinnow mandarin and found lowest fruit drop of 12.95 per cent, increased number of fruits/plant and fruit weight/plant. In this case maximum TSS (12.03%), Reducing sugars (3.44%), Non-reducing sugars (5.75) and Total sugars (8.86%) were found in 30ppm 2, 4-D and minimum acidity (0.78%) was found in 10ppm 2, 4-D.

Jain *et al*. (2009) reported improvedfruit quality and more shelf life in mandarin fruit with the foliar application of 2,4-D.

Amiri *et al*. (2012) applied 0, 10, 30 and 60 ppm 2,4-D through foliar spray and found that 60 ppm spray reduced pre harvest drop compare to control, significantly decreased percent of small, very small fruit size and increase large and marketable fruit size in Satsuma mandarin.

Reddy and Prasad (2012) reported that application of 2,4-D at 20, 30 and 40 ppm three times starting at full bloom and, subsequently, at 45 and 90 days after fruit set in pomegranate cv. Ganesh, has resulted significantly increased fruit size in length, breadth and volume and higher fruit weight (262.23g), higher aril percent and maximum number of fruits (64.00) which resulted in highest fruit yield of 16.78 kg/plant.

Ashraf *et al*. (2013) conducted an experiment to see the influence of 2,4-D in Kinnow and observed improved fruit weight, more number of fruits per plant, juice percentage, total soluble solids (TSS), ascorbic acid content, acidity, TSS/acid ratio, and reduced the fruit drop.

2.4 Effect of Triacontanol on Growth, Yield and Quality Attributes

Sud and Parmar (1990) found that application of triacontanol at 300 ppm in apricot cv. ‘New Castle’ both on pea and pit hardening stage resulted in largest size fruit with highest sugar content.

Zhang *et al.* (1988) reported that application of 1.0 to 2.0 ppm triacontanol at flowering stage in litchi cv. 'Lantek' resulted in increased fruit set.

Nagalaxmi and Gunasekaran (1989) observed improved total number of leaves and growth in 'Poovan' banana by application of triacontanol.

In guava Mandal and Kumar (1989) found that foliar spray of triacontanol in the form of mixtalol @ 6 ml/10 l water was found to be effective with respect to length of terminal shoot, number of leaves and increase in leaf area

Jindal and Chandel (1996) reported that application with 20 ppm triacontanol in plum significantly increased fruit set percentage.

Barwa (1998) observed that foliar spray with 2.5 to 10 ppm triacontanol in 'Santa Rosa' plum has increased fruit retention.

Sud and Thakur (1998) reported that application of triacontanol at 2.5, 5.0, 7.5 and 10 ppm in peach cv. Elberta at two active stages of fruit development i.e. pea stage and after pit hardening and resulted that spray with 5ppm triacontanol at the pea stage increased fruit size in terms of length, diameter, weight and volume, total soluble solids, total sugar and vitamin C content was noticed to be maximum with 7.5 ppm concentration.

Mandal and Kumar (1999) sprayguava plant with mixtalol [triacontanol] at 2, 4 and 6 ml, miraculam [triacontanol] at 2.5, 5.0 and 7.5 ml and vipul [triacontanol] at 0.25, 0.5, and 1.0 ml, 3 weeks before fruit set and after fruit set and observed highest increase in leaf area (57.43%), highest fruit set (92%), length (6.92 cm) , diameter (6.76 cm) and reducing sugar content (4.90%) with 6 ml mixtalol . Mixtalol and miraculam at 6 and 7.5 ml, respectively, resulted in the lowest fruit acidity (0.35%).

Mahajan and Sharma (1999) observed that spray of triaccotanol at 10 and 20 ppm in plum significantly increased fruit size, weight and TSS content of fruit over control.

Borowski *et al.* (2000) concluded that spray of triacontanol had significantly increased the chlorophyll content of leaves and yield of fruits in tomato.

Murlidharan *et al.* (2000) found that application with 0.1 per cent Vipul (triacontanol) at 300 ml / ha gave the significantly higher yield in tomato.

Power *et al.* (2000) found that spray with 0.5 per cent triacontanol resulted in the highest value for vine length, number of leaves and 100 leaf weights in betelvine.

Ghawade et al. (2002) studied of physico chemical characters of the fruits in Nagpur mandarin located at different sides of trees and found that, fruits located inside the tree contain less TSS and acid whereas, those exposed in the sun had more total soluble solids, ascorbic acid and rapid colour development resulting in early ripening.

Mahajan and Sharma (1999) observed that application of triacontanol at 10 and 20 ppm in plum significantly increased fruit size, weight and TSS content of fruit.

Brar and Rana (2005) sprayed triacontanol on temperate fruits and highlighted its effect on plant growth characteristics, fruit set, yield and quality.

Tomar and Singh (2007) studied the influence of foliar application of nutrients and bioregulators on growth, fruit set, yield and nut quality in walnut cv. Local Selection.

Sharma *et al.* (2008) found that application of triacontanol at 2.5, 5.0, 7.5 and 10.0 ppm thrice, viz., 7 days before full bloom, 15 days after full bloom and one month after second application in apple cv. Red Delicious and recorded that spray of 7.5ppm triacontanol increased shoot extension growth, fruit set, fruit quality and fruit yield significantly in comparison to other triacontanol treatments.

Sharma and Singh (2008) observed that application of triacontanolat 5 ppm in plum proved more effective in promoting tree growth, fruit weight, volume and increased yield.

Shinde *et al.* (2008) reported that application of triacontanol at 300, 500, and 700ppm at flowering, pea and marble stage of fruit development in mango cv. Parbhani Bhusan and showed that spray of 700ppm triacontanol significantly given maximum length (10.91 cm), breath (8.91 cm), volume (336.58 cm3), weight (330.41 g), mesocarp (69.92%) and lowest proportion of endocarp (12.00%) .

Chowdhary *et al*. (2009) found that spray with triacontanol 0.05% in two cultivars of water chestnut and observed increased the volume of individual fruit by 45.32% in Haldipada green and 47.11% in Haldipada red cultivars and the fresh fruit yield also increased 32% in green and 31.25% in red cultivars. But the soluble carbohydrate content in fresh fruits decreased by 25.46% to 29.61% in triacontanol treated green and red fruit cultivars.

Borowska and Prusinski (2011) observed that applicationof Triacontanol in yellow lupin and reported significantly increased yield.

CHAPTER - 3

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled **"Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco.) cv. Nagpur"** was conducted during the year 2012-13 at the Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalawar. The details of techniques followed and materials used during the course of experimentation are described below :

3.1 Climate and Weather

Zone – V (Humid South Eastern Plain)

District Jhalawar extends over 6.32 lakh ha. land area and located at 23°4' to 24°52' N – latitude and 75°29' to 76°56' E – Longitude in South Eastern Rajasthan. The climate of Jhalawar is typically sub-humid and characterized by extremes of temperature both summer and winter with high rainfall and moderate relative humidity. The average rainfall in the region is about 1000 mm. Maximum temperature range in the summer is 43– 48 ^{0}C and minimum 3– 5 ^{0}C during winter (Table 3.1 and Fig. 3.1). The mean weekly weather data for temperature, relative humidity and rainfall recorded during the experimentation (first week of July, 2012 to last week of April, 2013) are presented in Table 3.1 and depicted through Fig. 3.1. Agriculture and forest lands occupy 73.5 per cent area, respectively in the district. Major kharif crops of the district are soybean, maize and pulses. While in rabi, wheat, mustard, coriander and garlic are main crops. The district has attained premier position in cultivation of mandarin orange.

3.2 Soil conditions

In order to assess the physico-chemical properties of the experimental plot, the soil samples were drawn randomly from different location in the field at a depth of 0 – 30, 30 □ 60 and 60 □ 90 cm before the commencement of the experiment. A representative sample was prepared and subjected to mechanical, physical and chemical analysis. The detailed study of soil properties as observed is presented in Table 3.2.

Table 3.1: Mean weekly meteorological parameters for the period of experimentation (from July, 2012 to April, 2013)

Standard weeks number	Duration	Temperature (ºC)		Relative humidity (%)	Total rainfall during the week (mm)
		Max.	Min.	Sum.	
27	01-07 July, 2012	37.31	25.41	66.00	16.05
28	08-14 July, 2012	32.94	25.19	78.14	6.62
29	15-21 July, 2012	35.21	25.97	67.28	0.66
30	22-28 July, 2012	31.96	25.77	78.28	4.48
31	29 July-04 Aug., 2012	23.50	20.50	84.42	4.11
32	05-11 Aug., 2012	29.61	24.27	88.00	10.31
33	12-18 Aug., 2012	28.54	23.60	91.57	8.25
34	19-25 Aug., 2012	30.24	23.79	89.71	11.45
35	26 Aug.-01 Sep., 2012	31.89	24.19	90.42	24.19
36	02- 08 Sep., 2012	31.34	23.877	91.71	9.37
37	09-15 Sep., 2012	30.47	23.68	90.14	3.25
38	16-22 Sep., 2012	31.95	22.34	82.57	1.31
39	23-29 Sep., 2012	33.53	20.37	72.57	0.57
40	30 Sep.-06 Oct., 2012	35.53	19.34	56.42	0.057
41	07-13 Oct., 2012	35.25	17.69	46.85	0
42	14-20 Oct., 2012	35.12	16.90	45.42	0
43	21-27 Oct., 2021	31.64	17.99	41.00	0
44	28 Oct.- 03 Nov., 2012	30.93	12.83	42..42	0
45	04-10 Nov., 2012	29.99	11.17	43.71	0
46	11-17 Nov., 2012	30.36	11.57	40.28	0

47	18-24 Nov., 2012	26.58	10.85	49.42	0
48	25 Nov.-01 Dec., 2012	28.93	10.43	48.57	0
49	02-08 Dec., 2012	28.66	10.89	52.00	0
50	09-15 Dec., 2012	28.04	10.55	53.57	0
51	16-22 Dec., 2012	25.60	8.44	57.28	0
52	23-29 Dec., 2012	24.78	4.31	52.00	0
1	30 Dec.,12-05 Jan., 13	21.23	6.26	61.28	0
2	06-12 Jan., 2013	23.33	3.34	51.71	0
3	13-19 Jan., 2013	25.73	9.13	60.57	0.14
4	20-26 Jan., 2013	19.17	3.92	55.57	0
5	27 Jan.-02 Feb., 2013	20.17	4.92	54.57	0
6	03- 09 Feb., 2013	25.73	9.13	60.57	0
7	10-16 Feb., 2013	19.17	3.91	55.47	0
8	17-23 Feb., 2013	26.49	10.50	63.14	0.03
9	24 Feb-02 March, 2013	29.77	13.17	51.28	0
10	03-09 March, 2013	26.49	10.50	63.14	0
11	10-16 March, 2013	29.77	13.05	50.00	5.14
12	17-23 March, 2013	34.14	15.73	44.57	0.06
13	24-30 March, 2013	33.82	18.90	35.28	0.68
14	31 Marh-06 April, 2013	36.59	17.71	24.57	0
15	07-13 April, 2013	37.42	18.60	23.62	0
16	14-20 April, 2013	39.01	17.89	33.24	0
17	21-27 April	41.51	20.33	34.35	0

Source : Irrigation Department Government of Rajasthan, Jhalawar

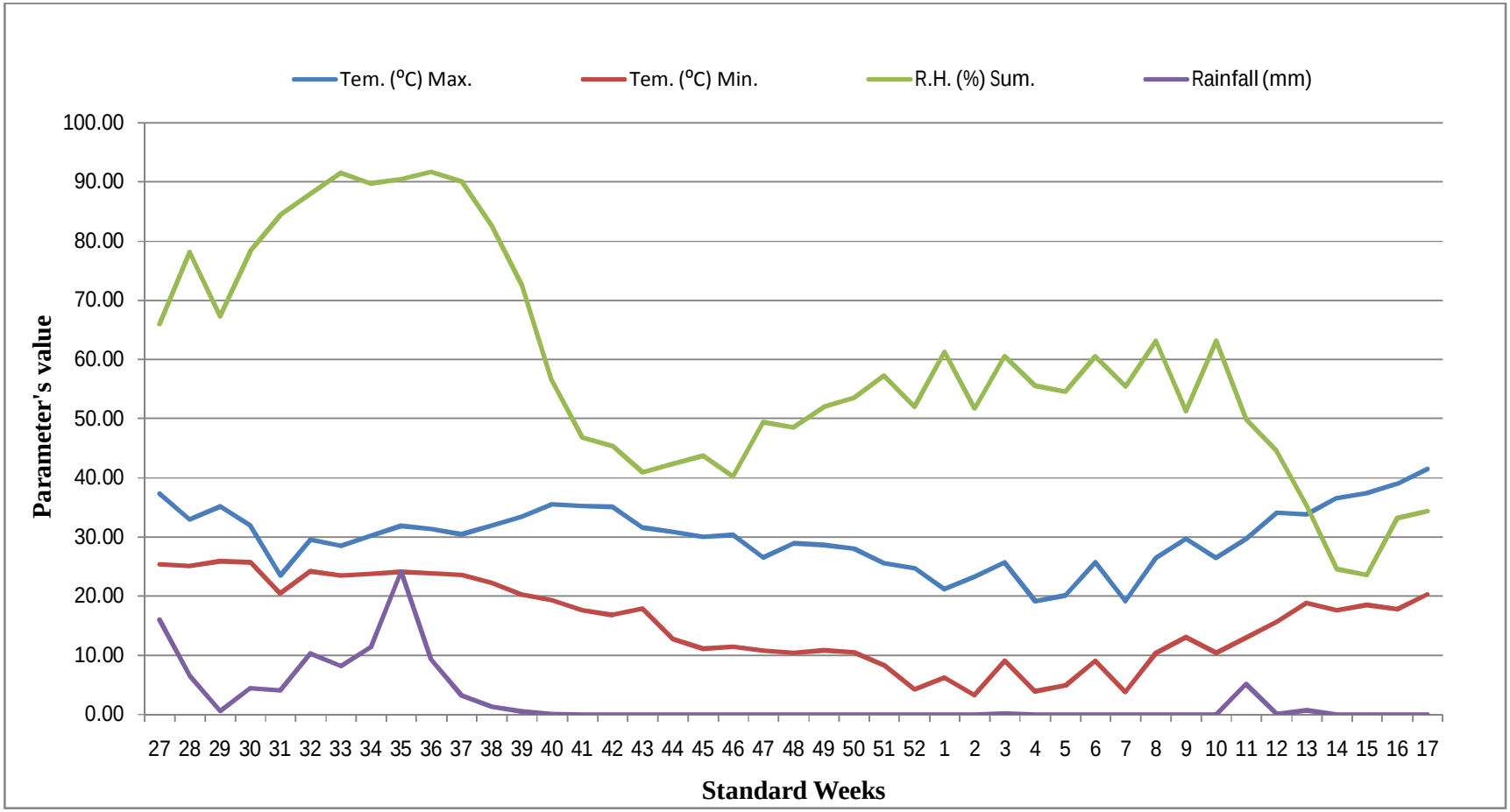


Fig. 3.1 Mean Weakly meteorological parameters for the period of experimentation (July, 2012 to April, 2013)

Table 3.2 Physico-chemical properties of soil of the experimental field

Properties		Value	Method employed
(A) Mechanical compositions			
1.	Sand (%)	23.1	Hydrometer method (Bouyoucos, 1927)
2.	Silt (%)	37.2	Hydrometer method (Bouyoucos, 1927)
3.	Clay (%)	39.6	Hydrometer method (Bouyoucos, 1927)
(B) Physical properties			
1.	Bulk density (Mg m^{-3})	1.40	Core sampler method (Piper, 1950)
2.	Particle density (Mg m^{-3})	2.65	Black (1965)
3.	Porosity (%)	43.2	Black (1965)
(C) Chemical properties			
1.	Organic carbon (%)	0.30	Walkley and Black (1934)
2.	Available Nitrogen (kg ha^{-1})	258.66	Alkaline $KMnO_4$ (Subbiah and Asija, 1956)
3.	Available phosphorus (P_2 O_5 kg ha^{-1})	20.83	Olsen's method (Olsen *et al.*, 1954)
4.	Available Potassium ($K_2$0 kg ha^{-1})	298	Flame photometer method (Metson, 1956)
5.	EC (dSm^{-1} at 25^0c)	0.52	Using solubridge (Jackson, 1973)
6.	pH (1 : 2 : Soil : water suspension)	8.1	Potentiometric method using pH meter (Jackson, 1973)
7.	Quantitative estimation of $CaCO_3$	16.50	Richards, 1954

The soil of experimental site was clay loam in texture (Black cotton soil), normal in reaction and medium in respect to nitrogen, phosphorus and potassium.

3.3 Plant Material

Six years old mandarin cv. 'Nagpur' plants of uniform size and growth were selected at Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalawar for experimentation. For this experiment, a total of 51 plants were selected from the mandarin "A" block during July, 2012 to April, 2013.

3.4 Treatments

This experiment was laid out in simple Randomized Block Design (RBD) with three replications. The treatments consisted of four different plant growth regulators namely NAA, GA_3, 2,4-D, and Triacontanol with four concentrations of each. The plain distilled water was sprayed on the plants for control. In this way, total seventeen treatments were imposed in this experiment. The treatments were applied during first week of July, 2012 after recording initial growth and development all parameter of plant.

The treatment details are given below

S. No.	Treatment	Dose/plant	Notation
1.	Control	Distilled water	T_0
2.	Napthalein acetic acid (NAA)	50 ppm	T_1
3.	Napthalein acetic acid (NAA)	100 ppm	T_2
4.	Napthalein acetic acid (NAA)	150 ppm	T_3
5.	Napthalein acetic acid (NAA)	200 ppm	T_4
6.	Gibberellic acid (GA_3)	25 ppm	T_5
7.	Gibberellic acid (GA_3)	50 ppm	T_6
8.	Gibberellic acid (GA_3)	75 ppm	T_7
9.	Gibberellic acid (GA_3)	100 ppm	T_8
10.	2,4-Di-chlorophenoxy acetic acid (2,4-D)	10 ppm	T_9
11.	2,4-Di-chlorophenoxy acetic acid (2,4-D)	20 ppm	T_{10}
12.	2,4-Di-chlorophenoxy acetic acid (2,4-D)	30 ppm	T_{11}
13.	2,4-Di-chlorophenoxy acetic acid (2,4-D)	40 ppm	T_{12}
14.	Triacontanol	5 ppm	T_{13}
15.	Triacontanol	10 ppm	T_{14}
16.	Triacontanol	15 ppm	T_{15}
17.	Triacontanol	20 ppm	T_{16}

3.5 Experimental Design and layout

- Crop = Mandarin
- Cultivar = “Nagpur”
- Age of plants in field = 6 years
- Spacing = 6 m x 6 m
- Planting system = Square
- Total no. of Treatments = 17
- Replications = 3
- Number of plant/replication = 1
- Total no. of plants under study = 51
- Experimental design = Randomized Block Design
- Observations were recorded at 30 days interval for a total period of 150 days.

3.6 Treatment application of plant growth regulators

The growth regulators, after weighing was dissolved in small quantity of 95 per cent absolute alcohol and 2,4-D was directly diluted in distilled water. Stock solution was first prepared for each growth regulator by diluting with distilled water. The solution of required concentration was then prepared by further dilutions of the measured volume of stock solution with distilled water.

Spray of growth regulators was done at first week of July 2012 under all treatments. Spraying was done as per treatment for each plant taking equal volume of the solution. Spraying was done in the evening with a compressed air hand sprayer. The control plant was sprayed with distilled water.

FIG. 3.2 Layout plan of experimental field at the Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalawar

N

R_1	R_2	R_3
T_{10} R_1	T_4 R_2	T_1 R_3
T_8 R_1	T_{13} R_2	T_{15} R_3
T_0 R_1	T_6 R_2	T_0 R_3
T_6 R_1	T_{14} R_2	T_4 R_3
T_{17} R_1	T_{12} R_2	T_{14} R_3
T_{11} R_1	T_0 R_2	T_{10} R_3
T_4 R_1	T_{10} R_2	R_9 R_3
T_7 R_1	T_{17} R_2	T_{13} R_3
T_1 R_1	T_8 R_2	T_6 R_3
T_{13} R_1	T_{11R2}	T_3 R_3
T_{16} R_1	T_1 R_2	T_7 R_3
T_2 R_1	T_3 R_2	T_{16} R_3
T_9 R_1	T_9 R_2	T_8 R_3
T_{14} R_1	T_{16} R_2	T_{12} R_3
T_{12} R_1	T_2 R_2	T_{17} R_3
T_3 T_1	T_7 R_2	T_{11} R_3
T_{15} R_1	T_{15} R_2	T_2 R_3

Design : RBD **Replications :** Three **Plant spacing : 6 m x 6 m**

Plate 3.1: A panoramic view of experimental site

3.7 Observations

The following observations were recorded during the experimental period. In case of vegetative growth characters, observations were recorded at 30 days interval after recording initial observations in each treatment for a total period of 150 days.

3.7.1 Plant growth attributes

(1) Plant spread (cm)

(2) Crown volume (m^3)

3.7.2 Physical characteristics of fruits

(1) Diameter of fruit (cm)
(a) Horizontal diameter of fruit (cm)
(b) Vertical diameter of fruit (cm)
(2) Peel thickness (mm)
(3) Weight of fruit (g)
(4) Volume of fruit (cc)
(5) Number of seeds per fruit
(6) Average seeds weight per fruit (g)
(7) Number of sacs per fruit
(8) Number of fruits per tree
(9) Fruit retention (%)
(10) Days taken to first harvesting
(11) Total days taken to complete harvesting

3.7.3 Chemical characteristic or Quality attributing characteristics of fruits

(1) Total soluble solids (^{0}Brix)
(2) Total acidity (%)
(3) TSS acid ratio
(4) Reducing sugar (%)
(5) Non-reducing sugar (%)
(6) Total sugar (%)

(7) Ascorbic acid content (mg/100 ml juice)

(8) Juice recovery (%)

(9) Sensory score

3.7.4 Yield attributes

(1) Yield per plant (kg)

(2) Estimated yield per ha (tonnes)

3.8 Methodology used for observations

3.8.1 Plant Growth attributes

(a) Plant Spread (cm)

The area occupied by plant canopy was measured in E-W & N-S direction with the help of measuring scale and plant spread was calculated by taking volume E-W and N-S increase in plant spread.

(b) Crown volume (m^3)

The crown volume was calculated with the help of data observed as plant spread (E-W & N-S) and height of the plant by using following formula:

$$Canopy\,volume\left(m^3\right)=\frac{\left(E-W+N-S\right)^2}{4}\times\frac{1}{2}Plant\,height\times 4.19$$

3.8.2 Physical characteristics of fruits

(a) Diameter of fruit (cm)

(I) Horizontal diameter of fruit (cm)

Diameter of the randomly selected five fruits in each treatment was recorded transversely with the help of digital vernier caliper in centimeter and averaged.

(II) Vertical diameter of fruit (cm)

Diameter of the randomly selected five fruits in each treatment was recorded transversely with the help of digital vernier calipers in centimeter and averaged.

(b) Peel thickness (mm)

After removing of peel from the fruit, the peel was measured with the help of digital vernier caliper in millintimeter and averaged.

(c) Weight of fruit (g)

Randomly selected five fruits in each treatment during harvesting were weighed with the help of single pan balance and mean weight of fruit was calculated.

(d) Volume of fruit (cc)

The volume of five randomly selected fruits in each treatment was measured by water displacement method. For this purpose, the fruits were dipped in a full filled jar of water and the water displaced by the fruits was collected and measured by graduated glass jar and the recorded reading was averaged.

(e) Number of seeds per fruit

After removing the seeds with the help of hand and knife from fruit sacs, the seeds were counted.

(f) Average seeds weight/fruit (g)

After removing the seeds with the help of hand and knife from fruit sacs, the seeds were weighed by electronic weighing balance (Sartorius).

(g) Number of sacs per fruit

After removing the sacs with the help of hand from fruit, the sacs were counted.

(h) Number of fruits per tree

It was recorded by counting the number of fruits per tree at the time of harvesting.

(i) Fruit retention (%)

Total numbers of fruit set present on the tagged shoots were counted and then the total numbers of fruit were again counted at the time of fruit maturity. The per cent fruit retention was calculated on the basis of initial number of fruit set.

(j) Days taken to first harvesting

Number of days taken to first harvesting was counted from the date of treatment to first picking in each treatment.

(k) Total days taken to complete harvesting

Number of days taken to complete harvesting was counted from the date of treatment to last picking in each treatment.

3.8.2 Chemical characteristic or Quality attributing characteristics of fruits

(a) Total soluble solids (TSS ^{0}Brix **)**

Total soluble solids content of the fruit was determined by using a hand refractometer of 0-30 per cent range. In this case one drop of fruit juice was put on the prism of the refractometer and per cent TSS was recorded directly. The values were corrected at 20˚C and expressed as per cent total soluble solids of the fruits (A.O.A.C. 1990).

(b) Total acidity (%)

The acidity was determined by diluting the known volume of clean juice with distilled water and titrating the same against standard $^{N}/_{10}$ NaOH solution using phenolphthalein as in indicator until faint pink colour was appeared. The result was expressed in terms of per cent acidity of the fruit juice (A.O.A.C. 1990).

(c) TSS/Acid ratio

TSS/Acid ratio was calculated by dividing the value of total soluble solids content by per cent acidity.

(d) Reducing sugar (%)

Reducing sugar content was measured by following Nelsons Modifications of Somogyis Method (Somogyi, 1952) using arsenomolybdate colour forming reagent and two copper reagent ‘A’ and ‘B’. One ml of juice (100 times diluted) was added with a mixture of 1 ml copper reagent, from 24 parts of copper ‘A’ and 1 part of copper ‘B’ solution. This mixture was heated in boiling water bath in test tube and cooled, added

with the colour forming reagent and absorbance was measured at 620 nm on Spectronic-20. The value was plotted against a standard curve prepared from.

(e) Non-reducing sugar (%)

The amount of non-reducing sugar was obtained by substracting reducing sugar from the amount of total sugar and multiplying the resultant by factor 0.95.

$$\text{Non-reducing Sugar \%} = (\text{Total Sugar \%} - \text{Reducing Sugar \%}) \times 0.95$$

(f) Total sugar (%)

Total sugar content was determined by using anthrone reagent method (Dubois *et al.*, 1951). To 1 ml of diluted fruit juice (100 times), 5 ml of anthrone reagent was added, then heated for 10 to 15 minute in a water bath, cooled to room temperature and absorbance was measured at 630 nm on Spectronic-20. The amount of sugar present in juice was plotted against standard curve prepared from glucose. The content was expressed on percentage basis.

(g) Ascorbic acid (Vit.-C) mg/100 ml juice

Ascorbic acid content of juice was determined by diluting the known volume of clean juice with 3 per cent metaphosphoric acid to appropriate volume. A 10 ml of aliquot was taken and titrated against 2, 6 dichlorophenol indophenol solution after standardization (A.O.A.C. 1990) until light pink colour appeared. The result was expressed as mg ascorbic acid / 100 ml juice.

Standardization

Standardization of the 2, 6 dichlorophenol-indophenol dye was done by titrating it against standard ascorbic acid solution. The standard solution was prepared by dissolving 100 mg of L-ascorbic acid in 3% metaphosphoric acid and the volume was made to 100 ml and from this one ml solution was used for titration.

The ascorbic acid was calculated by following formula :-

$$\text{Ascorbic acid (mg/100ml juice)} = \frac{\text{Titre (ml)} \times \text{Dye factor} \times \text{Volume made up (ml)}}{\text{Aliquot (ml)} \times \text{Weight of juice (ml)}} \times 100$$

Where, Titre – Average burette reading

$$\text{Dye Factor} = \frac{0.5}{\text{Average biurette reading for standardization of dye solution}} \times 100$$

Aliquot – Volume of aliquot taken for estimation.

(h) Juice recovery percentage

The fruits of mandarin were cut into equal halves and their juice was extracted with simple juice extractor. The juice was weighed with the help of balance and the percentage of juice was worked out on the basis of total weight of fruit and weight of juice.

(i) Sensory score

A panel of five judges conducted organoleptic test of the fruits immediately after harvesting in each treatment. The observation were recorded on the basis of flavor, colour, taste and general appearance of fruit and rated as below out of 10.0 score

Excellent	:	9.1 to 10.0
Very Good	:	8.1 to 9.00
Good	:	6.1 to 8.0
Acceptable	:	5.1 to 6.0
Non-acceptable	:	0 to 5.0

3.8.4 Yield attributes

(a) Yield per plant (kg)

Mature fruits were harvested periodically in each treatment separately and the weight was recorded with the help of single pan balance. Then the total yield (kg / plant) was calculated.

Plate 3.2: Judges conducting organoleptic test of Nagpur mandarin fruits

T0R1
T0R2
T1R1
T1R2
T2R1
T2R2
T2R3

T3R2
T3R3
T15R1
T15R2
T15R3

T8R1
T9R1
T9R3
T10R1
T10R2
T10R3

T11R1
T12R1

T15R1
T15R2
T16R1
T16R3
T15R1
T15R2
T15R3

Plate 3.3: Samples of different Nagpur mandarin fruits for judging sensory score

(b) Estimated yield per ha (tonnes)

The yield of fruits per ha was calculated by multiplying the yield of fruits per plant with number of plant per ha i.e. 278 plants / ha in square planting system spacing 6×6 m.

3.8.5 Economics of the treatments used

The relative economics of different plant growth regulator treatments were determined on the plant basis of cost of treatment and yield of fruit per plant and per ha. The net income was decided by subtracting the treatment cost from gross income. It was expressed on net excess income over control. The percent increase in net profit over control was calculated.

3.9 Statistical Analysis

The data obtained during the experimentation were subjected to statistical analysis using Fisher's (1950) analysis of variance technique. The significance of the treatments was tested through 'F' test at 5 per cent level of significance. The critical difference CD was calculated to assess the significance of difference among the different treatments. The analysis of variance tables are presented in appendix at the end of this manuscript.

CHAPTER - 4

RESULTS

4. EXPERIMENTAL RESULTS

It this chapter, the experimental results of present investigation entitled **"Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco) cv. Nagpur"** has been presented. The results have been illustrated diagrammatically. Analysis of variance of various characteristics has been presented in Appendices at the end from I to XI.

The results are presented under the following heads:

4.1 Plant growth attributes

4.1.1 Plant spread (%)

4.1.2 Crown volume (%)

4.2 Physical characteristics of fruits

4.2.1 Diameter of fruit (cm)

4.2.1.1 Horizontal diameter of fruit (cm)

4.2.1.2 Vertical diameter of fruit (cm)

4.2.2 Peel thickness (mm)

4.2.3 Weight of fruit (g)

4.2.4 Volume of fruit (cc)

4.2.5 Number of seeds per fruit

4.2.6 Average seeds weight per fruit (g)

4.2.7 Number of sacs per fruit

4.2.8 Number of fruits per tree

4.2.9 Fruit retention (%)

4.2.10 Days taken to first harvesting

4.2.11 Total days taken to complete harvesting

4.3 Chemical characteristics or Quality attributing characteristics of fruits

4.3.1 Total soluble solids (^{0}Brix)

4.3.2 Total acidity (%)

4.3.3 TSS/Acid ratio

4.3.4 Reducing sugar (%)

4.3.5 Non-reducing sugar (%)

4.3.6 Total sugar (%)

4.3.7 Ascorbic acid (mg/100 ml juice)

4.3.8 Juice recovery (%)

4.3.9 Sensory score

4.4 Yield attributes

4.4.1 Yield per plant (kg)

4.4.2 Estimated yield per ha (tonnes)

4.1.1 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on per cent increase in plant spread of 'Nagpur' mandarin

The data presented in Table-4.1 and reference to Fig. 4.1 indicated that the plant spread was increased on all the days of observation from 0 to 150 days after treatment. However, the rate of per cent increase on plant spread was significantly influenced by use of various plant growth regulators at different concentrations (Appendix-I.). While on 150 days after treatment, the maximum increase in per cent plant spread 20.59 per cent was observed at T_8 (GA_3 @ 100 ppm) treatment, which was found to be at par with treatment T_5 (19.04%), T_6 (19.16%) and treatment T_7 (19.98%), respectively. The minimum increase in per cent plant spread 10. 64 per cent was recorded at treatment T_{12} (2,4-D @ 40 ppm).

4.1.2 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on per cent increase in crown volume of 'Nagpur' mandarin

A perusal of data presented in Table-4.2 and reference to Fig. 4.2 indicated that the crown volume was increased on all the days of observation from 0 to 150 days after treatment. However, the rate of increase on crown volume was significantly influenced by use of various plant growth regulators at different concentrations (Appendix-II.). While on 150 days after treatment, the maximum increase in per cent crown volume (38.42%) was observed at T_8 (GA_3 @ 100 ppm) treatment, which was found to be at par with T_7 (36.86%) and was significantly higher over other treatments. The minimum increase in per cent crown volume (17.77%) was recorded under T_{12} (2,4-D @ 40 ppm) treatment.

4.2.1.1 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on horizontal diameter (cm) of fruit of 'Nagpur' mandarin

A reference to data in Table 4.3 and Fig. 4.3 revealed that the spray of various plant growth regulators at different concentrations influenced the horizontal diameter of Nagpur mandarin fruits significantly (Appendix – III). The maximum horizontal diameter of fruit was recorded with the spray of T_8 treatment (GA_3 @ 100 ppm) having

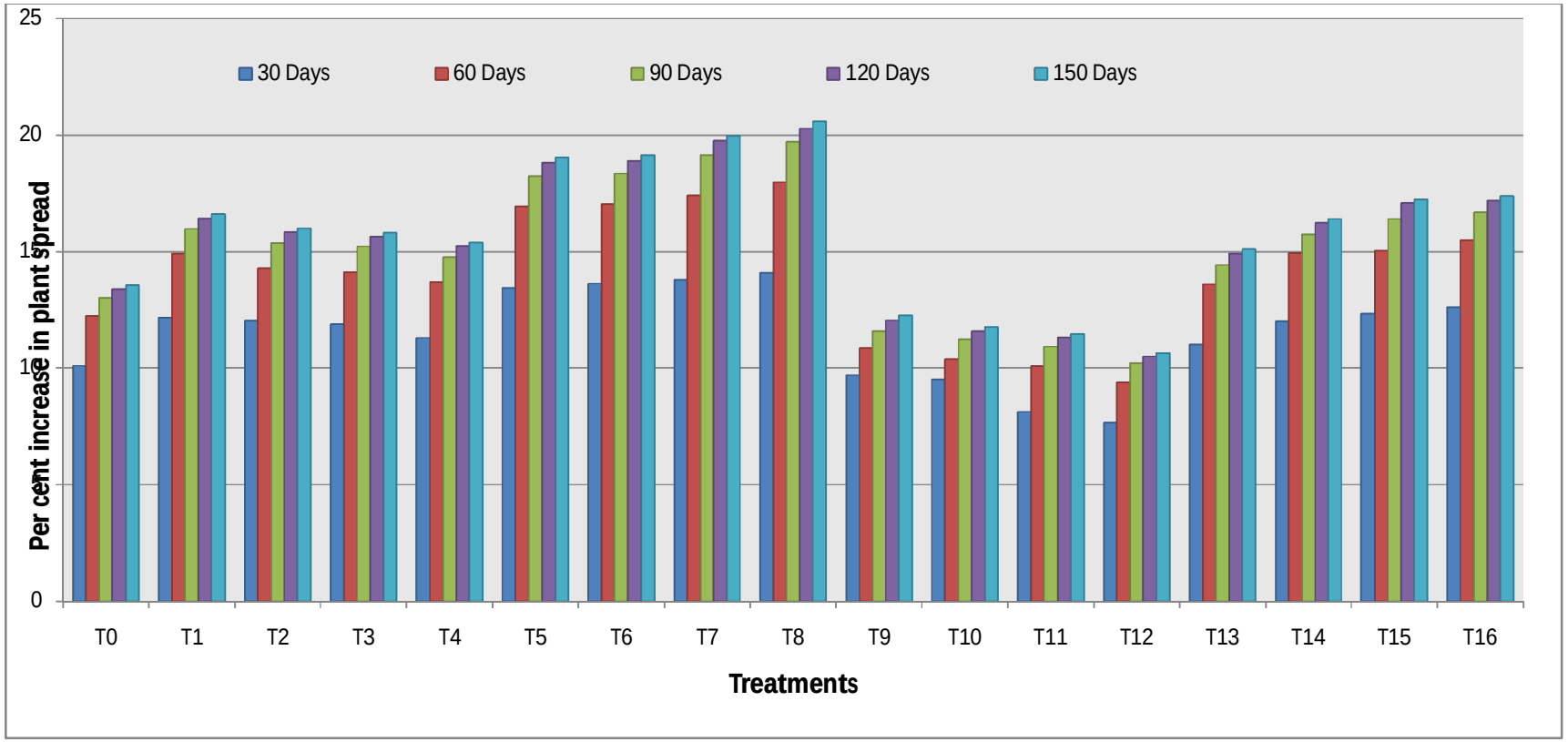
value of(8.03 cm) but it was found to be at par with T_{10} treatment (2.4-D @ 20 ppm) having value of (7.46 cm) and T_{11} treatment (2,4-D @ 30 ppm) having value of (7.64

Table – 4.1Effect of plant growth regulators on per cent increase in plant spread of 'Nagpur' mandarin

Treatments		Days after treatment				
		30	60	90	120	150
Control	(T_0)	10.11 (3.08)	12.25 (4.50)	13.01 (5.07)	13.40 (5.37)	13.56 (5.50)
NAA 50 ppm	(T_1)	12.17 (4.45)	14.92 (6.66)	15.97 (7.60)	16.42 (8.02)	16.61 (8.20)
NAA 100 ppm	(T_2)	12.04 (4.36)	14.29 (6.10)	15.37 (7.05)	15.84 (7.48)	16.00 (7.62)
NAA 150 ppm	(T_3)	11.90 (4.27)	14.13 (6.00)	15.23 (6.95)	15.66 (7.35)	15.82 (7.50)
NAA 200 ppm	(T_4)	11.31 (3.91)	13.71 (5.68)	14.75 (6.53)	15.24 (6.96)	15.40 (7.10)
GA_3 25 ppm	(T_5)	13.45 (5.42)	16.93 (8.50)	18.24 (9.81)	18.81 (10.42)	19.04 (10.66)
GA_3 50 ppm	(T_6)	13.63 (5.56)	17.03 (8.59)	18.35 (9.93)	18.89 (10.51)	19.16 (10.80)
GA_3 75 ppm	(T_7)	13.80 (5.69)	17.41 (8.98)	19.15 (10.80)	19.75 (11.47)	19.98 (11.72)
GA_3 100 ppm	(T_8)	14.10 (6.01)	17.98 (9.55)	19.72 (11.40)	20.28 (12.03)	20.59 (12.39)
2,4-D 10 ppm	(T_9)	9.70 (2.84)	10.85 (3.55)	11.59 (4.04)	12.05 (4.36)	12.26 (4.51)
2.4-D 20 ppm	(T_{10})	9.51 (2.74)	10.39 (3.27)	11.22 (3.80)	11.59 (4.05)	11.76 (4.17)
2,4-D 30 ppm	(T_{11})	8.13 (2.03)	10.08 (3.10)	10.92 (3.62)	11.32 (3.88)	11.47 (3.98)
2,4-D 40 ppm	(T_{12})	7.67 (1.79)	9.41 (2.68)	10.21 (3.16)	10.51 (3.35)	10.64 (3.43)
Triacontanol 5 ppm	(T_{13})	11.01 (3.66)	13.61 (5.55)	14.43 (6.23)	14.92 (6.65)	15.10 (6.80)
Triacontanol 10 ppm	($T1_4$)	12.00 (4.33)	14.94 (6.67)	15.74 (7.37)	16.24 (7.84)	16.40 (7.98)
Triacontanol 15 ppm	(T_{15})	12.33 (4.57)	15.03 (6.74)	16.39 (7.98)	17.08 (8.63)	17.25 (8.81)
Triacontanol 20 ppm	(T_{16})	12.61 (4.78)	15.49 (7.15)	16.68 (8.27)	17.20 (8.77)	17.39 (8.96)
SEm±		0.46	0.58	0.60	0.58	0.59
C.D. at 5%		1.33	1.69	1.72	1.69	1.71

* Figure in parenthesis are arc sin reconverted values.

Fig- 4.1 Effect of plant growth regulators on per cent increase in plant spread of 'Nagpur' mandarin



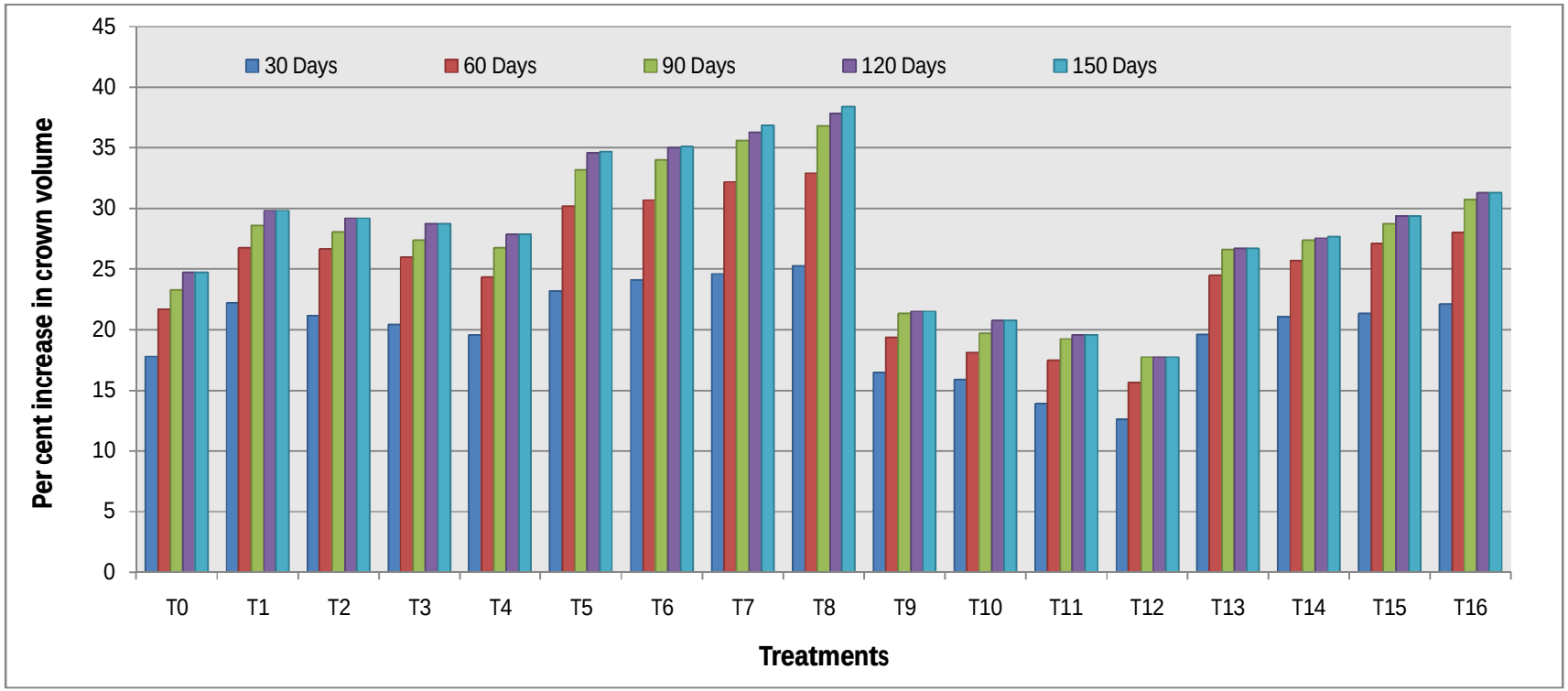
(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Table – 4.2 Effect of plant growth regulators on per cent increase in crown volume of 'Nagpur' mandarin

Treatments		Days after treatment				
		30	60	90	120	150
Control	(T_0)	17.79 (9.37)	21.69 (13.70)	23.31 (15.68)	24.75 (17.56)	24.75 (17.56)
NAA 50 ppm	(T_1)	22.19 (14.43)	26.74 (20.40)	28.62 (23.06)	29.82 (24.86)	29.82 (24.86)
NAA 100 ppm	(T_2)	21.15 (13.03)	26.66 (20.22)	28.07 (22.22)	29.21 (23.94)	29.21 (23.94)
NAA 150 ppm	(T_3)	20.42 (12.20)	25.99 (19.28)	27.37 (21.25)	28.75 (23.22)	28.75 (23.22)
NAA 200 ppm	(T_4)	19.57 (11.24)	24.36 (17.04)	26.73 (20.28)	27.87 (21.88)	27.87 (21.88)
GA_3 25 ppm	(T_5)	23.21 (15.56)	30.18 (25.30)	33.20 (30.02)	34.59 (32.26)	34.67 (32.40)
GA_3 50 ppm	(T_6)	24.09 (16.68)	30.71 (26.11)	34.03 (31.35)	35.01 (32.94)	35.12 (33.12)
GA_3 75 ppm	(T_7)	24.60 (17.36)	32.18 (28.40)	35.61 (33.95)	36.26 (35.05)	36.86 (36.03)
GA_3 100 ppm	(T_8)	25.23 (18.25)	32.92 (29.60)	36.82 (35.96)	37.81 (37.62)	38.42 (38.65)
2,4-D 10 ppm	(T_9)	16.50 (8.09)	19.39 (11.03)	21.32 (13.23)	21.52 (13.48)	21.52 (13.48)
2.4-D 20 ppm	(T_{10})	15.91 (7.53)	18.10 (9.67)	19.70 (11.39)	20.74 (12.55)	20.74 (12.55)
2,4-D 30 ppm	(T_{11})	13.88 (5.80)	17.48 (9.13)	19.26 (10.98)	19.55 (11.31)	19.55 (11.31)
2,4-D 40 ppm	(T_{12})	12.64 (4.81)	15.65 (7.35)	17.75 (9.35)	17.77 (9.37)	17.77 (9.37)
Triacontanol 5 ppm	(T_{13})	19.61 (11.27)	24.49 (17.21)	26.62 (20.10)	26.71 (20.22)	26.71 (20.22)
Triacontanol 10 ppm	($T1_4$)	21.07 (12.94)	25.71 (18.84)	27.39 (21.19)	27.57 (21.44)	27.68 (21.60)
Triacontanol 15 ppm	(T_{15})	21.34 (13.27)	27.12 (20.84)	28.74 (23.15)	29.39 (24.12)	29.39 (24.12)
Triacontanol 20 ppm	(T_{16})	22.13 (14.23)	28.03 (22.18)	30.72 (26.19)	31.30 (27.07)	31.30 (27.07)
SEm±		0.80	1.05	1.06	1.05	1.06
C.D. at 5%		2.31	3.05	3.07	3.02	3.06

* Figure in parenthesis are arc sin reconverted values.

Fig- 4.2 Effect of plant growth regulators on per cent increase in crown volume of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm**)**

cm), respectively and was found statistically significant over other treatments. The minimum horizontal diameter of fruit was recorded under control (6.12 cm).

4.2.1.2 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on vertical diameter (cm) of fruit of 'Nagpur' mandarin

The data on vertical diameter fruit of Nagpur mandarin as affected by various plant growth regulator treatments are given in Table 4.3 and depicted in Fig. 4.4. The analysis of variance of these data is given in Appendix – III.

The application of different plant growth regulators exerted significant difference on vertical diameter of fruits. The maximum vertical diameter of Nagpur mandarin fruit (8.23 cm) was observed with 100 ppm GA_3 in(T_8)treatment, which was closely followed by 30 ppm 2,4-D (7.83 cm) in T_9 treatment and was found statistically significant over other treatments . However, the minimum vertical diameter of fruit was observed in control (5.64 cm).

4.2.2 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on peel thickness (mm) of fruit of 'Nagpur' mandarin

A perusal of data in Table – 4.3 and Fig. 4.5 depicted that various plant growth regulators at different concentrations had a significant effect on peel thickness of fruits (Appendix - III). The minimum peel thickness (3.41 mm) of fruit was recorded with the spray of 30 ppm 2,4-Dunder(T_{11}) treatment and was found statistically lower over other treatments. However, the maximum peel thickness of fruit (5.33 mm) was recorded under control.

4.2.3 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on weight of fruit (g) of 'Nagpur' mandarin

It is clear from the data that the average weight of Nagpur mandarin fruits was significantly increased by the application of different plant growth regulator treatments (Table 4.4). However, among all the treatments attempted, the maximum average weight of fruit (191.22 g) was recorded under T_8 (GA_3 @ 100 ppm) treatment were found to be at par with T_9 treatment (2,4-D @ 10 ppm) having value of (172.11 g) and T_{11} treatment (2,4-D @ 30 ppm) having value of (184.22 g), respectively and was

Table – 4.3 Effect of plant growth regulators on horizontal diameter of fruit (cm), vertical diameter of fruit (cm) and peel thickness (mm) of 'Nagpur' mandarin

Treatments		Horizontal diameter of fruit (cm)	Vertical diameter of fruit (cm)	Peel thickness (mm)
Control	(T_0)	6.12	5.64	5.33
NAA 50 ppm	(T_1)	6.80	5.97	4.09
NAA 100 ppm	(T_2)	7.02	6.50	3.88
NAA 150 ppm	(T_3)	6.82	6.22	3.79
NAA 200 ppm	(T_4)	7.13	7.44	4.01
GA_3 25 ppm	(T_5)	7.26	7.27	4.77
GA_3 50 ppm	(T_6)	6.97	6.71	4.13
GA_3 75 ppm	(T_7)	6.59	6.37	4.25
GA_3 100 ppm	(T_8)	8.03	8.23	3.97
2,4-D10 ppm	(T_9)	6.43	6.38	4.96
2,4-D20 ppm	(T_{10})	7.46	7.39	5.11
2,4-D30 ppm	(T_{11})	7.64	7.83	3.41
2,4-D40 ppm	(T_{12})	6.97	6.75	3.48
Triacontanol 5 ppm	(T_{13})	6.90	6.26	3.98
Triacontanol 10 ppm	(T_{14})	7.40	7.34	4.41
Triacontanol 15 ppm	(T_{15})	7.08	6.37	3.66
Triacontanol 20 ppm	(T_{16})	6.65	6.28	3.94
SEm±		0.20	0.25	0.23
C.D. at 5%		0.59	0.72	0.67

Fig-4.3 Effect of plant growth regulators on horizontal diameter of fruit (cm) 'Nagpur' mandarin

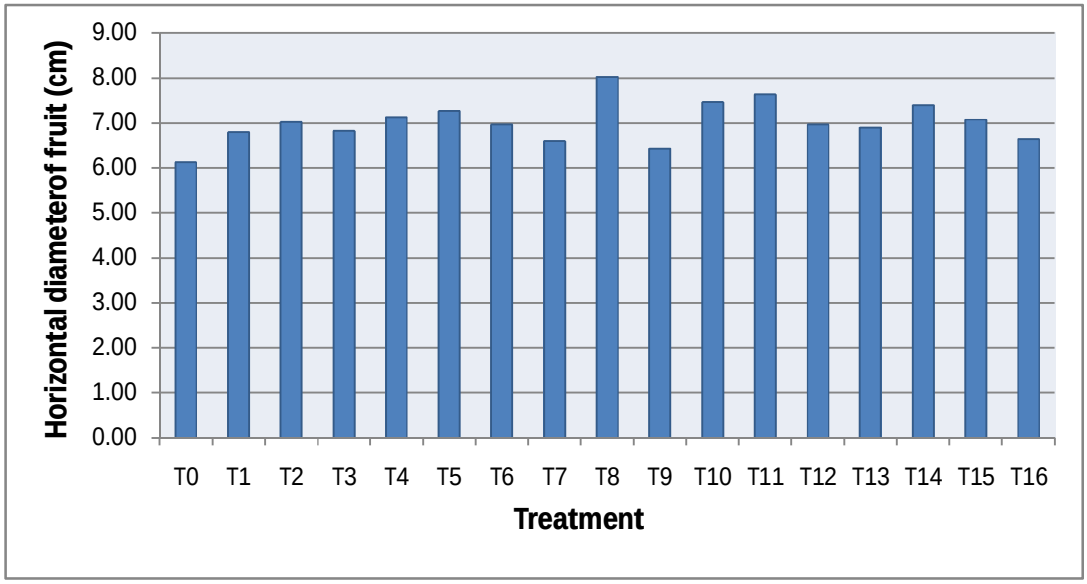
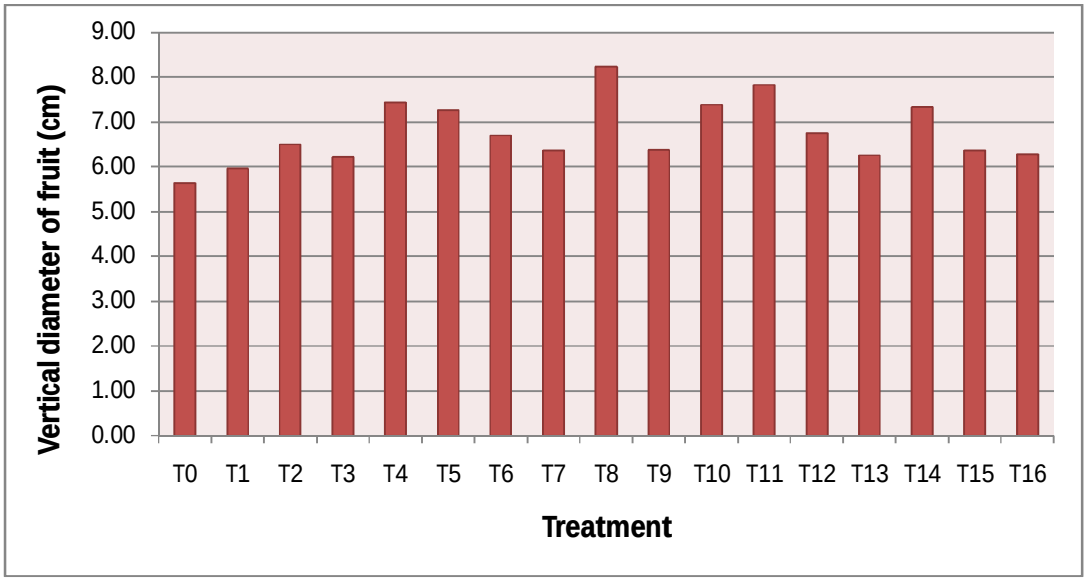
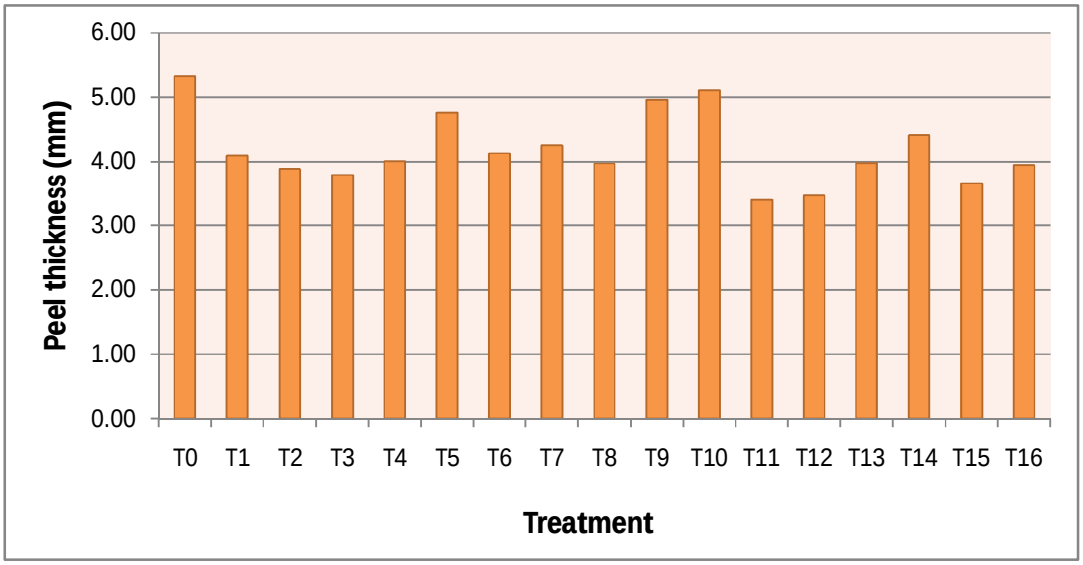


Fig-4.4 Effect of plant growth regulators on vertical diameter of fruit (cm) 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Fig-4.5 Effect of plant growth regulators on peel thickness (mm) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

statistically higher over other treatments. Whereas, the minimum fruit weight was recorded under control (135.56 g).

4.2.4 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on volume of fruit (cc) of 'Nagpur' mandarin

It is evident from the data that volume of fruit of Nagpur mandarin was significantly influenced by application of various plant growth regulators treatments (Table 4.4). The maximum volume of fruit (247.56 cc) was observed with 100 ppm GA_3 under (T_8) treatment followed by T_{11} (2,4-D @ 30 ppm), which was significantly higher over other treatments. The minimum volume of fruit (145.44 cc) was recorded in control.

4.2.5 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on number of seeds per fruit of 'Nagpur' mandarin

The data presented in Table-4.5 and reference to Fig. 4.8 indicated that the number of seeds per fruit of Nagpur mandarin fruits was significantly influenced by the application of different plant growth regulator treatment (Appendix - V). The minimum number of seeds per fruit (9.44) was observed in T_{11} treatment (2,4-D @ 30 ppm), which was found to be at par with T_{12} (2,4-D@ 40 ppm), T_5 (GA_3 @ 25 ppm), T_{16} (Triacontanol @ 20 ppm), T_3 (NAA @ 150 ppm), T_1 (NAA @ 50 ppm), T_{15} (Triacontanol @ 15 ppm) and T_7 (GA_3 @ 75 ppm) treatments, having values of (9.56), (9.89), (10.44), (10.44), (11.44), (11.56) and (12.44), respectively. However, the maximum number of seeds per fruit (15.44) was recorded under control.

4.2.6 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on average seeds weight per fruit (g) of 'Nagpur' mandarin

A perusal of data in Table-4.5 and Fig. 4.9 showed that different plant growth regulators had a significant effect on average seed weight per fruit of Nagpur mandarin (Appendix - V). The minimum average seeds weight per fruit (0.97 g) was observed under T_{11} treatment (2,4-D @ 30 ppm) and was found to be at par with treatments T_9 (2,4-D 10 ppm) having value of (0.98 g), T_5 (GA_3 @ 25 ppm) having value of (0.99 g), T_{14} (Triacontanol @ 10 ppm) having value of (1.01 g) T_1 (NAA @

Table – 4.4Effect of plant growth regulators on weight of fruit (g) and volume of fruit (cc) of 'Nagpur' mandarin

Treatments		Weight of fruit (g)	Volume of fruit (cc)
Control	(T_0)	135.56	145.44
NAA 50 ppm	(T_1)	144.11	155.22
NAA 100 ppm	(T_2)	150.22	171.78
NAA 150 ppm	(T_3)	143.11	164.22
NAA 200 ppm	(T_4)	164.89	189.44
GA_3 25 ppm	(T_5)	141.11	149.89
GA_3 50 ppm	(T_6)	145.56	177.78
GA_3 75 ppm	(T_7)	167.78	181.78
GA_3 100 ppm	(T_8)	191.22	247.56
2,4-D10 ppm	(T_9)	172.11	190.22
2,4-D20 ppm	(T_{10})	149.44	164.22
2,4-D30 ppm	(T_{11})	184.22	211.89
2,4-D40 ppm	(T_{12})	144.22	173.78
Triacontanol 5 ppm	(T_{13})	156.44	160.56
Triacontanol 10 ppm	(T_{14})	164.22	181.56
Triacontanol 15 ppm	(T_{15})	164.22	186.78
Triacontanol 20 ppm	(T_{16})	152.11	172.78
SEm±		7.95	10.66
C.D. at 5%		22.89	30.69

Fig-4.6 Effect of plant growth regulators on weight of fruit (g) of 'Nagpur' mandarin

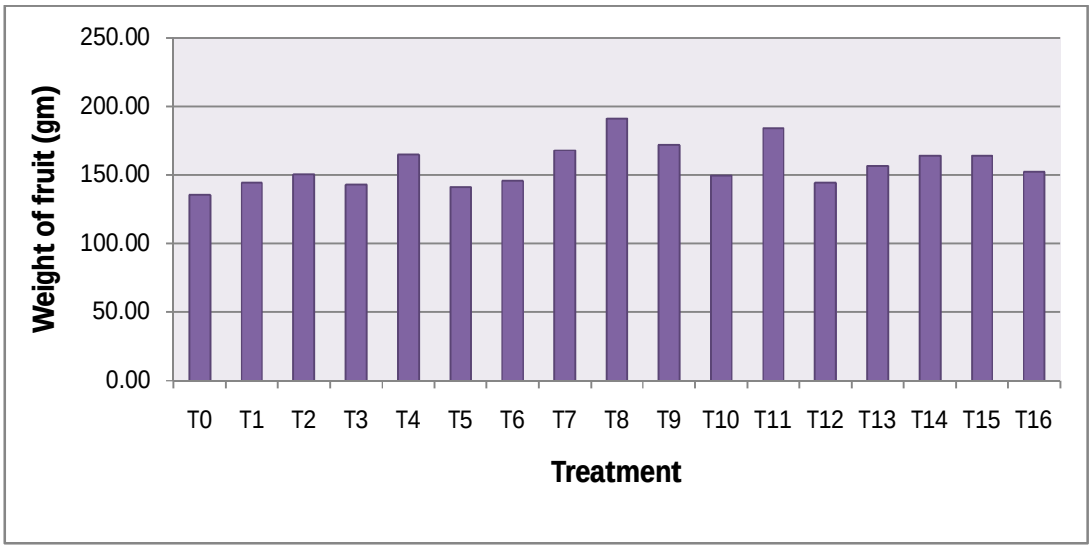
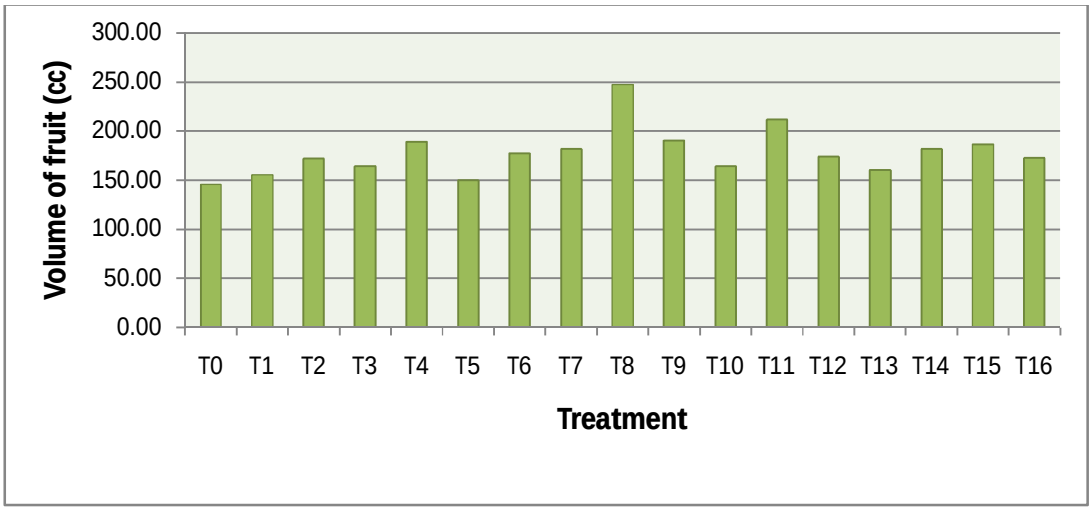


Fig-4.7 Effect of plant growth regulators on volume of fruit (cc) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Table – 4.5Effect of plant growth regulators on number of seeds per fruit, average seeds weight per fruit (g) and number of sacs per fruit of 'Nagpur' mandarin

Treatments		No. of seeds/fruit	Average seeds weight/fruit (g)	No. of sacs/fruit
Control	(T_0)	15.44	1.86	9.89
NAA 50 ppm	(T_1)	11.44	1.03	10.89
NAA 100 ppm	(T_2)	14.44	1.34	11.11
NAA 150 ppm	(T_3)	10.44	1.26	11.56
NAA 200 ppm	(T_4)	14.56	1.71	11.11
GA_3 25 ppm	(T_5)	9.89	0.99	11.44
GA_3 50 ppm	(T_6)	14.89	1.74	10.56
GA_3 75 ppm	(T_7)	12.44	1.04	11.44
GA_3 100 ppm	(T_8)	14.56	1.67	12.56
2,4-D10 ppm	(T_9)	14.78	0.98	11.11
2,4-D20 ppm	(T_{10})	13.67	1.55	11.78
2,4-D30 ppm	(T_{11})	9.44	0.97	12.22
2,4-D40 ppm	(T_{12})	9.56	1.41	10.89
Triacontanol 5 ppm	(T_{13})	14.44	1.48	11.44
Triacontanol 10 ppm	(T_{14})	14.56	1.01	10.89
Triacontanol 15 ppm	(T_{15})	11.56	1.42	10.44
Triacontanol 20 ppm	(T_{16})	10.44	1.04	10.56
SEm±		1.07	0.12	0.42
C.D. at 5%		3.09	0.36	1.21

Fig-4.8 Effect of plant growth regulators on number of seeds per fruit of 'Nagpur' mandarin

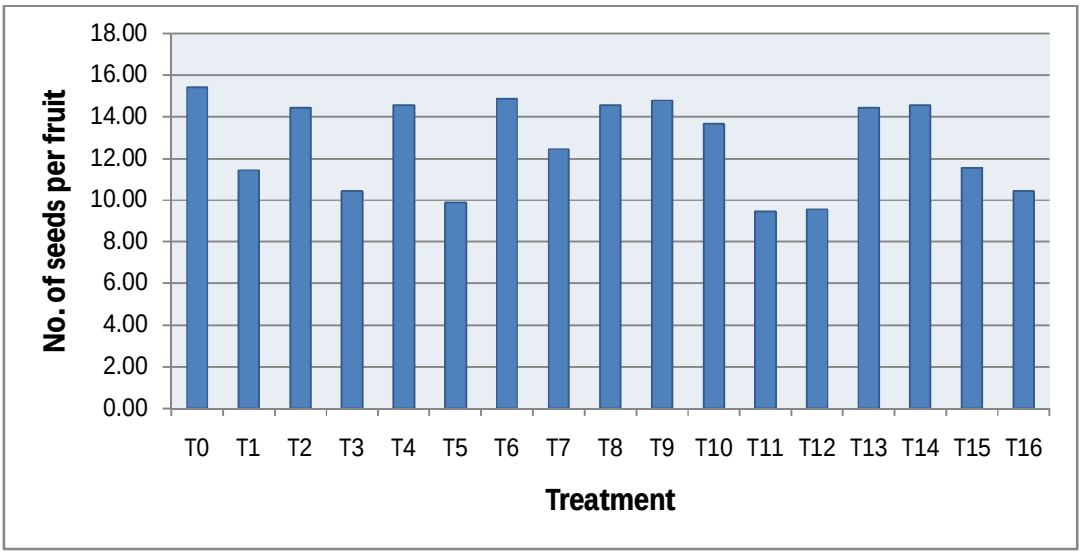
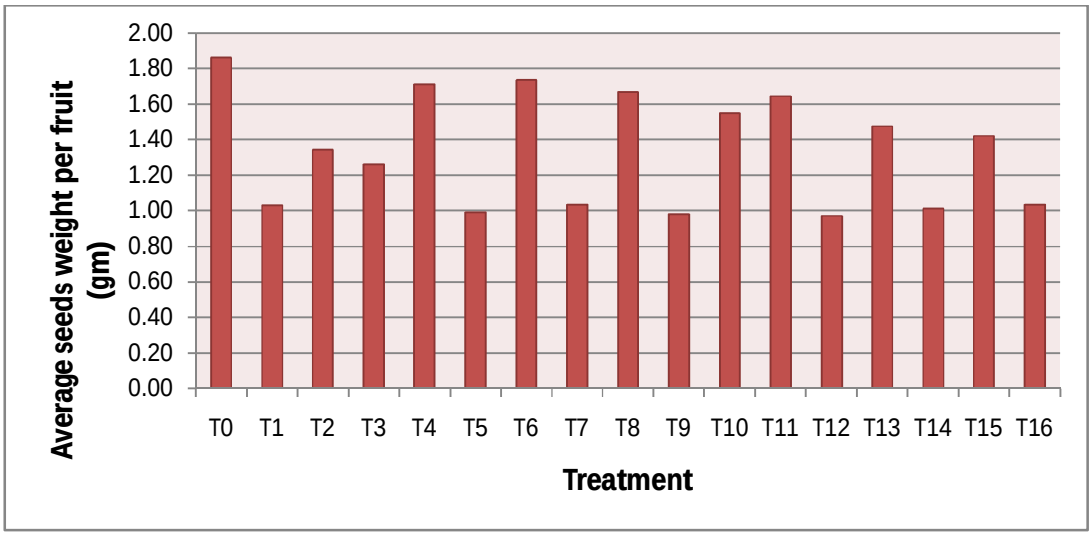
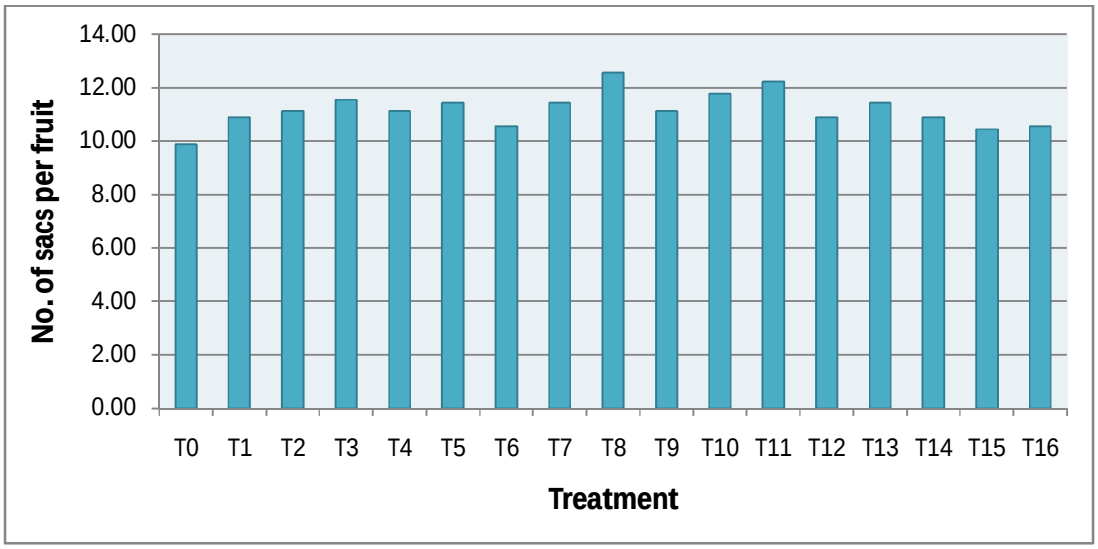


Fig-4.9 Effect of plant growth regulators on average seeds weight per fruit (g) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Fig-4.10 Effect of plant growth regulators on number of sacs per fruit of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

50 ppm) having value of (1.03 g), T_7 (GA_3 @ 75 ppm) having value of (1.04 g), T_{16} (Triacontanol @ 20 ppm) having value of (1.04 g) and T_3 (NAA @ 150 ppm) having value of (1.26 g) respectively. However, the maximum average seed weight per fruit (1.86 g) was recorded under control.

4.2.7Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on number of sacs per fruit of 'Nagpur' mandarin

The perusal of data in Table 4.5 and Fig. 4.10 revealed that the spray of various plant growth regulators at different concentrations influenced the number of sacs per fruit of Nagpur mandarin significantly (Appendix – V). Amongst all the treatments attempted, the maximum number of sacs per fruit (12.56) was recorded in 100 ppm GA_3 in(T_8)treatment, which were found at par with T_5 treatment (GA_3 @ 25 ppm) having number of (11.44), T_7 treatment (GA_3 @ 75 ppm) having number of (11.44), T_{13} treatment (Triacontanol @ 5 ppm) having number of (11.44), T_3 treatment (NAA @ 150 ppm) having number of (11.56), T_{10} treatment (2,4-D @ 20 ppm) having number of (11.78) and T_{11} treatment (2,4-D @ 30 ppm) having number of (12.22), respectively. Whereas, the minimum number of sacs per fruit (9.89) was recorded under control.

4.2.8 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on number of fruits per tree of 'Nagpur' mandarin

The data on number of fruits per tree of Nagpur mandarin as influenced by different plant growth regulators treatments are presented in table 4.6 and depicted in Fig. 4.11. The analysis of variance is given in Appendix – VI.

The application of various plant growth regulators at different concentrations showed a significant effect on number of fruits per tree of Nagpur mandarin. The number of fruits was increased in all the treatments of plant growth regulator at different concentrations over control. The maximum number of fruits per tree were obtained in T_{11} treatment (2,4-D @ 30 ppm) having value of (126.0), which was closely followed by T_9 treatment (2,4-D @ 10 ppm) having value of (117.67), T_{12} treatment (2,4-D @ 40 ppm) having value of (119.67) and T_{10} treatment (2,4-D @ 20 ppm) having value of (123.67), respectively. However, the minimum number of fruits per tree (100.67) was obtained in control.

4.2.9 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on fruit retention (%) of 'Nagpur' mandarin

The data on per cent fruit retention of Nagpur mandarin as influenced by plant growth regulator treatments are presented in Table 4.6 and depicted in Fig. 4.12. The analysis of variance is given in Appendix – VI.

From the table it, can be observed that there was significant difference on per cent fruit retention due to different plant growth regulators treatment. However, the maximum fruit retention (70.68%) was obtained in T_{11} treatment (2,4-D @ 30 ppm), which was found to be at par with (69.04%) and (69.21%) recorded with 25 ppm GA_3 in(T_5)and 10 ppm 2,4-D in (T_9) treatments, respectively and was statistically significantly than all other treatments. However, the minimum fruit retention per cent (56.42%) was observed in control.

4.2.10 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on days taken to first harvesting of 'Nagpur' mandarin

The data on days taken to first harvesting of Nagpur mandarin as influenced by various plant growth regulator treatments are presented in Table 4.7 and Fig. 4.13. The analysis of variance is given in Appendix – VII.

The application of different plant growth regulators had a significant effect on days taken to first harvesting (maturity days) of Nagpur mandarin. The days taken to harvesting were reduced due to different treatments of plant growth regulators at various concentrations over control. However, the minimum days taken to first harvesting was recorded with T_8 treatment (GA_3 @ 100 ppm) having number of days (231.67days), which was found to be at par with T_{11} (2,4-D @ 30 ppm), T_7 (GA_3 @ 75 ppm), T_6 (GA_3 @ 50 ppm), T_{12} (2,4-D @ 40 ppm), T_5 (GA_3 @ 25 ppm), T_{10} (2,4-D @ 20 ppm) and T_9 (2,4-D @ 10 ppm) treatments, having values of (233.67 days), (234.33 days), (235.67 days), (236.67 days), (238.33 days), (239.33 days) and (240.67 days), respectively. The maximum number of days taken to first harvesting of fruit (260.33 days) was recorded under control.

Table – 4.6 Effect of plant growth regulators on number of fruits per tree and fruit retention (%) of 'Nagpur' mandarin

Treatments		No. of fruits/tree	Fruit retention (%)
Control	(T_0)	100.67	56.42 (69.43)
NAA 50 ppm	(T_1)	115.67	67.42 (85.27)
NAA 100 ppm	(T_2)	112.33	66.32 (83.89)
NAA 150 ppm	(T_3)	109.33	66.24 (83.78)
NAA 200 ppm	(T_4)	110.33	65.07 (82.17)
GA_3 25 ppm	(T_5)	107.67	69.04 (87.08)
GA_3 50 ppm	(T_6)	110.33	66.50 (84.11)
GA_3 75 ppm	(T_7)	106.67	67.49 (85.36)
GA_3 100 ppm	(T_8)	113.33	65.29 (82.53)
2,4-D10 ppm	(T_9)	117.67	69.21 (87.34)
2,4-D20 ppm	(T_{10})	123.67	67.25 (85.06)
2,4-D30 ppm	(T_{11})	126.00	70.68 (89.05)
2,4-D40 ppm	(T_{12})	119.67	64.60 (81.61)
Triacontanol 5 ppm	(T_{13})	101.67	62.96 (79.32)
Triacontanol 10 ppm	(T_{14})	107.67	64.17 (81.03)
Triacontanol 15 ppm	(T_{15})	105.33	59.93 (74.88)
Triacontanol 20 ppm	(T_{16})	114.67	61.20 (76.79)
SEm±		3.12	1.03
C.D. at 5%		8.98	2.99

* Figure in parenthesis are arc sin reconverted values.

Fig-4.11 Effect of plant growth regulators on number of fruits per tree of 'Nagpur' mandarin

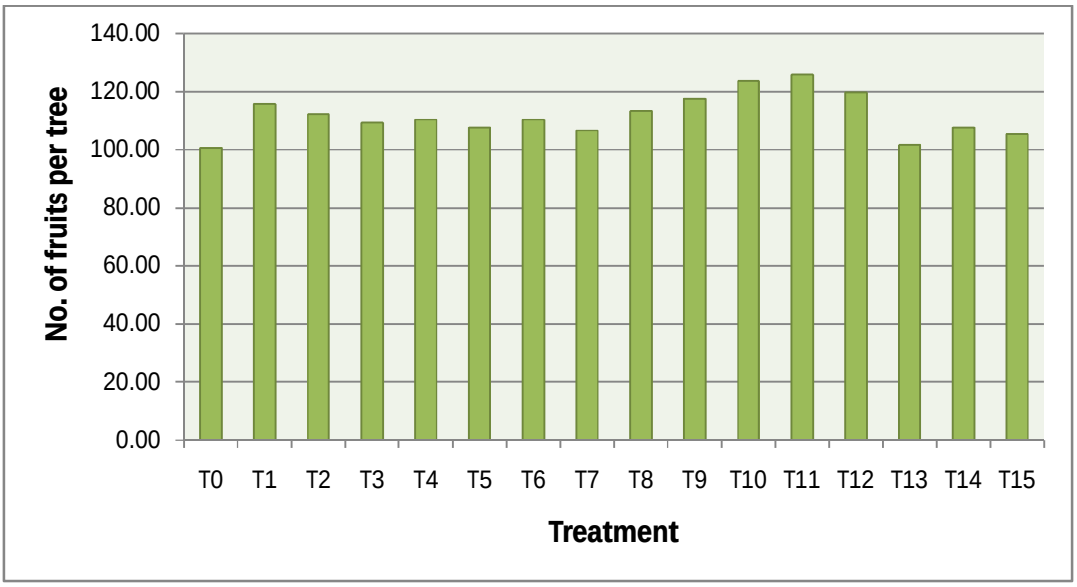
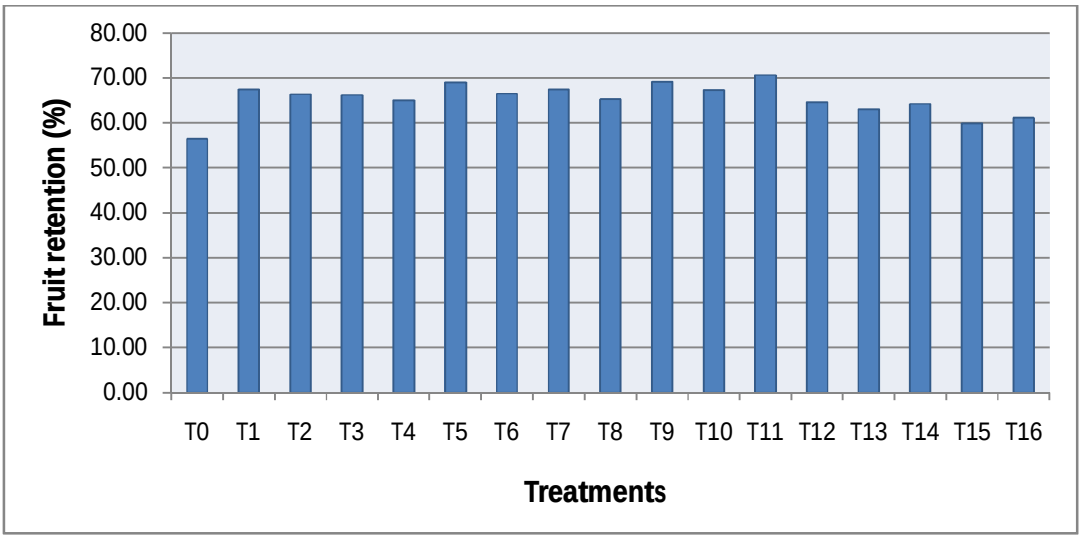


Fig-4.12 Effect of plant growth regulators on fruit retention (%) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm, **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Plate 4.1 and 4.2: Showing maximum fruit retention in treatment T_{11} (2,4-D @ 30 ppm)

4.2.11 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on total days taken to complete harvesting of 'Nagpur' mandarin

The total data on days taken to complete harvesting of Nagpur mandarin as influenced by various plant growth regulator treatments are presented in Table 4.7 and Fig. 4.14. The analysis of variance is given in Appendix – VII.

The application of various plant growth regulators at different concentrations had a significant effect on total days taken to complete harvesting (maturity days) of Nagpur mandarin. The days taken to harvesting were reduced due to different treatments of plant growth regulators at various concentrations over control. The minimum total days taken to complete harvesting was recorded with T_8 treatment (GA_3 @ 100 ppm) having number of days (261.67days), which was found to be at par with T_{11} (2,4-D @ 30 ppm), T_7 (GA_3 @ 75 ppm), T_6 (GA_3 @ 50 ppm), T_{12} (2,4-D @ 40 ppm), T_5 (GA_3 @ 25 ppm), T_{10} (2,4-D @ 20 ppm) and T_9 (2,4-D @ 10 ppm) treatments, having values (263.67 days), (264.67 days), (265.67 days), (266.67 days), (268.33 days), (269.33 days) and (270.67 days), respectively. The maximum number of total days taken to complete harvesting of fruit was (294.67 days) recorded under control.

4.3.1 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on total soluble solids (^{0}Brix) of 'Nagpur' mandarin

The data on total soluble solids content of Nagpur mandarin fruits as affected by different plant growth regulator treatments are presented in Table 4.8 and depicted in Fig. 4.15. The analysis of variance has been given in Appendix – VIII.

The application of various plant growth regulators treatment at different concentrations significantly increased the TSS content of fruit of Nagpur mandarin over control. However, the maximum total soluble solids content (12.05 ^{0}Brix) was recorded in T_{11} (2,4-D @ 30 ppm) treatment, which was closely followed by T_5 (GA_3 @ 25 ppm), T_6 (GA3 @ 50 ppm), T_1 (NAA @ 50 ppm), T_8 (GA_3 @100 ppm) and T_{10} (2,4-D @ 20 ppm) treatments, having values of (11.20 ^{0}Brix), (11.34 ^{0}Brix), (11.49 ^{0}Brix), (11.72 ^{0}Brix), and (11.77 ^{0}Brix), respectively. However, the minimum total soluble solids content of fruit (8.59 ^{0}Brix) was recorded in control.

Table – 4.7Effect of plant growth regulators on days taken to first harvesting and total days taken to complete harvesting of 'Nagpur' mandarin

Treatments		Days taken to first harvesting	Total days taken to complete harvesting
Control	(T_0)	260.33	294.67
NAA 50 ppm	(T_1)	254.67	285.33
NAA 100 ppm	(T_2)	253.33	283.33
NAA 150 ppm	(T_3)	251.33	281.33
NAA 200 ppm	(T_4)	248.67	278.67
GA_3 25 ppm	(T_5)	238.33	268.33
GA_3 50 ppm	(T_6)	235.67	265.67
GA_3 75 ppm	(T_7)	234.33	264.33
GA_3 100 ppm	(T_8)	231.67	261.67
2,4-D10 ppm	(T_9)	240.67	270.67
2,4-D20 ppm	(T_{10})	239.33	269.33
2,4-D30 ppm	(T_{11})	233.67	263.67
2,4-D40 ppm	(T_{12})	236.67	266.67
Triacontanol 5 ppm	(T_{13})	253.33	283.33
Triacontanol 10 ppm	(T_{14})	251.67	281.67
Triacontanol 15 ppm	(T_{15})	249.67	279.67
Triacontanol 20 ppm	(T_{16})	248.33	278.33
SEm±		5.30	5.35
C.D. at 5%		15.27	15.42

Fig-4.13 Effect of plant growth regulators on days taken to first harvesting of 'Nagpur' mandarin

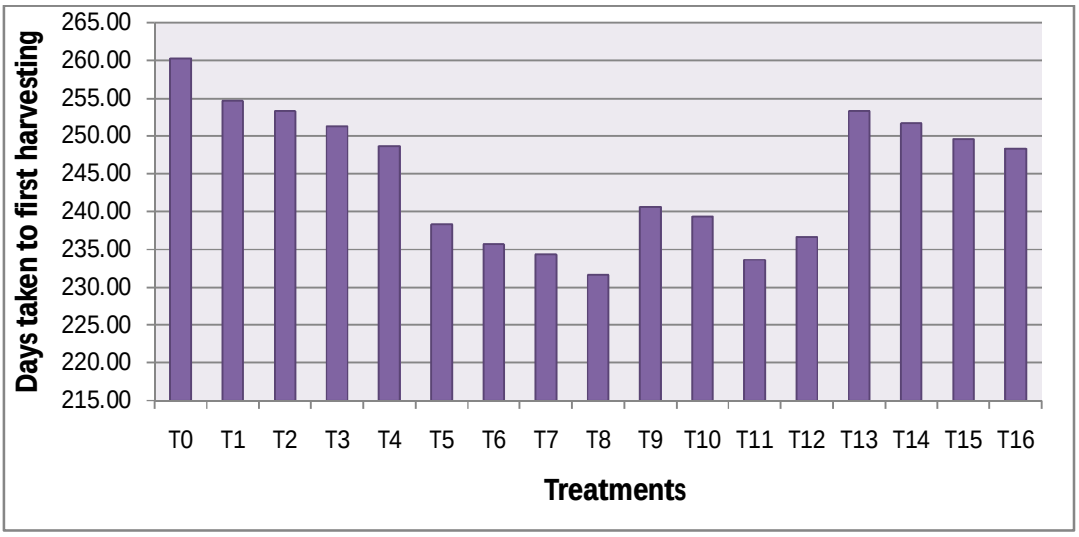
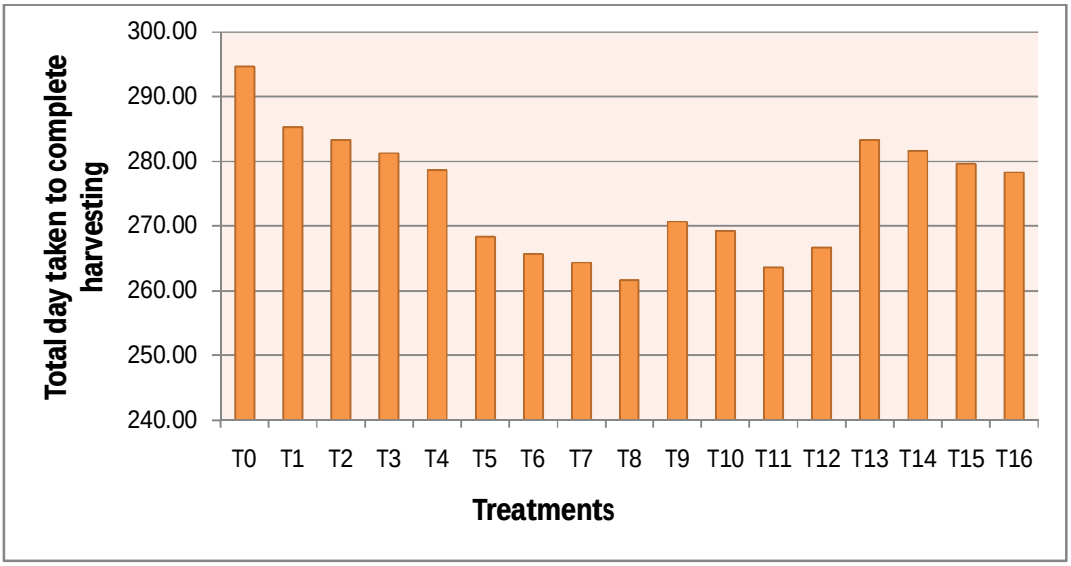


Fig-4.14 Effect of plant growth regulators on total days taken to complete harvesting of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

4.3.2 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on total acidity (%) of 'Nagpur' mandarin

The data on total acidity per cent of Nagpur mandarin fruits as affected by different treatments of plant growth regulators are presented in Table 4.8 and depicted in Fig. 4.16. The analysis of variance is given in Appendix – VIII.

The data on total acidity per cent of Nagpur mandarin fruit as influenced by different plant growth regulators reveals that the acidity per cent of fruit was significantly reduced by various treatments. The minimum acidity of fruit (0.66%) was recorded in 30 ppm 2,4-D (T_{11}) treatment which was at par with T_{10} treatment (2,4-D @ 20 ppm) having value of (0.70%), T_4 treatment (NAA @ 200 ppm) having value of (0.71%), T_{12} treatment (2,4-D @ 40 ppm) having value of (0.75%) and T_{16} treatment (Triacontanol @ 20 ppm) having value of (0.75%), respectively. However, the maximum acidity (1.15%) was obtained under control which was significantly higher than all the other plant growth regulator treatments.

4.3.3 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on TSS/Acid ratio of 'Nagpur' mandarin

The data of TSS/Acid ratio of Nagpur mandarin fruits as influenced by different treatments of plant growth regulators are presented in Table 4.8 and depicted in Fig. 4.17. The analysis of variance is given in Appendix – VIII. The TSS/Acid ratio of fruit was significantly increased due to application of plant growth regulators over control.

The maximum TSS/Acid ratio of Nagpur mandarin fruit (15.89) was observed with T_{11} (2,4-D @ 30 ppm) treatment, which was found to be at par with T_5 treatment (GA_3 @ 25 ppm) having value of (14.34), T_{10} treatment (2,4-D @ 20 ppm) having value of (14.73) and T_4 treatment (NAA @ 200 ppm) having value of (15.18), respectively and was statistically significant over other treatments. While, the minimum TSS/Acid ratio (7.47) was obtained in control.

Table – 4.8Effect of plant growth regulators on total soluble solids (^{0}Brix), total acidity (%) and TSS/Acid ratio of 'Nagpur' mandarin

Treatments		TSS (^{0}Brix)	Total acidity (%)	TSS/Acid ratio
Control	(T_0)	8.59	1.15	7.47
NAA 50 ppm	(T_1)	11.49	0.96	12.01
NAA 100 ppm	(T_2)	10.10	0.86	11.78
NAA 150 ppm	(T_3)	11.00	0.96	11.51
NAA 200 ppm	(T_4)	10.66	0.71	15.18
GA_3 25 ppm	(T_5)	11.20	0.79	14.34
GA_3 50 ppm	(T_6)	11.34	0.81	14.09
GA_3 75 ppm	(T_7)	11.02	0.81	13.65
GA_3 100 ppm	(T_8)	11.72	0.85	13.84
2,4-D10 ppm	(T_9)	10.50	0.94	12.83
2,4-D20 ppm	(T_{10})	11.77	0.70	14.73
2,4-D30 ppm	(T_{11})	12.05	0.66	15.89
2,4-D40 ppm	(T_{12})	10.05	0.75	13.35
Triacontanol 5 ppm	(T_{13})	10.36	0.89	11.64
Triacontanol 10 ppm	(T_{14})	9.90	0.79	12.57
Triacontanol 15 ppm	(T_{15})	10.42	0.83	13.16
Triacontanol 20 ppm	(T_{16})	9.49	0.75	12.65
SEm±		0.30	0.03	0.55
C.D. at 5%		0.86	0.10	1.59

Fig-4.15 Effect of plant growth regulators on total soluble solids (%) of 'Nagpur' mandarin

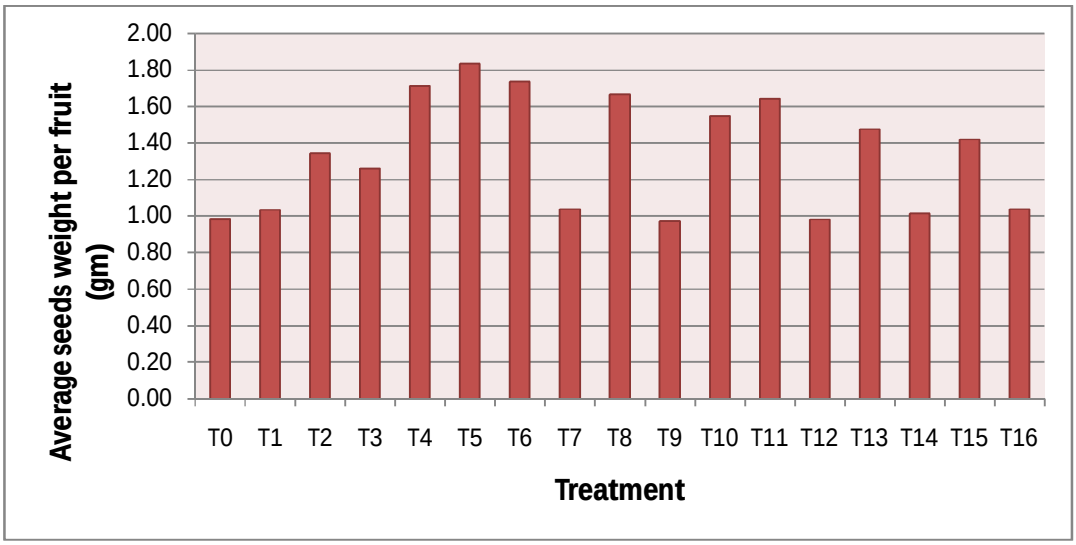
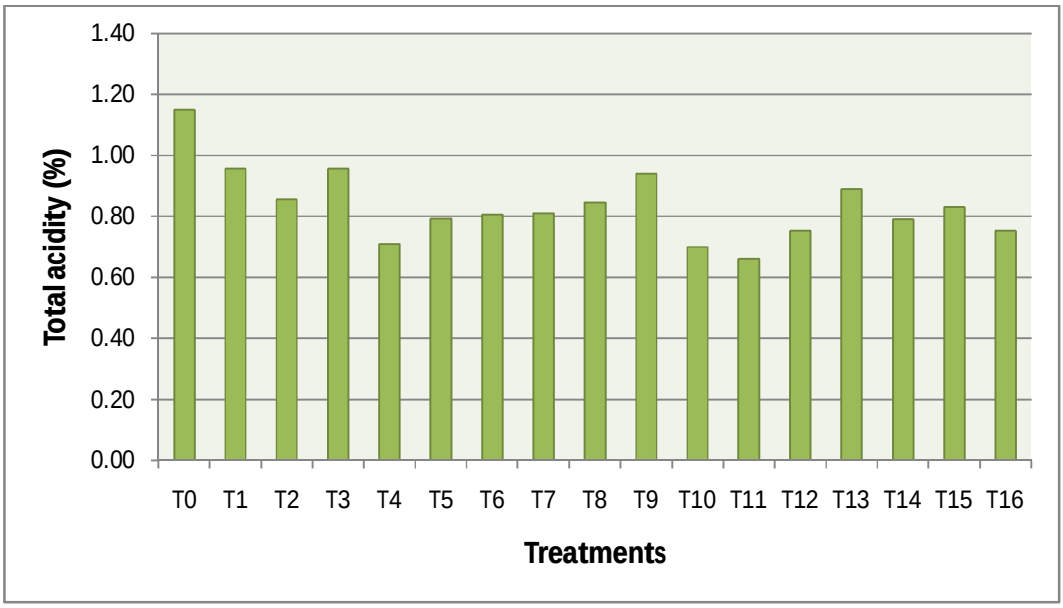
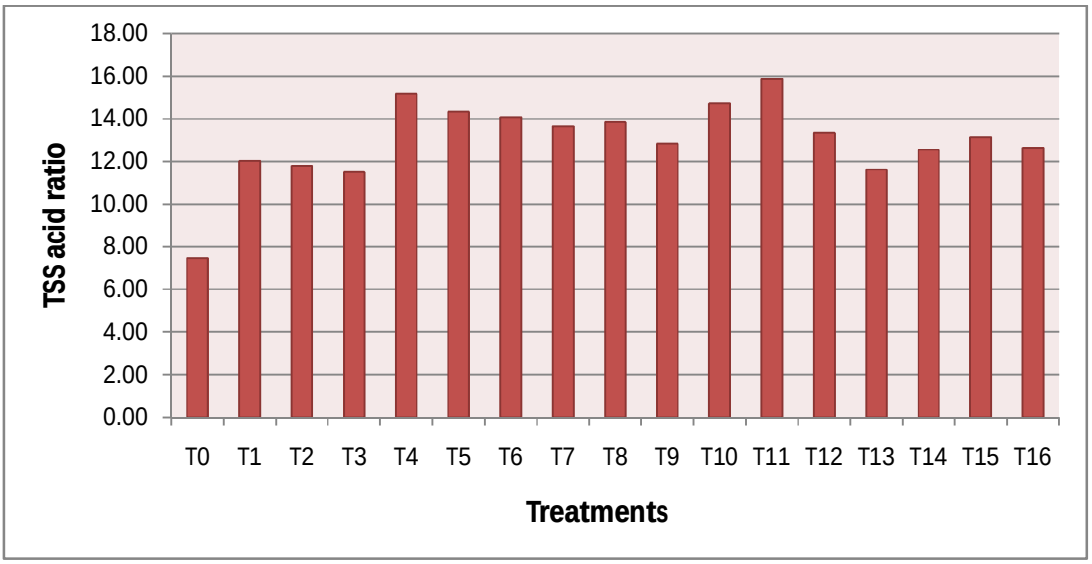


Fig-4.16 Effect of plant growth regulators on total acidity (%) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Fig-4.17 Effect of plant growth regulators on TSS/Acid ratio of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

4.3.4 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on reducing sugar (%) of 'Nagpur' mandarin

The data on reducing sugar content of Nagpur mandarin fruit as influenced by different plant growth regulator treatments are given in Table 4.9 and depicted in Fig. 4.18. The analysis of variance is given in Appendix – IX.

The application of various plant growth regulator treatments at different concentrations increased the reducing sugar content of Nagpur mandarin fruits significantly as compared to control. The maximum reducing sugar content (6.33%) was observed with T_{11} treatment (2,4-D @ 30 ppm), which was found to be at par with T_5 treatment (GA_3 @ 25 ppm) having value of (5.88%), T_6 treatment (GA_3 @ 50 ppm) having value of (5.96%), T_1 treatment (NAA @ 50 ppm) having value of (6.03%), T_8 treatment (GA_3 @ 100 ppm) having value of (6.15%) and T_{10} treatment (2,4-D @ 20 ppm) having value of (6.17%), respectively . However, the minimum reducing sugar content (4.51%) was recorded under control which was significantly lower than all the treatments.

4.3.5 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on non- reducing sugar (%) of 'Nagpur' mandarin

The data on non-reducing sugar content of Nagpur mandarin fruit as affected by various plant growth regulator treatments are presented in Table 4.9 and depicted in Fig. 4.19. The analysis of variance is given in Appendix – IX. The application of plant growth regulator treatments showed significantly pronounced effect on non-reducing sugar content of fruit over control.

The non-reducing sugar content of Nagpur mandarin fruits was increased by application of different plant growth regulator treatments. The maximum non-reducing sugar content (2.58%) was obtained in 30 ppm 2,4-D (T_{11}) treatment, which was closely followed by T_3 treatment (NAA @ 150 ppm) having value of (2.35%), T_7 treatment (GA_3 @ 75 ppm) having value of (2.36%), T_5 treatment (GA_3 @ 25 ppm) having value of (2.39%), T_6 treatment (GA_3 @ 50 ppm) having value of (2.42%), T_1 treatment (NAA @ 50 ppm) having value of (2.46%) and T_{10} treatment (2,4-D @ 20 ppm) having value of (2.52%), respectively. The minimum non-reducing sugar content (1.83%) was obtained under control.

4.3.6 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on total sugar (%) of 'Nagpur' mandarin

The data on total sugar content of Nagpur mandarin fruits as affected by various plant growth regulator treatments used in present study are presented in Table 4.9 and depicted in Fig. 4.20. The analysis of variance is given in Appendix – IX.

The application of various plant growth regulator treatments at different concentrations significantly increased the total sugar content of Nagpur mandarin fruits over control. The maximum total sugar content (9.04%) in observed with T_{11} treatment (2,4-D @ 30 ppm) which was at par with T_5 treatment (GA_3 @ 25 ppm) having value of (8.40%), T_6 treatment (GA_3 @ 50 ppm) having value of (8.51%), T_1 treatment (NAA @ 50 ppm) having value of (8.62%), T_8 treatment (GA_3 @ 100 ppm) having value of (8.79%), T_{10} treatment (2,4-D @ 20 ppm) having value of (8.82%), respectively. The minimum sugar content (6.44%) was observed in control

4.3.7 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on ascorbic acid (mg/100 ml juice) of 'Nagpur' mandarin

The data on ascorbic acid content of Nagpur mandarin fruits as affected by various plant growth regulator treatments are presented in Table 4.10 and depicted in Fig. 4.21. The analysis of variance has been presented in Appendix – X.

A perusal of data reveals that ascorbic acid content of Nagpur mandarin fruits was significantly increased as a result of different plant growth regulator treatments. The maximum ascorbic acid content (53.41 mg/100ml juice) was recorded in 30 ppm 2,4-D (T_{11})treatment, which was closely followed by T_{10} treatment (2,4-D @ 20 ppm) having value of (50.34 mg/100ml juice), respectively and were found to be significantly higher than other treatments. While, the minimum ascorbic acid content (34.69 mg/100ml juice) was recorded in control.

4.3.8 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on juice recovery per cent of 'Nagpur' mandarin

The data on effect of plant growth regulator treatments on juice content of Nagpur mandarin fruits are presented in Table 4.10 and depicted in Fig. 4.22. The

analysis of variance is given in Appendix – X. The application of various plant growth regulators at different concentrations had significantly increased juice content of Nagpur mandarin fruits.

However, the maximum juice recovery per cent of Nagpur mandarin fruits was observed with T_8 treatment (GA_3 @ 100 ppm) having value of (46.67%) followed by T_{11} (2,4-D @ 30 ppm) which was significantly superior over other treatments. Whereas, the minimum juice recovery per cent (35.71) was recorded in control.

4.3.9 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on sensory score of 'Nagpur' mandarin

The data related to sensory score of Nagpur mandarin fruits as influenced by various plant growth regulator treatments are given in Table 4.10 and depicted in Fig. 4.23. The analysis of variance is given in Appendix – X.

The data recorded in present investigation reveals that sensory score of Nagpur mandarin fruit was significantly increased due to application of various plant growth regulators over control. The maximum sensory score (9.71) of fruit was observed in 30 ppm 2,4-D in (T_{11}) treatment, which was found to be at par with T_{10} treatment (2,4-D @ 20 ppm) having value of (9.53) and was statistically higher than over other treatments. While, the minimum sensory score of Nagpur mandarin fruits (7.20) was recorded under control.

4.4 Effect of plant growth regulators (NAA, GA_3, 2,4-D and Triacontanol) on yield per plant (kg) and estimated yield per ha (tonnes) of 'Nagpur' mandarin

The data on yield kg/plant and tonnes/ha of Nagpur mandarin as affected by various plant growth regulator treatments are presented in Table 4.11 and depicted in Fig. 4.24 and 4.25. The analysis of the variance is given in Appendix – XI.

The application of various plant growth regulator treatments at different concentrations had significantly increased in yield attributes of Nagpur mandarin. However, the maximum yield (21.80 kg/plant and 6.08 tonnes/ha) was recorded in 30 ppm 2,4-D (T_{11}) treatment, which was found at par with T_8 treatment (GA_3 @ 100

ppm) having value of (21.67 kg/plant and 6.03 tonnes/ha) and T_9 treatment (2,4-D @ 10 ppm) having value of (21.68 kg/plant and 6.03 tonnes/ha) treatments. However, the minimum yield (12.94 kg/plant and 3.60 tonnes/ha) was obtained in control.

Table – 4.9Effect of plant growth regulators on reducing sugar (%), non-reducing sugar (%) and total sugar (%) of 'Nagpur' mandarin

Treatments		Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
Control	(T_0)	4.51	1.83	6.44
NAA 50 ppm	(T_1)	6.03	2.46	8.62
NAA 100 ppm	(T_2)	5.31	2.16	7.58
NAA 150 ppm	(T_3)	5.78	2.35	8.25
NAA 200 ppm	(T_4)	5.60	2.28	8.00
GA_3 25 ppm	(T_5)	5.88	2.39	8.40
GA_3 50 ppm	(T_6)	5.96	2.42	8..51
GA_3 75 ppm	(T_7)	5.78	2.36	8.26
GA_3 100 ppm	(T_8)	6.15	2.51	8.79
2,4-D10 ppm	(T_9)	5.52	2.24	7.88
2,4-D20 ppm	(T_{10})	6.17	2.52	8.82
2,4-D30 ppm	(T_{11})	6.33	2.58	9.04
2,4-D40 ppm	(T_{12})	5.28	2.15	7.54
Triacontanol 5 ppm	(T_{13})	5.44	2.21	7.77
Triacontanol 10 ppm	(T_{14})	5.20	2.12	7.43
Triacontanol 15 ppm	(T_{15})	5.47	2.23	7.82
Triacontanol 20 ppm	(T_{16})	4.98	2.03	7.12
SEm±		0.16	0.09	0.23
C.D. at 5%		0.46	0.26	0.65

Fig-4.18 Effect of plant growth regulators on reducing sugar (%) of 'Nagpur' mandarin

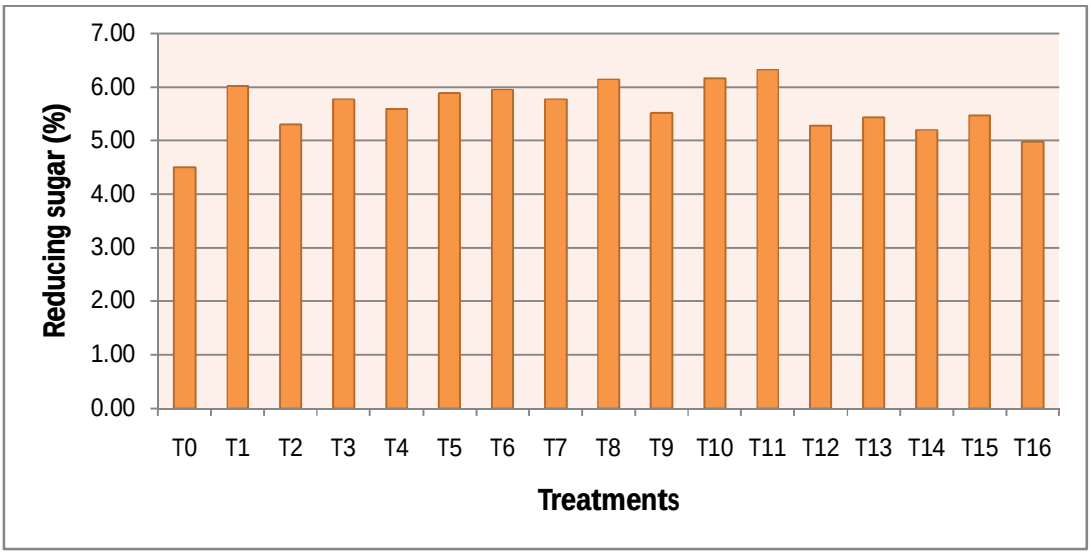
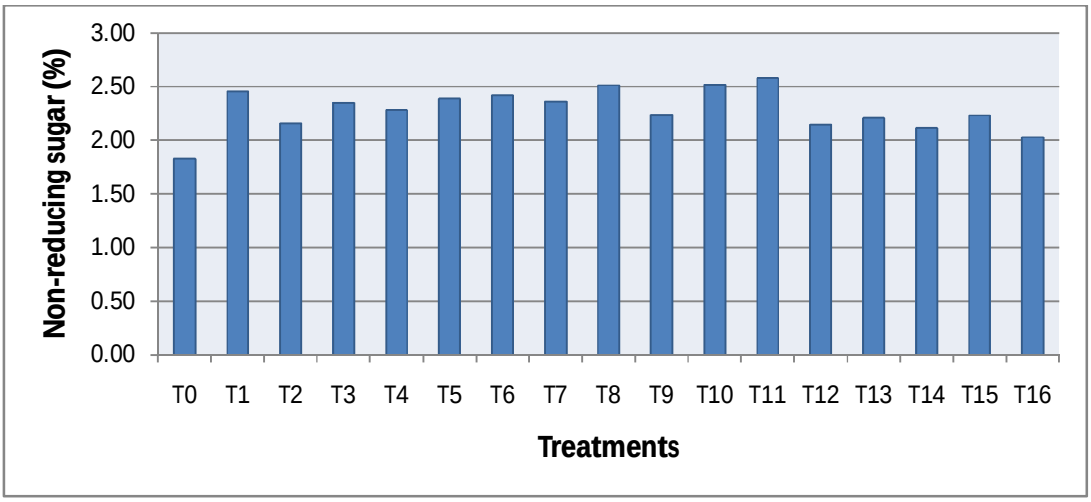
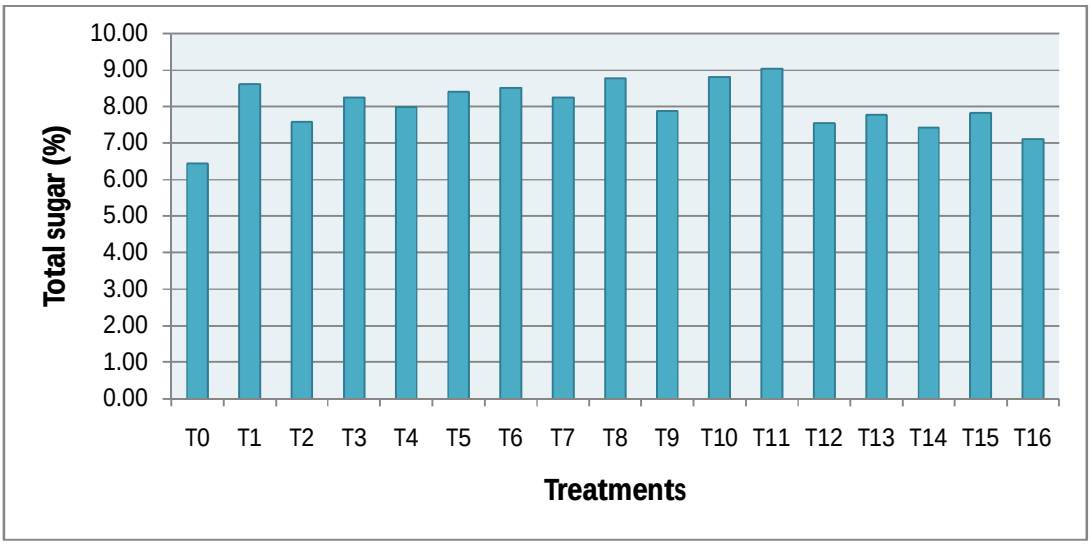


Fig-4.19 Effect of plant growth regulators on non-reducing sugar (%) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Fig-4.20 Effect of plant growth regulators on total sugar (%) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Table – 4.10Effect of plant growth regulators on ascorbic acid (mg/100ml juice), juice recovery per cent and sensory score of 'Nagpur' mandarin

Treatments		Ascorbic acid (mg/100ml juice)	Juice recovery (%)	Sensory score
Control	(T_0)	34.69	35.71 (34.11)	7.20
NAA 50 ppm	(T_1)	48.51	39.36 (40.25)	7.85
NAA 100 ppm	(T_2)	44.97	40.76 (42.66)	8.07
NAA 150 ppm	(T_3)	36.28	42.31 (45.35)	8.08
NAA 200 ppm	(T_4)	47.34	38.01 (37.95)	8.14
GA_3 25 ppm	(T_5)	46.76	40.44 (42.10)	7.67
GA_3 50 ppm	(T_6)	39.59	42.83 (46.25)	8.36
GA_3 75 ppm	(T_7)	37.80	36.23 (34.97)	8.23
GA_3 100 ppm	(T_8)	39.92	46.67 (52.94)	9.21
2,4-D10 ppm	(T_9)	35.83	38.22 (38.31)	9.04
2,4-D20 ppm	(T_{10})	50.34	42.24 (45.22)	9.53
2,4-D30 ppm	(T_{11})	53.41	43.92 (48.15)	9.71
2,4-D40 ppm	(T_{12})	41.39	39.79 (41.00)	8.50
Triacontanol 5 ppm	(T_{13})	41.34	42.45 (45.58)	8.56
Triacontanol 10 ppm	(T_{14})	44.97	36.93 (36.14)	8.45
Triacontanol 15 ppm	(T_{15})	36.01	42.06 (44.91)	8.33
Triacontanol 20 ppm	(T_{16})	46.93	38.92 (39.49)	8.76
SEm±		1.65	0.67	0.15
C.D. at 5%		4.75	1.94	0.43

* Figure in parenthesis are arc sin reconverted values.

Fig-4.21 Effect of plant growth regulators on ascorbic acid (mg/100ml juice) of 'Nagpur' mandarin

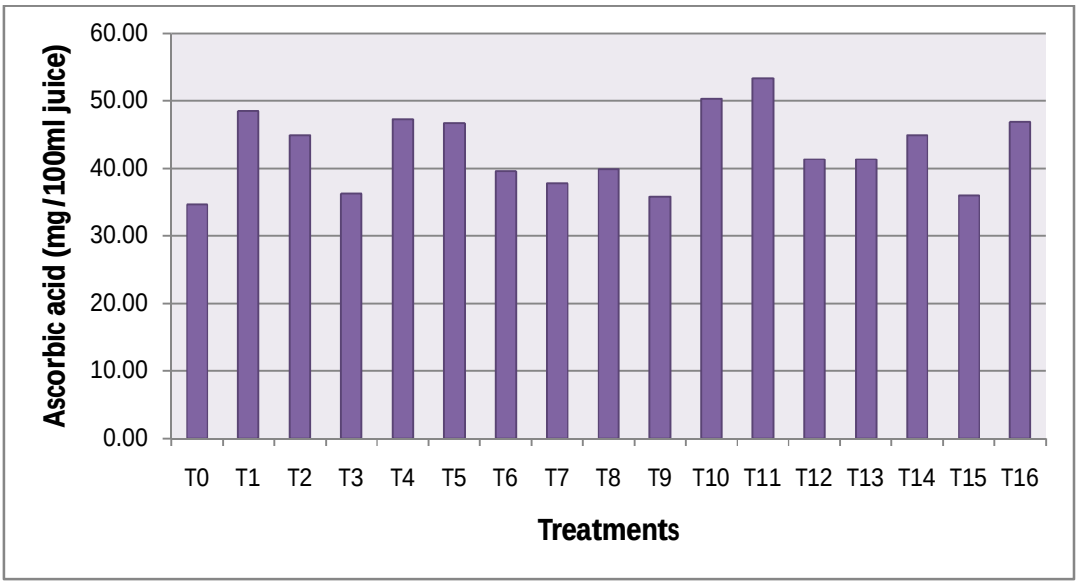
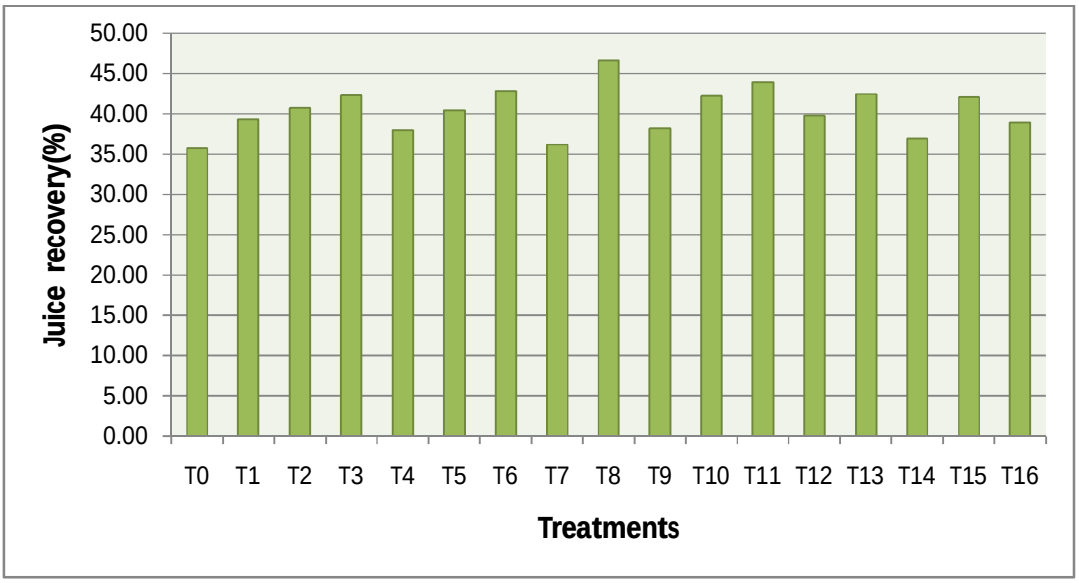
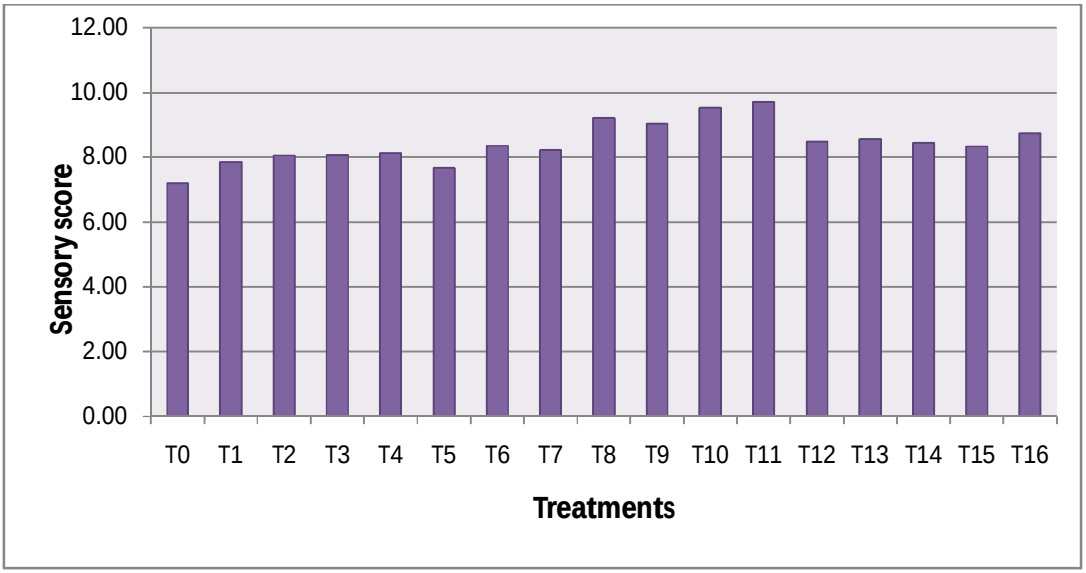


Fig-4.22 Effect of plant growth regulators on juice recovery (%) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Fig-4.23 Effect of plant growth regulators on sensory score of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

Table – 4.11 Effect of plant growth regulators on yield per plant (kg) and estimated yield per ha (tonnes) of 'Nagpur' mandarin

Treatments		Yield per plant (kg)	Estimated yield per ha (tonnes)
Control	(T_0)	12.94	3.60
NAA 50 ppm	(T_1)	16.67	4.64
NAA 100 ppm	(T_2)	16.87	4.69
NAA 150 ppm	(T_3)	15.65	4.35
NAA 200 ppm	(T_4)	18.19	5.06
GA_3 25 ppm	(T_5)	14.12	3.93
GA_3 50 ppm	(T_6)	16.06	4.46
GA_3 75 ppm	(T_7)	17.89	4.98
GA_3 100 ppm	(T_8)	21.67	6.03
2,4-D10 ppm	(T_9)	21.68	6.03
2,4-D20 ppm	(T_{10})	18.48	5.14
2,4-D30 ppm	(T_{11})	21.80	6.08
2,4-D40 ppm	(T_{12})	17.26	4.80
Triacontanol 5 ppm	(T_{13})	15.91	4.42
Triacontanol 10 ppm	(T_{14})	17.68	4.92
Triacontanol 15 ppm	(T_{15})	17.30	4.81
Triacontanol 20 ppm	(T_{16})	17.44	4.85
SEm±		0.50	0.14
C.D. at 5%		1.44	0.40

Fig-4.24 Effect of plant growth regulators on yield per plant (kg) of 'Nagpur' mandarin

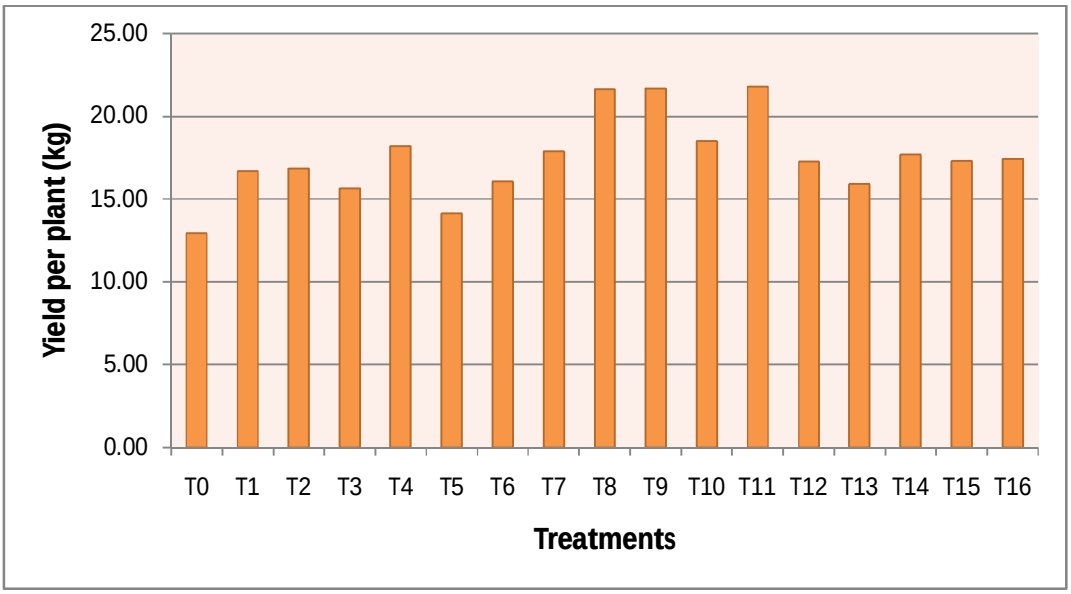
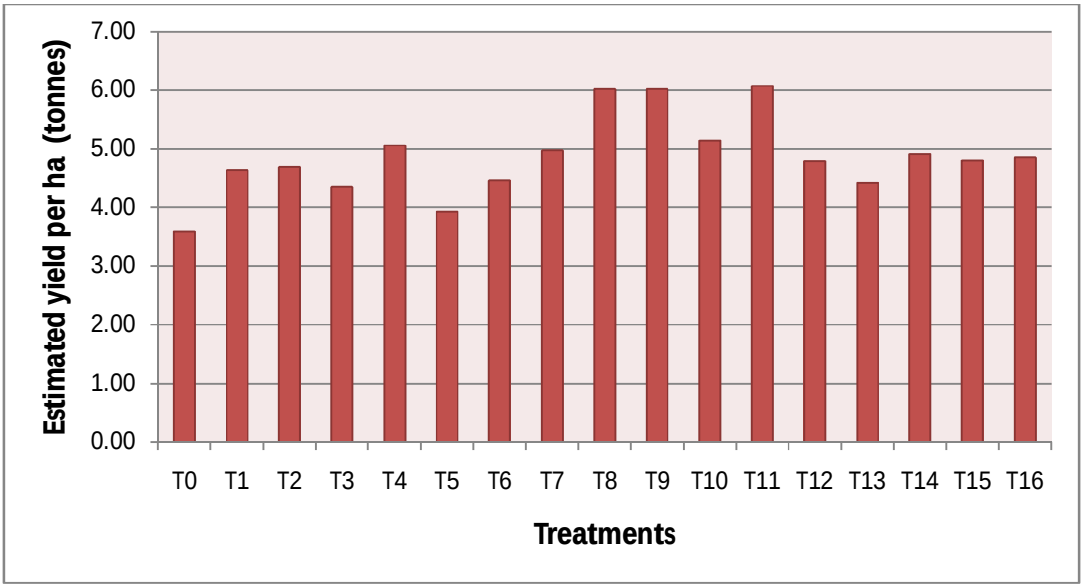


Fig-4.25 Effect of plant growth regulators on estimated yield per ha (tonnes) of 'Nagpur' mandarin



(**T_0**- Control, **T_1**- NAA 50ppm, **T_2**- NAA 100ppm, **T_3**- NAA 150ppm, **T_4**- NAA 200ppm**,** **T_5**- GA_3 25ppm, **T_6**- GA_3 50ppm, **T_7**- GA_3 75ppm, **T_8**- GA_3 100ppm, **T_9**- 2,4-D 10ppm, **T_{10}**- 2,4-D 20ppm, **T_{11}**- 2,4-D 30ppm, **T_{12}**- 2,4-D 40ppm, **T_{13}**- Triacontanol 5ppm, **T_{14}**- Triacontanol 10ppm, **T_{15}**- Triacontanol 15ppm, **T_{16}**- Triacontanol 20ppm)

CHAPTER - 5

DISCUSSION

5. DISCUSSION

Present investigation entitled '**Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco.) cv. 'Nagpur'** was carried out at Fruit Research Farm, Department of Fruit science, College of Horticulture and Forestry, Jhalawar during 2012-13.

The observations were recorded on different aspects viz. plant growth characteristics (plant spread and crown volume), physical characteristics of fruits (horizontal diameter of fruit, vertical diameter of fruit, peel thickness, weight of fruit, volume of fruit, number of seeds per fruit, average seeds weight per fruit, number of sacs per fruit, number of fruits per tree, fruit retention per cent, days taken to first harvesting and total days taken to complete harvesting), chemical characteristics or quality attributing characteristics of fruits (TSS content, total acidity, T.S.S/Acid ratio, reducing sugars, non-reducing sugars, total sugars, ascorbic acid content, juice recovery per cent and sensory score of fruit) and yield attributes (kg/plant and tones / ha), to assess the impact of plant growth regulators on above mentioned growth and quality traits of 'Nagpur' mandarin . The results obtained are discussed below :

5.1 Plant growth characteristics

It is evident from the results that the application of different plant growth regulator treatments at different concentrations had significantly influenced various vegetative growth characters as compared to control. In the present investigation, it was observed that amongst the various plant growth regulator, application of GA_3 and NAA resulted in higher rate on per cent increase in plant spread and crown volume as compared to other treatments. On 150 days after treatment application, the maximum per cent increase in plant spread and crown volume of 20.59 per cent and 38.42 per cent respectively, were recorded due to application of 100 ppm GA_3 treatment which was closely followed by 75 ppm GA_3 in(T_7) treatment (Table 4.1 and 4.2). Similar effect of GA_3 treatment on per cent increase in plant spread and crown volume was recorded by Eelkim *et al.* (2003) in Satsuma mandarin, who observed that 25, 50 and 100ppm GA_3 concentrations increased the number of vegetative shoots in response to progressive

increase in the doses of treatments. The application of GA_3 at 50, 100 and 150 ppm and showed that spray of 150 ppm GA_3 was effective for promotingearliness in sprouting of new shoot, increased shoot length and maximum number of leaves per shoot in sapota (Bhujbal *et al*. 2012).

The maximum per cent increase in plant spread and canopy volume with the spray of GA_3 might be due to beneficial effect of GA_3 in cell elongation and enlargement. The increased uptake of water and nutrients due to persuasive swelling forces leading the softening of cell wall and thereby favoured better development of plants resulting in greater height and number of branches per plant and ultimately the greater plant spread and canopy volume. These results are in close conformity with those reported by Gregoriou *et al.* (1993) in Carrizo citrange, Thukral *et al*. (1993), Nath and Baruah (1999) in Assam lemon,Sharma and Singh (2008) in plum, Saleem *et al.* (2007) in 'Blood Red' sweet orange, Kumar *et al.* (2012) in strawberry and Kacha *et al.*(2012) in phalsa.

5.2 Physical characteristics of fruits

It is evident from the present results that application of various plant growth regulators at different concentrations significantly improved physical characteristics of fruits like horizontal diameter of fruit, vertical diameter of fruit, peel thickness, weight of fruit, volume of fruit, number of seeds per fruit, average seeds weight per fruit, number of sacs per fruit, number of fruits per tree, fruit retention, days taken to first harvesting and total days taken to complete harvesting as compared to control.

The data recorded on horizontal and vertical diameter of fruit (Table 4.3) clearly indicate that application of GA_3 at 100 ppm exhibited maximum horizontal (8.03 cm) and vertical diameter (8.23 cm) of fruit whichwas found at par with 30 ppm 2,4-D horizontal (7.64 cm) and vertical diameter (7.83 cm) of fruit. The minimum horizontal diameter of fruit (6.12 cm.) and vertical diameter of fruit (5.64 cm.) was recorded at control.The results obtained in present investigation are supported by the findings of Chao *et al*. (2011) in mandarin. Likewise Garner et al. (2011) working with 'Hass' avocado reported that foliar application of GA_3 at 25ppm to increased yield and fruit size.

The influence of plant growth regulator on peel thickness of fruit is presented in Table 4.3. Among the various plant growth regulator treatments, the minimum peel thickness of 3.41 mm was recorded at 30 ppm 2,4-D treatment. Whereas, the maximum peel thickness (5.33 mm) was observed under control. The present results are in close conformity with the finding of Davies *et al*. (1999) in 'Hamlin' sweet orange and Ingle et al. (2001)in 'Nagpur' mandarin.

Application of plant growth regulators had significantly increased the weight and volume of fruits over control (Table 4.4). However, in the present study, the maximum fruit weight (191.22 g) was recorded by 100 ppm GA_3 treatment closely followed by 30 ppm 2,4-D (184.22 g) as compared to minimum at control (135.56 g). Similarly, the maximum volume of fruit (247.56 cc.) was recorded at 100 ppm GA_3 treatment that was followed by 30 ppm 2,4-D (211.89 cc) while the minimum volume (145.44 cc) was recorded in control. The increase in weight and volume of fruit due to GA_3 treatment were also recorded by Reddy and Prasad (2012) in pomegranate and Chao *et al*. (2011) in mandarin. Similarly Nawaz *et al.* (2008) fount the increased fruit size (71.20 mm) by application of 10 ppm GA_3 treatmentand fruit weight (155.53g) and juice percentage (52.16%) were recorted in 100 ppm GA_3 treatment inKinnow mandarin and likewise findings were also reported by Kacha *et al*. (2012) in phalsa fruits.

The influence of plant growth regulator on number of seeds per fruit and average seeds weight per fruit are presented in Table 4.5. The data reveals that the application of plant growth regulator had significantly affected the number of seeds per fruit and average seeds weight per fruit of Nagpur mandarin over control. Among the various plant growth regulator treatments, the minimum number of seeds per fruit of (9.44) and minimum average seeds weight per fruit of (0.97 g) were recorded at 30 ppm 2,4-D treatment. However, the maximum number of seeds per fruit (15.44) and maximum average seeds weight per fruit (1.86 g) were observed at control. The present results are in consonance with the findings of Saleem *et al*. (2008) in 'Blood Red' sweet orange and Saleem *et al.* (2007) in sweet orange.

The number of sacs per fruit of Nagpur mandarin was significantly improved by application of different plant growth regulator treatments at various concentrations (Table 4.5). It is evident from the data obtained that application of GA_3 at 100 ppm

concentration had exhibited highest number of sacs per fruit as compared to other treatments and control. The maximum number of sacs per fruit of 12.56 was recorded at 100 ppm GA_3 treatment, which was closely followed by 30 ppm 2,4-D. However, the minimum number of sacs per fruit of 9.89 was recorded at control, respectively. The variation in the number of sacs per fruit due to different plant growth regulators might be attributed to difference in enzymetion alluding during cell division and cell differentiation phases of fruit developments.

The application of plant growth regulator treatments had significantly increased the number of fruits per tree and fruit retention per cent over control (Table 4.6). The maximum number of fruits per tree (126.0) was recorded at 30 ppm 2,4-D treatment as compared to minimum (100.67) in control. Similarly the maximum fruit retention per cent (70.68) was recorded at 30 ppm 2,4-D treatment closely followed by 10 ppm 2,4-D (69.21%) treatment. The minimum fruit retention of 56.42 per cent was recorded at control. The application of 2, 4-D at 40 ppm gave significantly maximum number of fruits (64.00) in pomegranate Reddy and Prasad (2012).Similar beneficial effect of 2,4-D on number of fruit per tree and fruit retention per cent was also recorded by Nawaz *et al.* (2008) and Ashraf *at el*. (2013) in Kinnow mandarin, and Chattha *et al.* (1999) in mango, which supports the present results.

It is evident form the data (Table 4.7) that, the minimum days taken to first harvesting (231.67 days) was recorded at 100 ppm GA_3 treatment which was closely followed by 30 ppm 2,4-D (233.67 days). The maximum days taken to first harvesting (260.33) was recorded at control. Similar results of minimum total days taken to complete harvesting (261.67 days) was recorded at 100 ppm GA_3 treatment which was closely followed by 30 ppm 2,4-D (263.67 days). The maximum days taken to first harvesting (294.67) was recorded under control. A similar result of earlier harvesting due to application of GA_3 was recorded by Duarte *et al.* (2006) in `Clausellina' Satsuma Mandarin. This might be attributed to harvesting of fruit maturity under different GA_3 concentration.

5.3 Chemical characteristics or Quality attributing characteristics of fruits

It is evident from the results that the application of plant growth regulators on Nagpur mandarin had significantly improved the nutritional quality of fruits in terms of TSS, acidity content, TSS/Acid ratio, sugars contents (reducing, non-reducing and

total), ascorbic acid content, juice recovery per cent and sensory score of fruit as compared to control. It is further evident from the present results that amongst the various treatment of plant growth regulators in Nagpur mandarin, the application of 2,4-D, GA_3, NAA and Triacontanol at different concentrations was found to be significantly superior over control with respect to nutritional quality parameters of the fruit. However, the highest TSS (12.05%), lowest total acidity (0.66%) and maximum TSS/Acid ratio (15.89%) were recorded at 30 ppm 2,4-D treatment and 20 ppm 2,4-D was found second best treatment with regards to TSS, acidity and TSS / acid ratio (Table 4.8). Similar beneficial effect on TSS, acidity and TSS / acid ratio was also recorded byAshraf *at el*. (2013) in Kinnow. Nawaz *et a**l.*** (2008) also reported increase in TSS and decrease in acidity by 2,4-D application in Kinnow mandarin. They explained that the beneficial effect of 2,4-D might be due to its influence on physiological process, particularly respiration and photosynthesis which possibly led to accumulation of dry matter, minerals and carbohydrates. The increase in TSS and reduction in acidity due to application of 2,4-D in the present investigation are supported by the findings ofJain *et al*. (2009) in mandarin. The similar results of increase in TSS, reduction in acidity and there by increased TSS / acid ratio were also observed by application of these plant growth regulator treatments bySaleem *et al*. (2007) in sweet orange,Duarte *et al*. (2006) in`Clausellina' Satsuma, Ingle et al. (2001) in Nagpur mandarin and Khalid *et al*. (2012) in ‘Kinnow’ mandarin

The data presented in Table 4.9 clearly indicates that the application of plant growth regulators had significantly increased the sugar content (reducing, non-reducing and total sugar) of Nagpur mandarin fruits. In the present investigation of Nagpur mandarin, the highest reducing, non-reducing and total sugar content of 6.33, 2.58 and 9.04 per cent, respectively were recorded in 30 ppm 2,4-D treatment. Whereas, the minimum reducing sugar (4.51%), non-reducing sugar (1.83%) and total sugar (6.44%) were recorded at control. The plants treated with 2,4-D had higher quantity of soluble carbohydrates in the cell sap and glucose concentration was strikingly high due to marked increase in carbon assimilation, thereby favoring better electrolytic composition. The present results are corroborated with the findings of Ashraf *at el*. (2013) in Kinnow, Nawaz *et al*. (2008) in Kinnow mandarin, Jain *et al*. (2009) in mandarin, Ingle et al. (2001) in Nagpur mandarin and Khalid *et al*. (2012) in ‘Kinnow’ mandarin.

The influence of plant growth regulator on ascorbic acid and sensory score of fruit are presented in Table 4.10. The data reveals that the application of plant growth regulator had significantly increased the ascorbic acid and sensory score of the Nagpur mandarin fruit over control. Among the various plant growth regulator treatments, the maximum ascorbic acid content of 53.41 mg/100 ml juice and sensory score of 9.71 out of 10 were recorded at 30 ppm 2,4-D treatment. Whereas, the minimum ascorbic acid content of 34.69 mg/100 ml juice and sensory score (7.20 out of 10) were observed at control. The maximum organoleptic rating due to application of 2,4-D treatment might be due to better sugar acid ratio and reduced the fruit pressure and overall enhancement of fruit quality. Ashraf *et al*. (2013) reported that foliar applications of 2,4-D treatment improved the fruit weight, number of fruits per plant, juice percentage, total soluble solids (TSS), ascorbic acid content, acidity, and TSS/acid ratio in Kinnow.

The present results are in line with the finding ofJain *et al*. (2009) in mandarin, Greenberg *et al*. (2006) in 'Nova' mandarin, Duarte *et al.* (2006) in`Clausellina' Satsuma and Khalid *et al*. (2012) in 'Kinnow' mandarin.

Juice content (Table 4.10) significantly increased with the application of different plant growth regulators over control. The maximum juice content 46.67 per cent was recorded with 100 ppm GA_3 followed by 30 ppm 2,4-D and significantly superior over other treatments and control. Kacha *et al*. (2012) the application of GA_3 50, 100 and 150 ppm observed that sprayed 150 ppm GA_3 significantly increased of juice content (57.78%) in phalsa. These results are in close conformity with those of Nawaz *et al*. (2008) in 'Kinnow' mandarin, Saleem *et al.* (2008) in 'Blood Red' sweet orange and Arzani and Akhlaghi-Amiri (2001) in Satsuma mandarin.

5.4 Yield attributing characteristics

The effect of plant growth regulators on yield of Nagpur mandarin fruits are presented in Table 4.11. The data showed that the application of different plant growth regulators at various concentrations had significantly increased the yield of Nagpur mandarin fruits over control in the present investigation. Amongst the various plant growth regulator treatments attempted the maximum yield of 21.80 kg/plant and (6.08 tonnes/ha.) was recorded at 30 ppm 2,4-D treatment followed by 10 ppm 2.4-D treatment. The minimum yield of (12.94 kg/plant and 3.60 tonnes/ha.) was observed at

control. The increase in yield of Nagpur mandarin fruits by application of 2,4-D and GA_3 treatmentsmay be attributed to the fact that partitioning of assimilates by 2,4-D and GA_3 more towards the fruit development and better translocation of assimilates further leads to improvement in yield contributing characters like size and weight of fruits as evident by the present study which finally increased the yield. Similar results were also observed by application of 2,4-D treatment, in pomegranate (Reddy and Prasad, 2012), in 'Nova' mandarin (Greenberg *et al.*, 2006),in Nagpur mandarin (Ingle et al., 2001, in plum (Sharma and Singh, 2008**)** and Khalid *et al*., (2012) in 'Kinnow' mandarin.

5.6 Economics of the treatment used

The economics of different plant growth regulator treatments used at various concentrations in the present investigation are calculated and presented in Table 5. The economic feasibility of various treatments clearly showed that the application of 30 ppm 2,4-D treatment has resulted the maximum gross return of Rs. 1,21,600/ha which was Rs. 49600/ha excess over control. Further, the highest net profit (Rs. 48,855/ha) was estimated at 30 ppm 2,4-D treatment which was 67.85 per cent higher than control, which was closely followed by 10 ppm 2,4-D and 100 ppm GA_3. Ingle et al. (2001) revealed that foliar application of 2, 4-D at 10 ppm treatment increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control in Nagpur mandarin. Amiri *et al.* (2008) found that spray of 2, 4-D in Italian orange and is an effective and economical way to reduce citrus pre harvest fruit drop. The application of 20 ppm 2,4-D treatment was observed by Nawaz et al. (2008) whose findings revealed that the the lowest fruit drop of 12.95% and increased number of fruits/plant and fruit weight/plant in Kinnow mandarin.

The highest percent increase in net profit due to 30 ppm 2,4-D treatment may be because of highest yield and qualitative fruits under this treatment as evident from the present results discussed earlier in the text. Therefore, among the various plant growth regulator treatments attempted under present investigation, the application of 30 ppm 2,4-D was found to be most economic and desirable treatment.

The relative economics of the various plant growth regulator treatments was also worked out. On the basis of relative economics it can again be suggested that 30

ppm 2,4-D treatment was found to be most effective and desirable on the basis of early maturity and highest yield coupled with superior nutritional qualities of mandarin cv. 'Nagpur' fruit. Thus, the present investigation leads to following important findings.

(1) Among the various plant growth regulators tried, 2,4-D and GA_3 were found to be most effective for increasing the yield of mandarin cv. 'Nagpur' fruit.

(2) Of the two most effective treatments i.e. 30 ppm 2,4-D and GA_3 100 ppm, the 2,4-D treatment is economically cheaper than GA_3.

Therefore, based on the findings the Nagpur mandarin growers may be advised to preferably spray the Nagpur mandarin plant with 30 ppm 2,4-D in the month of July to get better yield of 'Nagpur' mandarin crop with superior quality. Further more, it is suggested that in future research can be initiated on the following lines.

(1) Some more concentrations of 2,4-D and GA_3 may be tried so as to increase the yield over control.

(2) 2,4-D might be used in rainy season crop (mrig bahar)to improve quality and quantity of fruits.

(3) Treatments tried in the present investigation may be confirmed by applying in some other varieties of mandarin including Kinnow.

(4) Similar studies can also be extended to Nagpur mandarin orchard where such work has not been done.

(5) It can also be investigated that up to how many years 2,4-D will keep continue to improving the yield of Nagpur mandarin with this rate of increment.

CHAPTER - 6

SUMMARY

6. SUMMARY

The experiment entitled "Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco) cv. Nagpur" was conducted during the year 2012-13 at the Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalawar. The results obtained and discussed in the preceding chapter have been summarized below:

1. The application of various plant growth regulators at different concentrations had significant impact on per cent increase in plant spread of 'Nagpur' mandarin. The maximum per cent increase in plant spread (20.59%) was recorded at 100 ppm GA_3 treatment on 150days after treatment.

2. The per cent increase in crown volume was significantly influenced by application of various plant growth regulator treatments at different concentrations. On 150 days after treatment, the maximum per cent increase in crown volume (38.42%) was recorded at 100 ppm GA_3 treatment which was found significantly better than all other treatments but at par with 75 ppm GA_3 treatment.

3. The horizontal diameter and vertical diameter of fruit were significantly increased by application of different plant growth regulator treatments over control. The maximum horizontal diameter of fruit (8.03 cm) and vertical diameter of fruit (8.23 cm) were observed in 100 ppm GA_3 treatment closely followed by 30 ppm 2,4-D treatment.

4. Plant growth regulator treatments had significantly affected the peel thickness of fruit. The minimum peel thickness of (3.41 mm) was observed in 30 ppm 2,4-D treatment which was closely followed by 40 ppm 2,4-D treatment (3.48 mm).

5. The application of various plant growth regulator treatments at different concentrations significantly increased the of fruit weight over control. The maximum fruit weight (191.22 g) was recorded with the spray of 100 ppm GA_3

treatment andfound it was at par with 30 ppm 2,4-D (184.22 g), while minimum weight of fruit (135.56 g) was noticed in control.

6. The volume of fruit significantly increased due to application of various plant growth regulator treatments as compared to control. The maximum fruit volume (247.56 cc) was recorded at 100 ppm GA_3 treatment, which was closely followed by 30 ppm 2,4-D as compared to minimum of 145.44 cc in control.

7. Number of seeds per fruit of Nagpur mandarin was significantly affected due to application of plant growth regulator treatments. The minimum number of seeds per fruit (9.44) was recorded with the spray of 30 ppm 2,4-D treatment,as compared to maximum number of seeds per fruit (15.44) under control.

8. The application of various plant growth regulators at different concentrations had significantly affected the average seeds weight per fruit of Nagpur mandarin. The minimum average seeds weight per fruit (0.97 g) was recorded with the spray of 30 ppm 2,4-D treatment closelyfollowed by 10 ppm 2,4-D (0.98 g).

9. The maximum number of sacs (12.56) per fruit of Nagpur mandarin was obtained with the spray of 100 ppm GA_3 treatment closelyfollowed by 30 ppm 2,4-D (12.22).

10. The number of fruits per tree was significantly increased as a result of different plant growth regulator treatments over control. The maximum number of fruits per tree 126.0 was recorded at 30 ppm 2,4-D treatment as compared to minimum (100.67) in control.

11. The fruit retention was increased significantly as a result of different plant growth regulator treatments over control. The maximum fruit retention per cent of (70.68) was observed in 30 ppm 2,4-D treatment. While the minimum fruit retention per cent was recorded in control 56.42 per cent.

12. The application of various plant growth regulator treatments at different concentrations had significantly decreased the days required to first harvesting of fruits as compared to control. The minimum days taken to first harvesting (231.67 days) was recorded at 100 ppm GA_3 treatment which was closely followed by 30 ppm 2,4-D (233.67 days) treatment.

13. The application of different plant growth regulator treatments had significantly decreased the total days taken to complete harvesting of fruits as compared to control. The minimum total days taken to complete harvesting (261.67 days) was recorded at 100 ppm GA_3 treatment which was closely followed by 30 ppm 2,4-D (263.67 days) treatment.

14. The total soluble solids content of fruit significantly increased by the application of various plant growth regulators treatments at different concentrations as against control. The maximum TSS content of fruit 12.05 ^{0}Brix was observed in 30 ppm 2,4-D treatment as compared to minimum total soluble solids content 8.59 ^{0}Brix in control.

15. The application of plant growth regulator treatments in Nagpur mandarin significantly reduced the acidity of fruit as compared to control. The minimum acidity of 0.66 percent was recorded in 30 ppm 2,4-D treatment which was closely followed by 20 ppm 2,4-D (0.70%).

16. TSS/Acid ratio of fruit was significantly increased due to application of various plant growth regulator treatments at different concentrations as compared to control. The maximum TSS/Acid ratio of 15.89 was recorded at 30 ppm 2,4-D treatment as compared to minimum TSS/Acid ratio in control (7.47).

17. Reducing sugar content of Nagpur mandarin fruit was increased significantly due to application of various plant growth regulator treatments over control. The maximum reducing sugar content of fruit (6.33%) was recorded in 30 ppm 2,4-D treatment, while minimum in control (4.51%).

18. The non-reducing sugar content of Nagpur mandarin fruit was significantly increased due to application of plant growth regulator treatments. The maximum non-reducing sugar content (2.58%) was obtained with the spray of 30 ppm 2,4-D treatment closely followed by spray of 20 ppm 2,4-D (2.52%).

19. The application of various plant growth regulator treatments at different concentrations significantly increased the total sugar content of fruit over control. The maximum total sugar content of 9.04 per cent was observed in 30 ppm 2,4-D treatment as compared to minimum 6.44 per cent in control.

20. Ascorbic acid (Vit.- C) content of Nagpur mandarin fruit was significantly increased as a result of different plant growth regulator treatments over control. The maximum ascorbic acid content 53.41 mg/100 ml juice was recorded in 30 ppm 2,4-D treatment as compared to minimum under control (34.69 mg/100 ml juice).

21. Plant growth regulator treatments had significantly affected the juice recovery per cent of Nagpur mandarin fruit. The maximum juice content 46.67 per cent was recorded under the treatment 100 ppm GA_3 followed by 30 ppm 2,4-D, which was found to be significantly better than all other treatments and control.

22. Sensory score of Nagpur mandarin fruits was significantly increased as a result of various plant growth regulator treatments at different concentrations over control. The maximum sensory score 9.71 out of 10.0 was recorded in 30 ppm 2,4-D treatment which was closely followed by 20 ppm 2,4-D 9.53 out of 10.

23. The yield of Nagpur mandarin was significantly increased due to application of various plant growth regulator treatments over control. The maximum yield of Nagpur mandarin fruit 21.80 kg/plant and 6.08 tonnes/ha were recorded in 30 ppm 2,4-D treatment as compared to minimum in control (12.94 kg/plant and 3.60 tonnes/ha).

CHAPTER - 7

CONCLUSION

7. CONCLUSION

On the basis of results obtained from the field experiment entitled "**Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco) cv. Nagpur"** it may be concluded that the application of different plant growth regulators was found beneficial for plant growth, yield and quality of mandarin cv. 'Nagpur' specially under Agro-climatic zone V of Rajasthan i.e. in Jhalawar condition.

The application of 100 ppm GA_3 treatment has given maximum per cent increase in plant spread, crown volume which was closely followed by 75 ppm GA_3. Further thistreatment has also givenmaximum increase in horizontal diameter, vertical diameter, weight, volume of fruit, juice content of fruits, number of sacs per fruit and significantly reduced days taken to first harvesting and total days taken to complete harvesting closely followed by 30 ppm 2,4-D.

The application of 30 ppm 2,4-D treatment resulted in significantreduction in peel thickness, minimum number of seeds per fruit, minimum average seeds weight per fruit and significantly increased number of fruits per tree, fruit retention per cent which ultimately increased the yield per plant and thereby per hectare and by the application of 30 ppm 2,4-D treatment the maximum increase was observed in total soluble solids, TSS/Acid ratio, ascorbic acid content and minimum total acidity percentage of fruits. Further this treatment has also increased significantly the total sugar content of fruit including reducing and non-reducing sugars over control.

The application of 30 ppm 2,4-D treatment has also resulted maximum yield (6.08 Tonn/ha) with gross return of Rs. 1,21,600/ha along with an additional net profit of Rs. 48,855/ha with a 67.85 per cent increase over control followed by 10 ppm 2,4-D.

Table 5 Economic feasibility of plant growth regulator treatments in mandarin cv. 'Nagpur'

Treatments	Additional treatment cost	Yield (tones/ha)	Gross return (@ Rs. 20/kg)	Excess income over control	Net profit due to treatment	% Increase in yield over control	% Increase in net profit over control
Control (T_0)	-	3.60	72,000	-	-	-	-
NAA 50 ppm (T_1)	914.50	4.64	92,800	20,800	19,885	28.89	27.62
NAA 100 ppm (T_2)	1129.00	4.69	93,800	21,800	20,671	30.28	28.71
NAA 150 ppm (T_3)	1343.50	4.35	87,000	15,000	13,656	20.83	18.97
NAA 200 ppm (T_4)	1558.00	5.06	1,01200	29,200	27,602	40.56	38.39
GA_3 25 ppm (T_5)	2515.00	3.93	78,600	6,600	4,085	9.17	5.67
GA_3 50 ppm (T_6)	4330.00	4.46	89,200	17,200	12,870	23.89	17.88
GA_3 75 ppm (T_7)	6345.00	4.98	99,600	27,600	21,255	38.33	29.52
GA_3 100 ppm (T_8)	7960.00	6.03	1,20,600	48,600	40,640	67.50	56.44
2,4-D 10 ppm (T_9)	714.85	6.03	1,20,600	48,600	47,885	67.50	66.51
2,4-D 20 ppm (T_{10})	729.70	5.14	1,02800	30,800	30,070	42.78	41.76
2,4-D 30 ppm (T_{11})	744.55	6.08	1,21,600	49,600	48,855	68.89	67.85
2,4-D 40 ppm (T_{12})	759.40	4.80	96,000	24,000	23,240	33.33	32.28
Triacontanol 5 ppm (T_{13})	2350.00	4.42	88,400	16,400	14,050	22.78	19.51
Triacontanol 10 ppm (T_{14})	4000.00	4.92	98,400	26,400	22,400	36.67	31.11
Triacontanol 15 ppm (T_{15})	5650.00	4.81	96,200	24,200	18,550	33.61	25.76
Triacontanol 20 ppm (T_{16})	7300.00	4.85	97,000	25,000	17,700	34.72	24.58

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Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco) cv. 'Nagpur'

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ABSTRACT

A field experiment entitled "**Effect of plant growth regulators on growth, yield and quality of mandarin (*Citrus reticulata* Blanco) cv. 'Nagpur'** was conducted at the fruit research farm, Department of Fruit science, College of Horticulture and Forestry, Jhalawar during July 2012 to April, 2013. The experiment was consisting of 17 treatments having four levels of each NAA (50, 100, 150 and 200 ppm), GA_3 (25, 50, 75 and 100 ppm), 2,4-D (10, 20, 30 and 40 ppm) and Triacontanol (5, 10, 15 and 20 ppm) along with water spray as control. The experiment was laid out in randomized block design with three replications.

Results revealed that spray of various plant growth regulators at different levels significantly influenced the overall performance of Nagpur mandarin. The maximum per cent increase in plant spread and crown volume was recorded with the spray of 100 ppm GA_3, which was found at par with 75 ppm GA_3 treatment. The fruits qualitative characters like maximum increase in diameter (horizontal and vertical), weight, volume and number of sacs per fruit, minimum days taken to first harvesting and complete harvesting was recorded with the spray of 100 ppm GA_3, which was closely followed by 30 ppm 2,4-D. The minimum peel thickness, number of seeds per fruit and average seeds weight per fruit was also recorded highest total soluble solids, TSS/Acid ratio, reducing sugar, non-reducing sugar, total sugar, ascorbic acid content, sensory score and lowest total acidity of fruit was observed with the spray of 30 ppm 2,4-D. The highest juice content of fruit was observed in 100 ppm GA_3 treatment followed by 30 ppm 2,4-D. The maximum number of fruit per tree, fruit retention per cent and yield per plant and per hectare was recorded with the spray of 30 ppm 2,4-D which was at par with 10 ppm 2,4-D.

Similarly, this 2,4-D @ 30 ppm treatment has resulted the maximum gross return of Rs. 1,21,600/ha which was Rs. 49600/ha excess over control. Further, the highest net profit (Rs. 48,885/ha) was also estimated at this treatment which was 67.85 per cent higher than control.

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APPENDICES

APPENDICES

Appendix – I Analysis of variance for effect of plant growth regulators on per cent increase in plant spread of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square				
		30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
Replication	2	2.25	0.21	1.12	1.66	1.92
Treatment	16	11.05**	21.21**	25.74**	27.09**	27.72**
Error	32	0.63	1.02	1.06	1.02	1.05
Total	50					

Appendix –IIAnalysis of variance for effect of plant growth regulators on per cent increase in crown volume of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square				
		30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
Replication	2	0.92	1.22	3.1	1.22	3.06
Treatment	16	40.33**	80.50**	97.86**	104.61**	109.21**
Error	32	1.91	3.33	3.38	3.28	3.36
Total	50					

Appendix –IIIAnalysis of variance for effect of plant growth regulators on horizontal diameter of fruit (cm), vertical diameter of fruit (cm) and peel thickness (mm) of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square		
		Horizontal diameter of fruit (cm)	Vertical diameter of fruit (cm)	Peel thickness (mm)
Replication	2	0.0025	0.07	0.07
Treatment	16	0.64**	1.48**	0.93**
Error	32	0.13	0.19	0.16
Total	50			

** Significant at 5% level of significance.

DAT – Day after treatment

Appendix –IVAnalysis of variance for effect of plant growth regulators on weight of fruit (gm) and volume of fruit (cc) of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square	
		Weight of fruit (gm)	Volume of fruit (cc)
Replication	2	21.01	77.44
Treatment	16	734.27**	1695.14**
Error	32	189.35	340.58
Total	50		

Appendix – VAnalysis of variance for effect of plant growth regulators on number of seeds per fruit, average seeds weight per fruit (gm) and number of sacs per fruit of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square		
		No. of seeds/fruit	Average seeds weight/fruit (g)	No. of sacs/fruit
Replication	2	2.12	0.007	0.11
Treatment	16	14.15**	0.30**	1.30**
Error	32	3.45	0.05	0.53
Total	50			

Appendix –VIAnalysis of variance for effect of plant growth regulators on fruit retention (%) and number of fruits per tree of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square	
		Fruit retention (%)	No. of fruits/tree
Replication	2	1.71	2.02
Treatment	16	38.70**	150.69**
Error	32	3.20	29.14
Total	50		

** Significant at 5% level of significance.

Appendix – VIIAnalysis of variance for effect of plant growth regulators on days taken to first harvesting and total days taken to complete harvesting of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square	
		Days taken to first harvesting	Total days taken to complete harvesting
Replication	2	4.84	42.02
Treatment	16	160.37**	110.17**
Error	32	10.13	13.19
Total	50		

Appendix –VIIIAnalysis of variance for effect of plant growth regulators on TSS (^{0}Brix), total acidity (%) and TSS/Acid ratio of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square		
		TSS (^{0}Brix)	Total acidity (%)	TSS/Acid ratio
Replication	2	0.15	0.005	2.72
Treatment	16	2.44**	0.043**	10.83**
Error	32	0.27	0.003	0.91
Total	50			

Appendix –IXAnalysis of variance for effect of plant growth regulators on reducing sugar (%), non-reducing sugar (%) and total sugar (%) of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square		
		Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
Replication	2	0.03	0.0002	0.07
Treatment	16	0.67**	0.114**	1.37**
Error	32	0.08	0.024	0.15
Total	50			

** Significant at 5% level of significance.

Appendix – X Analysis of variance for effect of plant growth regulators on ascorbic acid (mg/100 ml juice), juice recovery (%) and sensory score of 'Nagpur' mandarin

Source of variation	d. f.	Mean Sum of Square		
		Ascorbic acid (mg/100 ml juice)	Juice recovery (%)	Sensory score
Replication	2	11.32	0.25	0.03
Treatment	16	96.63**	25.72**	1.27**
Error	32	8.14	1.35	0.07
Total	50			

Appendix –XIAnalysis of variance for effect of plant growth regulators on yield per plant (kg) and estimated yield per ha (tonnnes) of 'Nagpur' mandarin.

Source of variation	d. f.	Mean Sum of Square	
		Yield per plant (kg)	Estimated yield per ha (tonnes)
Replication	2	0.07	0.0005
Treatment	16	18.09**	1.41**
Error	32	0.75	0.06
Total	50		

** Significant at 5% level of significance.