

**“EFFECT OF PLANT GROWTH REGULATORS ON
GROWTH, YIELD AND QUALITY OF CUSTARD APPLE
(*Annona squamosa* Linn.) CV. ‘LOCAL’”**

**A
THESIS
SUBMITTED TO THE
ANAND AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENT
FOR THE AWARD OF THE DEGREE**

**OF
Master of Science
(HORTICULTURE)**

**IN
FRUIT SCIENCE**

**BY
PRAJAPATI RAHUL DALPATBHAI
B. Sc. (Agri.)**

**DEPARTMENT OF HORTICULTURE
B. A. COLLEGE OF AGRICULTURE
ANAND AGRICULTURAL UNIVERSITY**

ANAND – 388110 GUJARAT (INDIA)

2013

Reg. No: 04-1682-2011

**“Effect of plant growth regulators on growth, yield and quality of custard apple
(*Annona squamosa* Linn.) cv. ‘Local’”**

Name of student
Prajapati Rahul D.

Major Advisor
Dr. N. S. Parekh

DEPARTMENT OF HORTICULTURE
B. A. COLLEGE OF AGRICULTURE
ANAND AGRICULTURAL UNIVERSITY
ANAND – 3 8 8 1 1 0.

A B S T R A C T

The present investigation entitled “Effect of plant growth regulators on growth, yield and quality of custard apple (*Annona squamosa* Linn.) cv. Local” was conducted at the Horticultural Research Farm, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand during *kharif-rabi* season of the year 2012-13. The experiment was laid out in a Randomized Block Design with 10 treatments viz. T₁: GA₃ 40 mg/l, T₂: GA₃ 60 mg/l, T₃: GA₃ 80 mg/l, T₄: NAA 30 mg/l, T₅: NAA 60 mg/l, T₆: NAA 90 mg/l, T₇: GA₃ 20 + NAA 15 mg/l, T₈: GA₃ 30 + NAA 30 mg/l, T₉: GA₃ 40 + NAA 45 mg/l and T₁₀: control (water spray) with three replications. Two foliar spray were carried out, 1st spray before flowering (second fortnight of May) and 2nd spray after 30 days of 1st spray (second fortnight of June).

The results revealed that the growth parameters like tree spread (E-W and N-S), number of primary branches per tree, number of secondary branches per tree and girth of primary branch (cm) as affected by plant growth regulators were found non-significant.

The results revealed that in yield parameters, treatment T₇ (GA₃ 20 + NAA 15 mg/l) took significantly minimum days to first flower initiation (20.00 days), minimum days to peak flowering (28.00 days), while the higher number of flower clusters per branch (3.69), number of fruits set per branch (5.20), number of fruits per tree (118.33), average fruit weight (227.67 g) and fruit yield per tree (26.94 kg).

The result showed that in quality parameters, treatment T₈ (GA₃ 30 + NAA 30 mg/l) recorded maximum ascorbic acid content (22.80 mg/100 g pulp). Treatment T₉ (GA₃ 40 + NAA 45 mg/l) recorded higher reducing sugar (20.08 %), non reducing sugar (2.01 %) and total sugars (22.09 %). Whereas, TSS was found non-significant.

From economic point of view, the highest net realization (₹ 3, 36, 786 ha⁻¹) was obtained with the treatment T₇ (GA₃ 20 + NAA 15 mg/l) followed by treatment T₆ (NAA 90 mg/l) (₹ 3, 31, 314 ha⁻¹) as compared to the control (₹ 2, 12, 708 ha⁻¹). The treatment T₆ (NAA 90 mg/l) recorded the highest CBR (9.81) as compared to other treatments.

The present study indicated that an application of GA₃ 20 + NAA 15 mg/l twice was found beneficial for getting higher fruit yield and net realization.

Dr. N. S. Parekh
Associate Professor
Department of Horticulture
B.A.College of Agriculture
Anand Agricultural University
Anand - 388110



CERTIFICATE

This is to certify that the thesis entitled “**EFFECT OF PLANT GROWTH REGULATORS ON GROWTH, YIELD AND QUALITY OF CUSTARD APPLE (*Annona squamosa* Linn.) cv. 'LOCAL'”** submitted by **PRAJAPATI RAHUL DALPATBHAI** Reg. No. **04-1682-2011** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** in subject of **FRUIT SCIENCE** of the Anand Agricultural University is a record of bonafide research work carried out by him under my personal guidance, supervision and no part of the thesis has previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand
Date: / /2013

(N. S. Parekh)
Major Advisor

DECLARATION

This is to certify that whole of the research work reported in the thesis in partial fulfillment of the requirement for the award of the degree of **Master of Science (Horticulture)** in the subject of **Fruit science** is the result of investigation done by undersigned under the direct guidance and supervision of **Dr. N. S. Parekh, Associate Professor**, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand-388110 and no part of the research work has been submitted for any other degree so far.

Place: Anand

Date: / /2013

(Rahul D. Prajapati)

Counter signed by:

Dr. N. S. PAREKH
Associate Professor
Department of Horticulture
B.A.College of Agriculture
Anand Agricultural University
Anand – 388 110

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist only one copy of any part of this thesis for rendering reference service in a library of documentation centre.

Place: ANAND
Date: / /2013

(Rahul D. Prajapati)

ACKNOWLEDGEMENT

Acknowledgement is written at last, placed at first and read the least, but still it is the only opportunity to thank one and all who are responsible in completion of this mite of nine to science.

This memorable occasion provides me an unique privilege to express my deep sense of gratitude and indebtedness to my honourable Major Advisor **DR. N. S. Parekh**, Associate Professor, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand for his valuable guidance, encouragement, constructive criticism, ever willing help and sustained interest right from the selection of my research problem up to the final shaping of the thesis in the present form as well as for his keen interest in the preparation of this manuscript.

I am very grateful to the members of my Advisory Committee, **Dr. J. C. Chavda**, Research Scientist (Plant Physiology), Bidi Tobacco Research Station, Anand Agricultural University, Anand, **Dr. H. H. Sitapara**, Assistant Professor, Sheth D. M. Polytechnic in Horticulture, Model Farm, A.A.U., Vadodara, **Dr. J. S. Patel**, Professor and Head, Department of Agricultural statistics, Anand Agricultural University, Anand.

I express my sincere thanks to Dr. H. C. Patel, Professor and Head, Department of Horticulture, B.A.C.A., AAU, Anand, for his valuable comments and helpful suggestions during the course of this investigation.

I wish to extend my thanks to Dr. K. P. Patel, Principal and dean, B.A. college of Agriculture, A.A.U.,

Anand for providing necessary facilities throughout the period of studies.

I have also treasured immense assistance and incomparable affection from Dr. R. G. Jadav, Associate professor, Dr. K. M. Patel, Assistant Professor, DR. M. J. Patel, Associate professor, Dr. N. R. Rai, Assistant Professor, and Shri. J. S. Patel, Assistant professor.

I express my sincere thanks to my department staff members (**Shri J.C.Patel, Shri A.S.Parmar, Prakashbhai, kamleshbhai, Dhanjibhai, Ashokbhai**) of Department of Horticulture, B.A.C.A., AAU, Anand for their help during the course of this investigation.

I am thankful to all the staff members of Horticulture research farm, Department of Horticulture, BACA, AAU, Anand for rendering constant help for successful conduction of the research work.

I express my heartiest feelings through words to my beloved Parents **Shri. Dalpatbhai** and **Smt. Shardaben** without whose moral support, sacrifice and blessings, my dream would not have been a reality. My elder sisters **Dharmisthaben, Harshaben**, My Jiju **Shri. Bhaskarkumar** and **Dr. Chetankumar** and My elder brother **Vipul** and bhabhi **Manisha** whose moral support influence me immensely in realizing my goal.

No words in this mortal world can suffice, to express my feelings, high appreciation and thanks towards my beloved grandfather **Dungarbhai** for him love, support, encouragement and inspiration during my study period.

I would like to extend a multitude of thanks to my friends **Ketul, Bhavik, Nilesh, Hiren**, Shri Dhiraj Nehete, Mukesh, Hiten, Chetan, Haresh, Amit, Sandeep, Jayesh, Ajit, Nagireddy, Himanshu, Pratik, Vatsal,

Thupten tsomu who have inspired me and helped me in all respects during this study to whom I remain indebted forever.

*Lastly, I am thankful to the **"GOD"** and **"GOODNESS"** and all whosoever have helped in making this mission for the study a success.*

Place : Anand

Date : / / 2013

(Prajapati Rahul D.)

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-16
III	MATERIALS AND METHODS	17-28
IV	EXPERIMENTAL RESULTS	29-51
V	DISCUSSION	52-56
VI	SUMMARY AND CONCLUSION	57-61
	BIBLIOGRAPHY	I-VIII
	APPENDICES	I-III

CONTENTS

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
3.1	Physical properties of the experimental soil	19
3.2	Chemical properties of the experimental soil	19
4.1	Effect of plant growth regulators on tree spread (m) (E-W) direction at different growth stages of custard apple cv. 'Local'	31
4.2	Effect of plant growth regulators on tree spread (m) (N-S) direction at different growth stages of custard apple cv. 'Local'	32
4.3	Effect of plant growth regulators on number of primary branches per tree at different growth stages of custard apple cv. 'Local'	33
4.4	Effect of plant growth regulators on number of secondary branches per tree at different growth stages of custard apple cv. 'Local'	34
4.5	Effect of plant growth regulators on girth of primary branch (cm) at different growth stages of custard apple cv. 'Local'	35
4.6	Effect of plant growth regulators on days to first flower initiation and days to peak flowering of custard apple cv. 'Local'	37
4.7	Effect of plant growth regulators on number of flower clusters per branch, number of fruits set per branch of custard apple cv. 'Local'	40
4.8	Effect of plant growth regulators on number of fruits per tree and fruit yield per tree (kg) of custard apple cv. 'Local'	41
4.9	Effect of plant growth regulators on average fruit weight (g) and fruit volume (cc) of custard apple cv. 'Local'	42
4.10	Effect of plant growth regulators on days taken for ripening of fruits, total soluble solids (%), ascorbic acid (mg/100g pulp) of custard apple cv. 'Local'	44
4.11	Effect of plant growth regulators on reducing sugar (%), non reducing sugar (%) and total sugars (%) of custard apple cv. 'Local'	47
4.12	Effect of plant growth regulators on seed-aril ratio and peel (%) of custard apple cv. 'Local'	49
4.13	Effect of plant growth regulators on organoleptic test of custard apple cv. 'Local'	50
4.14	Economics of custard apple cv. 'Local' as influenced by various	51

	treatments	
--	------------	--

LIST OF FIGURES

FIGURE NO.	TITLE	AFTER PAGE NO.
3.1	Mean weekly weather parameters recorded during the experiment period from May, 2012 to December, 2012	18
4.1	Effect of plant growth regulators on days to first flower initiation and days to peak flowering of custard apple cv. 'Local'	37
4.2	Effect of plant growth regulators on number of flower clusters per branch and number of fruits set per branch of custard apple cv. 'Local'	40
4.3	Effect of plant growth regulators on number of fruits per tree of custard apple cv. 'Local'	41
4.4	Effect of plant growth regulators on fruit yield per tree (kg) of custard apple cv. 'Local'	41
4.5	Effect of plant growth regulators on average fruit weight (g) of custard apple cv. 'Local'	42
4.6	Effect of plant growth regulators on ascorbic acid (mg/100g pulp) of custard apple cv. 'Local'	44
4.7	Effect of plant growth regulators on reducing sugar (%) of custard apple cv. 'Local'	47
4.8	Effect of plant growth regulators on non reducing sugar (%) of custard apple cv. 'Local'	47
4.9	Effect of plant growth regulators on total sugars (%) of custard apple cv. 'Local'	47
4.10	Economics of custard apple cv. 'Local' as influenced by various treatments	51

LIST OF PLATES

PLATE NO.	TITLE	AFTER PAGE NO.
1	General view of an experimental field of custard apple cv. 'Local'	21
2	Custard apple cv. 'Local' fruiting under treatment GA ₃ 20 + NAA 15 mg/l	41
3	Custard apple cv. 'Local' fruiting under treatment Control (water spray)	41
4	Effect of T ₇ (GA ₃ 20 + NAA 15 mg/l) v/s T ₁₀ Control (water spray) on average fruit weight (g) of custard apple cv. 'Local'	42

LIST OF ABBREVIATIONS AND SYMBOLS

AAU	Anand Agricultural University
Anon.	Anonymous
@	At the rate of
°C	degree Celsius
°	Degree
CBR	Cost-benefit ratio
CC	Cubic Centimeter
CD	Critical Difference
cm	Centimeter
C.V.	Coefficient of variation
cv.	Cultivar
dS	Deci Symonds
E	East
EC	Electrical conductivity
<i>et al.</i>	et alii : and others
etc.	Etcetera
Fig.	Figure
FYM	Farm Yard Manure
g	Gram
ha	Hectare
hr.	Hour
i.e.	That is
GA ₃	Gibberellic Acid
Kg	Kilogram
Km	Kilometer
L	Labour
m	Meter
mm	Millimeter
Max.	Maximum
Min.	Minimum
PGR's	Plant growth regulators

N	North
N	Nitrogen
No.	Number
NS	Non-significant
NAA	Naphthalene Acetic Acid
%	Per cent
pH	Potential of hydrogen ions
q	Quintal
RH	Relative humidity
`	Rupees
S	South
S.Em. \pm	Standard error of mean
Sr.	Serial
Std	Standard
T	Treatment
t	tonne
viz.,	Namely
W	West
Wt.	Weight
/	Per
:	Ratio

I. INTRODUCTION

Custard apple (*Annona squamosa* L.) a delicious and important minor fruit crop is cultivated in tropical and sub-tropical climate. It comes under the family “Annonaceae” and its native is West Indies. It is also cultivated throughout Central America to Southern Mexico during early times. The genus *Annona* contains more than 50 species; among them few produce edible fruits of some importance. In India it is cultivated especially in Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, and Orissa states.

Custard apple is an arid fruit crop and hardy in nature requires dry climate with mild winter. It can grow from sea level up to 100 m above the mean sea level elevation and also under drought conditions (Singh, 1992). Custard apple flowers during the period of May to August. Due to high temperature, low atmospheric humidity, lack of irrigation water and natural stress results in less number of flowers, poor fruit setting and low fruit yield with degraded quality.

The custard apple is commonly known as “Sitaphal” or “Sugar apple” and considered as minor fruit of commercial value. However, it is important due to its nutritive value. The ripened custard apples are consumed mainly in fresh dessert fruits. The fruit has its delightful taste and flavour with a high nutritional status. It is also known for its pleasant distinctive texture of pulp with less acidic and aromatic flavour. Moreover, fruit pulp can be used in preparation of juice, ice-cream, confectionary, beverages, pudding and certain milk products (Paull, 1982). The edible portion or pulp is a creamy and granular with a good blend of sweetness. Custard apple contains Protein (1.6 g), Fat (0.5-0.6 g), Carbohydrates (23.5g), Crude Fiber (0.9-6.6 g), Calcium (17.6 mg), Phosphorus (47 mg), Iron (1.5 mg), Thiamine (0.075-0.119 mg), Riboflavin (0.086-0.175 mg), Ascorbic Acid (15.0 - 44.4 mg), Nicotinic Acid (0.5 mg) per 100 g of edible portion. An ancorin is extracted from custard apple

seed/pulp, which has insecticidal properties and therefore used as botanical insecticide. Due to the presence of annonaine, the leaves, stem and other portion of the plant are also bitter and the plant is not attacked by goats or cattle (Katyal *et al.* 1963).

In India, the area under custard apple cultivation is about 19000 ha with the production of 127000 MT. Out of these Gujarat state contributes 5126 ha area with 55541 MT productions (Anon., 2012).

The successful commercial cultivation of custard apple depends on many factors such as variety, climate, soil, irrigation, pollination and fertilization, plant density per unit area, age of plant etc. However, use of plant growth regulators may also be helpful to increase the yield and improve the quality of custard apple. Adequate supply of auxins in the plant body plays a vital role in the flowering and fruiting of plants. It has been reported that auxin level in the flowering plants has to fall before flower initiation but relatively higher level is required for the flower development.

There is a problem with fruit set because of incomplete pollination, in which plant growth regulators may be useful to increase the fruit set. Plant growth regulators sprayed near the terminal buds of trees increased the rate of growth by stimulating enzymatic activities during its growth. Therefore, Plant growth regulators are used mainly to delay and reduce unwanted fruit abscission (fruit drop), to delay the senescence and to inhibit the growth of suckers on the trunk. The plant growth regulator like GA₃ is also useful to increase the fruit setting per branch, number of fruits per tree, fruit weight and ultimately increase the fruit yield (Shinde *et al.*, 2008). Application of NAA checks the fruit drop and thereby increased the fruit retention, fruit weight and TSS of the fruits (Singh and Chohan, 1984).

Plant growth regulators are effective at very low concentration, hence they are cost effective. Presently growth regulators are given considerable importance for their value in regulating the various growth and development processes in plants. They are useful in increasing the fruit size, and thereby increase the fruit yield and quality of fruits. Now a days, use of plant growth regulators has become more popular in increasing the yield particularly in horticultural crops.

The research based information on use of plant growth regulators in custard apple is negligible. Considering the importance and future scope of this crop, the present experiment was carried out to study the “Effect of plant growth regulators on growth, yield and quality of custard apple (*Annona squamosa* Linn.) cv. Local” with the following objectives.

Objective:

To find out the effective concentration of GA₃ and NAA as well as their combination on fruit growth, yield and quality of custard apple.

II. REVIEW OF LITERATURE

In recent years a number of investigations have been reported towards ways and means for quantitative and qualitative improvement of crops. Among the various scientific tools applied for the betterment of the crops, plant growth regulators have been widely used. These substances when applied as spray have been found to regulate, modify or accelerate various growth processes of the plants. In present days of scientific agriculture, the plant growth regulators are widely used for better growth, increase in yield and improve the quality in some of the important fruit crops. However, the work carried out in India as well as abroad on custard apple is very scanty. Therefore, the present investigation was carried out to study the “Effect of plant growth regulators on growth, yield and quality of custard apple (*Annona squamosa* Linn.) cv. Local”.

Generally, GA₃ and NAA are more popular and more effective and thereby frequently used in horticultural crops. GA₃ play significant role in cell elongation, breaking seed dormancy, induce flowering. While, NAA is effective for cell division and apical dominance in plant. Hence, an attempt has been made here to review the literature with special reference on fruit crops under the following heads.

2.1 Effect of GA₃ (Gibberellic Acid) on growth, yield and quality parameters

2.2 Effect of NAA (Naphthalene Acetic Acid) on growth, yield and quality parameters

2.3 Combined effect of GA₃ and NAA on growth, yield and quality parameters

2.1 Effect of GA₃ (Gibberellic Acid) on growth, yield and quality parameters

2.1.1 Effect of GA₃ on growth parameters:

Rajput and Singh (1983) studied the effect of urea and GA₃ sprays on the growth, flowering and fruiting characters of Mango cv. 'Dashehari'. They tried different levels of urea and GA₃ spray just before blooming. They recorded significantly highest length of terminal shoot, number of leaves, leaf area per shoot, length of panicle, number of secondary branches per panicle with the treatments of Urea 6 % and GA₃ 30 mg/l.

Babu and Lavania (1985) revealed that GA₃ 40 mg/l increased the shoot length, tree height, number of leaves/shoot and leaf area when sprayed on five years old lemon tree.

Kassem *et al.* (2010) reported that foliar application of GA₄ @ 25 mg/l gave the maximum in shoot length in persimmon tree cv. 'Costata'.

Wahdan *et al.* (2011) studied the effect of certain chemicals on growth, fruiting, yield and fruit quality of mango cv. 'Succary Abiad'. Among the treatments, GA₃ @ 20 mg/l at one month after full bloom recorded the highest shoot length, number of leaves per shoot and leaf area as compared to control during first successive season.

Rakesh *et al.* (2012) conducted an experiment on foliar spray of GA₃ (25, 50, 75 mg/l), triacontanol (1.25, 2.5, 5 mg/l) and cycocel (300, 600, 900 mg/l) on strawberry cv. 'Sweet Charlie'. Among the treatments, GA₃ 75 mg/l increased all the vegetative characteristics of plant viz., plant height, petiole length, number of leaves, plant spread and leaf area index as compared to control.

Goswami *et al.* (2013) reported that application of GA₃ @ 25 mg/l was effective in increasing number of stems per plant at the time of pruning in pomegranate cv. 'Sinduri'.

2.1.2 Effect of GA₃ on yield parameters:

Sundararajan *et al.* (1968) reported that dipping the flower soon after anthesis, for about a minute, in different concentration of GA₃ (10, 25 and 50 mg/l) increased fruit set, size and weight of fruits in custard apple cv. 'Mammoth'. Among these, treatment of GA₃ @ 50 mg/l was most effective.

Rajput and Singh (1983) reported that an application of two foliar spray of urea and GA₃ every years on mango cv. 'Dashehari' just before blooming increased duration of flowering, number of flowers, fruit setting, fruit retention and thereby fruit yield.

Singh *et al.* (1987) conducted an experiment with foliar application of GA₃ on ber cv. 'Banarasi Karaka'. They sprayed different concentrations of GA₃ (20, 40, 60 and 80 mg/l) in month of October and first fortnight of December. They recorded maximum fruit set, fruit retention, fruit length and width as well as fruit yield with the treatment GA₃ (80 mg/l).

Biswar *et al.* (1988) sprayed GA₃ (50 and 100 mg/l) on guava cv. 'L-49' at 30 days after fruit set in the rainy and spring seasons. Application of GA₃ 100 mg/l recorded maximum fruit weight and size in spring season.

Banker and Prasad (1990) studied that foliar application of GA₃ (10, 20 and 30 mg/l) on ber at flowering and again 15 days later. They observed that fruit set and retention were increased by GA₃ 30 mg/l as compared to water spray (control).

Singh and Rajput (1991) studied the effect of growth regulators and calcium on flowering, fruiting and fruit quality of mango cv. 'Langra'. Application of GA₃ @ 30 mg/l recorded highest panicle length, total number of flowers, fruit set and fruit retention.

Chaudhary *et al.* (1992) conducted an experiment on 20 years old tree of loquat cv. 'Herds Mammoth'. They sprayed GA₃ and NAA each at 10, 20 and 40 mg/l. Among them, GA₃ @ 40 mg/l showed the highest percentage of fruit retention.

Brahmachari *et al.* (1997) sprayed GA₃ (50 and 100 mg/l) on guava cv. 'Allahabad Safeda' at pre bloom, full bloom and fruit set stage. They observed that application of GA₃ @ 100 mg/l increased maximum fruit set.

Pandey (1999) conducted an experiment on ber (*Zizyphus mauritiana*) cv. 'Banarasi Karaka' with NAA and GA₃ each at (5, 10, 15 and 20 mg/l) at the pea stage. Among the different concentrations, fruit retention and fruit yield were the highest in trees sprayed with GA₃ @ 15 mg/l.

Brahmachari and Rani (2000) tried different concentration of GA₃ (50 and 100 mg/l) on Litchi cv. 'Purbi' at panical emergence, after fruit set and at immature fruit stages. They observed that application of GA₃ 100 mg/l increased the fruit yield.

Ahmad and Zargar (2005) reported that foliar spray of GA₃ 50 mg/l increased bunch weight, bunch size, berry weight and number of berries per bunch over control in grape cv. 'Perlette'.

Ghosh *et al.* (2009) sprayed NAA (25 and 50 mg/l) and GA₃ (10 and 20 mg/l) on pomegranate cv. 'Ruby' at 50% flowering stage and subsequently at 21 days interval. They observed maximum fruit weight, length and breadth of fruit in GA₃ 10 mg/l treatment as compared to control.

Kassem *et al.* (2010) studied the effect of foliar sprays on fruit retention, quality and yield of 'Costata' persimmon tree during two successive years. They reported that foliar application of GA₄ @ 25 mg/l gave the highest number of fruits per tree and fruit yield.

Patel *et al.* (2010) studied the effect of culture and chemical treatments on fruit set and fruit yield of custard apple (*Annona squamosa* Linn.) cv. 'Sindhan'. They observed that an application of GA₃ 50 mg/l enhanced maximum fruit set and fruit retention as well as increased flowering duration.

Bhowmick and Banik (2011) studied the influence of pre-harvest foliar application of growth regulators and micronutrients on mango cv. 'Himsagar'. They obtained maximum fruit length, breadth, weight and yield with GA₃ (40 mg/l) treatment.

Reddy and Prashad (2011) studied the effect of plant growth regulators at the time of full bloom, and subsequently at 45 and 90 days after fruit set on fruit characters and fruit yield in pomegranate cv. 'Ganesh'. The application of GA₃ @ 75 mg/l recorded significantly the highest fruit length, diameter and fruit yield as compared to control.

Singh *et al.* (2011) sprayed GA₃ (40, 50 and 60 mg/l) on phalsa cv. 'Sharvati' at flowering stage. They observed that an application of GA₃ @ 50 mg/l increased fruit set, size of berry, weight of berries and thereby fruit yield.

2.1.3 Effect of GA₃ on quality parameters:

Sundararajan *et al.* (1968) reported that spraying of GA₃ @ 50 mg/l in rainy season increased the total soluble solids in custard apple cv. 'Mammoth'.

Singh *et al.* (1987) conducted an experiment with foliar application of GA₃ on ber cv. 'Banarasi Karaka'. They tried different concentration GA₃ (20, 40, 60 and 80 mg/l) in

month of October and first fortnight of December. They recorded maximum TSS and vit. C contents with GA₃ 80 mg/l treatment.

Brahmachari *et al.* (1997) observed maximum ascorbic acid and pectin contents with the application of GA₃ 100 mg/l in guava cv. 'Allahabad Safeda'.

Pandey (1999) conducted an experiment on ber (*Zizyphus mauritiana*) cv. 'Banarasi Karaka'. The application of GA₃ @ 15 mg/l increased fruit quality in terms of pulp percentage, total soluble solids content, acidity and ascorbic acid contents as compared to control.

Brahmachari and Rani (2000) observed that application of GA₃ (100 mg/l) increased in pulp weight and improved the edible/non-edible ratio in litchi cv. 'Purbi'.

Ahmad and Zargar (2005) reported that foliar spray of GA₃ 50 mg/l increased total soluble solids and total sugar percent, while decreased acidity over control in grape cv. 'Perlette'.

Bhat *et al.* (2006) observed that foliar spray of GA₃ 10 mg/l increased the juice content and decreased the acidity over control in lemon cv. 'Pant Lemon-1'.

Singh *et al.* (2011) reported that TSS and total sugars were increased, while acidity was decreased due to treatment of GA₃ @ 60mg/l in phalsa cv. 'Sharvati'.

2.2 Effect of NAA (Naphthalene Acetic Acid) on growth, yield and quality parameters

2.2.1 Effect of NAA on growth parameters:

Babu and Lavania (1985) studied the vegetative growth and nutritional status as influenced by auxins and gibberellic acid in lemon. They reported that an application of NAA at 10 and 20 mg/l increased the vegetative growth like shoot length, tree height and tree spread.

Goswami *et al.* (2013) observed the effect of plant growth substances on growth of pomegranate cv. 'Sinduri'. They reported that application of NAA 50 mg/l at the time of pruning was found effective in increasing maximum number of stems per plant.

2.2.2 Effect of NAA on yield parameters:

Sundararajan *et al.* (1968) reported that dipping the flower soon after anthesis, for about a minute, in different concentration of NAA (5, 10 and 25 mg/l) increased fruit set in custard apple cv. 'Mammoth'.

Keskar *et al.* (1986) reported that, among different concentration, 20 mg/l NAA, when applied four times at eight days interval during flowering, gave the highest fruit set in custard apple. They also found that NAA at 10 mg/l resulted in higher number of fruits, fruit size and weight of fruits.

Bankar and Prasad (1990) conducted an experiment on eight year old trees of ber (*Zizyphus mauritiana*) cv. 'Gola'. Trees were sprayed with GA₃ and NAA at 10, 20 and 30 mg/l alone or in combination, at flowering stage and again 15 days later. Fruit set and retention were increased by NAA at 30 mg/l as compared to control.

Ray *et al.* (1991) sprayed NAA (200, 300 and 400 mg/l) on sapota cv. 'Kalipatti' at two stages i.e. pre-bloom stage and pea stage. They observed significant improvement in fruit size and weight with 300 mg/l NAA as compared to control.

Brahmachari *et al.* (1995) carried out an experiment to study the effect of NAA (25 or 50 mg/l) on 'Sardar' Guava at flowering and again a month after fruit set. Application of NAA at both levels increased the fruit weight.

Kulkarni *et al.* (1995) studied the effect of different plant growth regulators (50, 100 mg/l GA₃; 20, 30 mg/l NAA and 15, 30 mg/l 2, 4-D) on custard apple cv. 'Mammoth'. They reported that NAA 30 mg/l gave significantly maximum average fruit weight and number of fruits per tree.

Brahmachari *et al.* (1997) conducted an experiment to study the effect of NAA (20 and 40 mg/l) on guava cv. 'Allahabad Safeda' at pre bloom stage and full bloom stage. Application of NAA @ 40 mg/l increased the fruit set as compared to control.

Singh *et al.* (2001) observed the response of foliar application of growth regulators and nutrients in ber cv. 'Umran'. The foliar spray of NAA 10 mg/l at full bloom stage, 40 and 120 days after first spray increased the fruit set, fruit weight, fruit size and yield.

Yadav *et al.* (2001) studied the effect of different plant growth regulators. i.e. NAA (20, 40, 60 mg/l) and GA₃ (50,100,150 mg/l) on 15 years old guava trees cv. 'L-49'. They reported that yield/tree was maximum in NAA @ 60mg/l treatment.

Bhati and Yadav (2004) sprayed NAA (10, 20 and 30 mg/l) on ber cv. 'Gola' at fruit setting stage and repeated after one month. They found that foliar application of NAA at 20 mg/l increased the fruit retention as compared to control.

Bal *et al.* (2007) sprayed NAA (10, 20, 30, 40 and 50 mg/l) on ber cv. 'Kaithali and Wallaiti' at flowering and one month later. In both the cultivars, NAA @ 20-30 mg/l increased fruit size, fruit weight and fruit yield as compared to control.

Dutta *et al.* (2008) studied the effect of plant bio-regulators on fruit quality and mineral composition of ripe Mango cv. 'Himsagar'. They reported that NAA at 200 mg/l

was most effective in increasing fruit yield, fruit weight, fruit length, fruit diameter followed by GA₃ and cycocel.

Ghosh *et al.* (2009) sprayed NAA (25 and 50 mg/l) and GA₃ (10 and 20 mg/l) on pomegranate cv. 'Ruby' at 50% flowering stage, subsequently, at 21 days interval. They observed that application of NAA @ 25 mg/l gave significantly the highest fruit set, fruit retention and fruit yield/plant than other treatments.

Gill and Bal (2009) sprayed different concentration of NAA (20, 30 and 40 mg/l) on four years old plants of ber cv. 'Sanuar-2' during last week of October and again in the last week of November. They observed that application of NAA @ 30 mg/l was better for fruit retention.

Patel *et al.* (2010) studied the effect of culture and chemical treatments on fruit set and fruit yield of custard apple (*Annona squamosa* Linn.) cv. 'Sindhan'. They observed that an application of NAA 20 mg/l with wheat straw mulch enhanced maximum fruit set and fruit retention.

Bhowmick and Banik (2011) studied the influence of pre-harvest foliar application of growth regulators and micronutrients on mango cv. 'Himsagar'. They observed maximum percentage of fruit retention with NAA @ 40 mg/l treatment.

Jain and Dashora (2011) sprayed NAA (100 and 200 mg/l) on guava cv. 'Sardar' at pre flowering stage. They observed maximum fruit diameter with 200 mg/l NAA treatment.

Garasiya *et al.* (2013) sprayed GA₃ (50, 100 mg/l), NAA (20, 40 mg/l), 2-4-D (5, 10 mg/l) and CCC (250, 500 mg/l) on guava cv. 'L-49'. They reported that application of

NAA 40 mg/l was found most effective in increasing number of fruits per tree, average fruit weight, fruit volume, fruit diameter and ultimately fruit yield.

2.2.3 Effect of NAA on quality parameters:

Ray *et al.* (1991) observed the effect of foliar application of NAA (200, 300 and 400 mg/l) on sapota 'Kalipatti' in two stages i.e. pre-bloom stage and pea stage. The application of NAA at 200 mg/l considerably improved the total soluble solids, non-reducing and total sugars contents in fruits.

Brahmachari *et al.* (1995) sprayed NAA (25 or 50 mg/l) on guava cv. 'Sardar' at flowering and again one month later. All the levels of NAA enhanced fruit quality. NAA at 50 mg/l increased total soluble solids, ascorbic acid and sugar content but reduced fruit acidity in terms of citric acid.

Kulkarni *et al.* (1995) conducted an experiment to study the effect of cultural and chemical treatments on yield and physico-chemical characteristics of custard apple cv. 'Mammoth'. The plant growth regulators used were 50 and 100 mg/l GA₃; 20 and 30 mg/l NAA and 15 and 30 mg/l 2, 4-D. Among them NAA @ 30 mg/l proved best for improvement of total sugars in custard apple.

Singh *et al.* (2001) studied the response of foliar application of growth regulators and nutrients in ber (*Zizyphus mauritiana* L.) cv. Umran. The highest pulp (%) and pulp/stone ratio were observed in NAA 20 mg/l treatment as compared to control.

Yadav *et al.* (2001) studied the effect of growth regulators viz., NAA (20, 40 and 60 mg/l), GA₃ (50, 100 and 150 mg/l) and ethrel (50, 75 and 100 mg/l) on 15 years old

guava trees cv. 'L-49'. Total soluble solids and total sugars were increased due to NAA treatment as compared to GA₃ and ethrel.

Singh *et al.* (2002) studied the response of foliar application of urea (1, 2 and 3 per cent), ZnSO₄ and Borax (0.25, 0.50 and 1.0 percent), K₂SO₄ (0.5, 1.0 and 1.5 per cent) and NAA (10, 20 and 40 mg/l) on quality attributes in ber cv. 'Umran'. The increased total soluble solids, reducing sugar, non-reducing sugar and minimum acidity were observed with 20 mg/l NAA as compared to control.

Bhati and Yadav (2003) reported that spraying of 20 mg/l NAA at fruit setting stage and repeated after one month increased the quality parameters like TSS, ascorbic acid, reducing sugar with minimum total acidity in ber cv. 'Gola'.

Bal *et al.* (2007) sprayed NAA (10, 20, 30, 40 and 50mg/l) on ber cv. 'Kaithali and Wallaiti' at flowering and one month later. Application of NAA @ 20-30mg/l decreased acidity of fruits in both the cultivars.

Dutta *et al.* (2008) studied the effect of plant bio-regulators on fruit quality and mineral composition of ripe Mango cv. 'Himsagar'. They found that NAA @ 200 mg/l was effective in increasing maximum total soluble solids, total sugars and β -carotene.

Ghosh *et al.* (2009) sprayed NAA (25 and 50 mg/l) and GA₃ (10 and 20 mg/l) on pomegranate cv. 'Ruby' at 50% flowering stage and subsequently, at 21 days interval. They observed that NAA @ 25 mg/l increased quality parameters than other treatments.

Gill and Bal (2009) sprayed different concentration of NAA (0, 10, 20 and 30 mg/l) on four years old plants of ber cv. 'Sanuar-2' during last week of October and again in the last week of November. They observed that application of NAA @ 30 mg/l was better for Vit. C. While, quality parameters were better with NAA at 40 mg/l.

Jain and Dashora (2011) sprayed NAA (100 and 200 mg/l) on guava cv. 'Sardar' at pre flowering stage. They observed that NAA @ 200 mg/l was most effective and recorded maximum physico-chemical characteristics.

2.3 Combined effect of GA₃ and NAA on growth, yield and quality parameters

2.3.1 Combined effect of GA₃ and NAA on growth parameters:

Goswami *et al.* (2013) studied the effect of plant growth substances on growth of pomegranate cv. 'Sinduri'. They observed maximum number of stems at the time of pruning due to application of NAA 25 mg/l + GA₃ 25 mg/l, remained at par with NAA 50 mg/l.

2.3.2 Combined effect of GA₃ and NAA on yield parameters:

Oosthuysen (1993) conducted an experiment to study the effect of urea spray and growth regulators on fruit set and retention of mango. Among different growth hormones, NAA 40 + GA₃ 40 mg/l, significantly increased fruit set and fruit retention as compared to control.

Singh *et al.* (2007) studied the effect of micro-nutrients and plant growth regulators on yield and physico-chemical characteristics of aonla fruits cv. 'Narendra Aonla-10'. They observed that application of ZnSO₄ 0.5 % + NAA 10 mg/l + GA₃ 25 mg/l recorded the highest fruit retention, fruit length and breadth, fruit weight, pulp weight, stone weight, pulp: stone ratio and fruit yield.

Srivastava *et al.* (2009) studied the efficacy of foliar feeding of plant growth regulators along with urea on yield and quality of aonla cv. 'NA-7'. They found the highest fruit width, fruit weight, fruit volume, pulp weight, pulp: stone ratio and fruit yield with GA₃ 50 mg/l + NAA 15 mg/l + urea 2 % which was significantly at par with GA₃ 50 mg/l + 2, 4-D 10 mg/l + urea 2 %.

Nkansah *et al.* (2012) studied the application of GA₃ and NAA on fruit retention, yield and quality of Mango cv. 'Keitt' at the Coastal Savanna Ecological Zone of Ghana during the two successive years. Trees were sprayed with three hormonal levels at two locations. They reported that application of GA₃ 25 mg/l + NAA 25 mg/l recorded the highest fruit set, fruit retention, number of fruits and fruit weight during both the years.

2.3.3 Combined effect of GA₃ and NAA on quality parameters:

Singh *et al.* (2007) studied the effect of micro-nutrients and plant growth regulators on yield and physico-chemical characteristics of aonla fruits cv. 'Narendra Aonla-10'. They observed that application of ZnSO₄ 0.5 % + NAA 10 mg/l + GA₃ 25 mg/l significantly recorded higher TSS, reducing sugar, total sugars and total phenols which remained at par with ZnSO₄ 0.5 % + CuSO₄ 0.4 % + NAA 10 mg/l treatment.

Srivastava *et al.* (2009) studied the efficacy of plant growth regulators along with urea as foliar spray on fruit yield and quality of aonla cv. 'NA-7'. They found the highest TSS, non-reducing sugar, ascorbic acid and lowest acidity were observed with the treatment GA₃ 50 mg/l + NAA 15 mg/l + urea 2 % which was significantly at par with the treatment GA₃ 50 mg/l + 2, 4-D 10 mg/l + urea 2 %.

III. MATERIALS AND METHODS

The details of materials used and experimental methods and techniques adopted during the course of the present investigation on “Effect of plant growth regulators on growth, yield and quality of custard apple (*Annona squamosa* Linn.) cv. Local” is described under following heads.

3.1 GENERAL

3.1.1 Experimental site

The experiment was carried out at Horticultural Research Farm, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand during *Kharif-Rabi* season of the year 2012-13.

3.1.2 Plant Materials

The experiment was carried out on nineteen years old trees of custard apple cv. ‘Local’ established at Horticultural Research Farm, Department of Horticulture, B.A. College of Agriculture, AAU, Anand.

3.1.3 Treatments Materials

3.1.3.1 Plant growth regulators

Plant growth regulators viz., GA₃ and NAA were obtained from Department of Horticulture, B.A. College of Agriculture, AAU, Anand.

3.1.3.2 Fertilizers

The fertilizers like FYM and Urea were obtained from Horticultural Research Farm, Department of Horticulture, B.A. college of Agriculture, Anand Agricultural University, Anand.

3.2 PHYSIOGRAPHIC SITUATION:

3.2.1 Location

Anand is situated on 22° 35' North latitude and 72° 56' East longitudes at an elevation of 45.1 meters above the mean sea level.

3.2.2 Climate and Weather conditions

The climate of Anand region is semi-arid and sub-tropical type. Winter is mild cool and dry, while summer is hot and dry. October to May are sunny months generally receiving an average of eight hours sunshine per day. Temperature during hot weather commences by about end of February and ends by about middle of June. Winter sets in the middle of October and continues till the end of February. Monsoon is warm and moderately humid. It commences by the end of June and ends by the middle of September. In this region monsoon is often erratic and uncertain, in respect of total rainfall and its distribution. The meteorological data on the average weekly maximum and minimum temperature, rainfall and relative humidity recorded at the Meteorological observatory AAU, Anand (during experimental period i.e. May-2012 to December-2012) are given in Appendix-I.

3.2.3 Soil characteristics

The soil of the experimental site was sandy loam, locally known as "Goradu". The soil is well drained and retentive of moisture. It responds well to irrigation and manuring, and is suitable for custard apple cultivation. The physical and chemical properties of the soil of experimental plot are given in Table -3.1 and 3.2 respectively.

Table 3.1: Physical properties of the experimental soil

Sr. No.	Particulars	Value in per cent (0-15 cm depth)	Method of analysis
1.	Coarse sand (%)	0.43	International pipette Method (Piper, 1950)
2.	Fine sand (%)	83.57	-do-
3.	Silt (%)	10.82	-do-
4.	Clay (%)	5.18	-do-
5.	Texture (%)	Sandy loam	

Table 3.2: Chemical properties of the experimental soil

Sr. No.	Soil characteristics	Value (0-15 cm depth)	Method of analysis
1.	Organic carbon (%)	0.34	Walkley and Black's method (Jackson, 1973)
2.	Available nitrogen (%)	0.043	Kjeldahl's method (Jackson, 1973)
3.	Available phosphorus (kg/ha)	42.38	Olsen's method (Jackson, 1973)
4.	Available potash (kg/ha)	275.71	Flame photometric Method (Jackson, 1973)
5.	Soil pH (1 :2.5, soil :water ratio)	7.08	Backman 's PH meter (Jackson, 1973)
6.	EC (ds/m) (1:2.5, soil :water ratio)	0.29	Solubridge method (Jackson, 1973)

3.3 EXPERIMENTAL DETAILS:

The details of experiment are given below.

3.3.1 Experimental design

Randomized Block Design (RBD)

3.3.2 Number of replications: 3 (Three)

3.3.3 Planting distance: 5 × 5 m

3.3.4 Crop and variety: Custard apple (*Annona squamosa* Linn.) cv. Local

3.3.5 Age of trees: 19 years old

3.3.6 Total number of treatments: 10 (Ten)

3.3.7 Number of trees per treatment: 1 (One)

3.3.8 Total number of trees: 30 (Thirty)

3.3.9 Treatment details

In this experiment, total 10 treatments were taken as under.

T₁ : GA₃ 40 mg/l

T₂ : GA₃ 60 mg/l

T₃ : GA₃ 80 mg/l

T₄ : NAA 30 mg/l

T₅ : NAA 60 mg/l

T₆ : NAA 90 mg/l

T₇ : GA₃ 20 + NAA 15 mg/l

T₈ : GA₃ 30 + NAA 30 mg/l

T₉ : GA₃ 40 + NAA 45 mg/l

T₁₀ : Control (water spray)

Note: Two foliar sprays were applied,

(i) 1st spray at before flowering (second fort-night of May)

(ii) 2nd spray after 30 days of 1st spray (second fort-night of June).

3.4 CULTURAL OPERATIONS:

3.4.1 Application of plant growth regulators

Plant growth regulators were applied in the form of foliar spray as per treatments during the month of May and June 2012.

3.4.2 Application of FYM

Well decomposed FYM @ 10 kg/tree and chemical fertilizers 200 g N: 100 g P: 50 g K₂O/tree were applied in all the treatments during the month of June 2012.

3.4.3 After care

All the cultural practices such as weeding, inter-culturing, earthing up, removal of water shoots and dead limbs were done as and when required.

3.4.4 Irrigation

First irrigation was given immediately after application of fertilizers and remaining irrigations were given as and when required.

3.4.5 Plant protection measure

There were no any major pests & diseases observed during course of the investigation.

3.5 COLLECTION OF EXPERIMENTAL DATA & SAMPLING TECHNIQUE:

The observations on growth, yield and quality parameters were recorded from the selected tagged plants.

3.6 OBSERVATIONS RECORDED:

3.6.1 Growth parameters

3.6.1.1 Tree spread East-West and North-South (m)

The tree spread measured in all four directions as East-West and North-South. Canopy spread was measured by metric scale at the time of first spray, 30 days after first spray and at the harvesting stage.

3.6.1.2 Number of primary branches/tree

Number of primary branches emerged from main stem of the plant was counted from each plant in the treatment.

3.6.1.3 Number of secondary branches/tree

Number of secondary branches emerged from primary branches was counted from each plant in the treatment.

3.6.1.4 Girth of primary branch (cm)

The girth of the primary branch was measured at the time of first spray, 30 days after first spray and at the time of harvesting stage with the help of measure tape.

Note: Growth Parameters were recorded at the time of first spray, 30 days after first spray and at the harvesting stage.

3.6.2 Yield parameters

3.6.2.1 Days to first flower initiation

The time between application of plant growth regulators and first flower opening was counted as days to flower initiation. Flower initiation was recorded from three tagged branches of the tree and average values were worked out.

3.6.2.2 Days to peak flowering

The time taken between application of plant growth regulators and days for the maximum flowers were counted and recorded from three tagged branches of the tree. The average days peak flowering were worked out.

3.6.2.3 Number of flower clusters per branch

Total number of flower clusters was recorded from randomly selected three tagged branches and average number of flower clusters per branch was calculated.

3.6.2.4 Number of fruits set per branch

Total number of flowers which set in to fruit was counted and percent fruit set was calculated on the basis of number of flowers per branch.

3.6.2.5 Number of fruits per plant

The number of marketable fruits was counted as per treatment at each picking and the total number of fruits per tree was worked out.

3.6.2.6 Average fruit weight (g)

From each of the treatment ten marketable fruits were randomly selected and their weight was recorded separately and average fruit weight was worked out in gram.

3.6.2.7 Fruit yield (kg/tree)

The fruits harvested from each tree were weighted from all the pickings and recorded in kilogram.

3.6.2.8 Fruit volume (cc)

The volume of fruit was measured by the water displacement method. Fruit was placed in measuring beaker of 1 liter capacity filled with full of water. The fruit was placed in cylinder, the replaced water was measured as volume and data were recorded as volume of fruits in ml. Then average value was calculated.

Note: Yield parameters were recorded from three tagged branches of the trees, while fruit yield and number of fruits were taken from the whole tree.

3.6.3 Quality parameters

3.6.3.1 Days taken for ripening of fruits

The time taken between harvest and ripening of fruits noted as days to ripening of fruits in each treatment.

3.6.3.2 Total soluble solids (%)

Total soluble solids (TSS) in percentage of fruit juice was recorded using an Erma made hand refractometer. Drop of extracted custard apple juice was put on hand

refractometer prime and reading was recorded and expressed in terms of percentage. Three readings were taken in each treatment and their average value was calculated.

3.6.3.3 Ascorbic acid (mg/100 g pulp)

The ascorbic acid content in the juice was determined titrimetrically using 2, 6- dichlorophenol indophenol dye described by Ranganna (1979). The dye solution was standardized against ascorbic acid (AR).

Sample preparation:

It included transfer of 10 g of homogenized sample into a 100 ml volumetric flask. The volume was made up to 100 ml by adding 3 percent oxalic acid solution. A known volume 10 ml of aliquot was drawn and used for titration.

The freshly prepared dye (2, 6-dichlorophenol indophenol) was standardized by titrating against standard ascorbic acid (freshly prepared) and the dye factor was calculated.

A known volume (10 ml) of aliquot was taken in to a 100 ml conical flask was titrated against the standardized dye solution. Titration was continued till the light pink colour persists.

The ascorbic acid content was calculated by using the following formula.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titrate value X dye factor X volume made up}}{\text{Aliquot taken for estimation X weight of sample taken}} \times 100$$

3.6.3.4 Reducing sugar (%)

The titrimetric method of Lane and Eynon described by Ranganna (1979) was adopted for estimation of reducing sugar, which is given as under:

Principle of the method

Invert sugars or reducing sugar reduces copper in the Fehling's solution to red insoluble cuprous oxide. The sugar in a sample was estimated by determining the volume of unknown sugar solution required to completely reduce a measured volume of Fehling's solution.

In advance, the mixture of Fehling's solution A and B (5 ml of A and 5 ml of B) was standardized against standard glucose for obtaining glucose equivalents and to arrive at a conversion factor.

Procedure

25 g of the homogenized pulp was taken in 250 ml volumetric flask and 2 ml of 45 per cent basic lead acetate solution added for clarification. After 10 minutes, the solution was de-leaded by adding potassium oxalate crystals in excess and the volume was made up with distilled water up to 250 ml. It was then filtered through Whitman No.1 filter paper. The filtrate was taken in a burette and titrated against boiling Fehling's mixture (5 ml of Fehling's solution A and 5 ml of Fehling's solution B) till the blue colour faded. Then 2-3 drop methylene blue indicator (1 %) was added and then titration continued till the contents attained a brick red colour. At this stage the titrate value was noted and percentage reducing sugar calculated by following formula:

$$\text{Reducing Sugar (\%)} = \frac{\text{Glucose equivalent (0.05) X Total Volume made up}}{\text{Titer X Weight of pulp}} \times 100$$

3.6.3.5 Non-reducing sugar (%)

It was calculated by subtracting the values of the reducing sugar from total sugars of the pulp from each sample separately.

3.6.3.6 Total sugars (%)

For estimation of total sugars, the filtrate obtained in the estimation of reducing sugar was used. The total sugars of the filtrate were estimated by standardized Fehling's solution A and B using methylene blue indicator as per the procedure described below.

Procedure

An aliquot (25 ml) from the filtrate was taken and one-fifth of its volume (5ml) hydrochloric acid (1:1) added and the inversion was carried out at room temperature for 24 hours. Subsequently, the contents were cooled and neutralized with 40 percent sodium hydroxide using phenolphthalein as indicator and the final volume was made up to 100 ml. The solution was filtered through Whatman No. 1 filter paper and than titrated against boiling Fehling's mixture as described earlier.

The percentage of total sugars was expressed as invert sugar according to the following formula.

$$\text{Total Sugar (\%)} = \frac{\text{Glucose eq. of Fehling solutions (0.05)}}{\text{Titre}} \times \frac{\text{Total volume made up}}{\text{Weight of pulp Taken}} \times \frac{\text{Volume made up after inversion}}{\text{Aliquot taken for inversion}} \times 100$$

3.6.3.7 Seed-aril ratio

The seed: aril ratio was calculated as under.

$$\text{Seed/aril ratio} = \frac{\text{Weight of seed}}{\text{-----}}$$

Weight of aril

3.6.3.8 Peel (%)

The peel (%) was calculated as under.

$$\text{Peel (\%)} = \frac{\text{Weight of peel}}{\text{Weight of fruit}} \times 100$$

3.6.3.9 Organoleptic test

The organoleptic evaluation for assessing the colour of pulp and skin, taste, texture and overall acceptability were determined by the expert's panel of five judges by using 10 points scale system.

Note: Quality parameters were taken at fruit ripening stage.

3.6.4 STATISTICAL ANALYSIS

The data collected from different parameters were subjected to statistical analysis of variance technique as described by Panse and sukhatme (1985). The method of "Analysis of Variance" for Randomized block design was used and treatment effects of all the characters were studied by employing 'F' test.

Five percent level of significance was used to test the "null hypothesis" for significance of results. The critical difference was calculated where the difference among the treatments was found significant by 'F' test. The C.V. percent was also worked out.

3.6.5 ECONOMICS

In order to find out most effective and remunerative treatment, the relative economics of each treatment was computed. For each treatment, the gross realization in terms of rupees per hectare was worked out taking in to consideration the prevailing market price of fruit. Likewise the cost of cultivation was also worked out by considering the expense incurred for cultural operation right from preparatory

tillage to the harvesting including PGR's, manures, fertilizers, weeding, irrigation etc. The cost of cultivation then deducted from the gross realization to work out net profit under each treatment and recorded accordingly.

The Cost Benefit Ratio (CBR) was calculated on the basis of the formula given below:

$$\text{CBR} = \frac{\text{Gross realization (Rs/ha)}}{\text{Total cost of cultivation (Rs/ha)}}$$

IV. EXPERIMENTAL RESULTS

This chapter embodies the results of the present investigation on “Effect of plant growth regulators on growth, yield and quality of custard apple (*Annona squamosa* Linn.) cv. Local” was carried out during *kharif-rabi* season of the year 2012-13 at the Horticulture Research Farm, Department of Horticulture, B.A. College of Agriculture, Anand Agricultural University, Anand. The data collected during the period of the experimentation were analysed statistically. The results along with statistical inferences are presented in this chapter.

4.1 EFFECT ON GROWTH PARAMETERS

The data pertaining to effect of plant growth regulators on growth parameters of custard apple *viz.*, tree spread (E-W) and (N-S) direction, number of primary branches per tree, number of secondary branches per tree and girth of primary branch per tree are presented as under.

4.1.1 Tree spread (E-W) (m)

The mean data pertaining to the effect of various treatments on tree spread (East-West direction) are presented in Table 4.1. The results revealed that effect of plant growth regulators on tree spread (E-W direction) was found non-significant at initial, 30 days and at the time of harvesting. However, it was increased with age of the tree with irrespective of the treatments.

4.1.2 Tree spread (N-S) (m)

Results regarding to the effect of various treatments on tree spread (North-South direction) are presented in Table 4.2. Tree spread (N-S) was increased with the age of the tree but the effect of plant growth regulators on tree spread (N-S direction) was found non-significant at initial, 30 days and at the time of harvesting.

4.1.3 Number of primary branches/tree

The mean data pertaining to number of primary branches per tree at initial, 30 days after treatment (DAT) and harvesting stage are presented in Table 4.3. The number of primary branches remained constant during the period of investigation in all the treatments. The data revealed that the effect of plant growth regulators on number of primary branches per tree was found non-significant at all growth stages.

4.1.4 Number of secondary branches/tree

The mean data pertaining to number of secondary branches per tree at initial, 30 DAT and harvesting stage are presented in Table 4.4. Here also, the secondary branches remained the almost similar between initial to harvesting stage. The results showed that the effect of plant growth regulators on number of secondary branches per tree was found non-significant at all growth stages.

4.1.5 Girth of primary branch (cm)

The mean data pertaining to girth of primary branch at initial, 30 DAT and at harvesting stage are presented in Table 4.5. The girth of primary branch was gradually increased with the advancement of the age of tree. However, the increment in the girth of primary branch found almost similar irrespective of the treatments. The result revealed that the effect of plant growth regulators on girth of primary branch was found non-significant at all growth stages.

Table 4.1: Effect of plant growth regulators on tree spread (m) (E-W) direction at different growth stages of custard apple cv. ‘Local’

Sr. No.	Treatments	Tree spread (m) at (E-W) direction		
		Initial	30 DAT	Harvesting time
1	T ₁ : GA ₃ 40 mg/l	5.17	5.29	5.44
2	T ₂ : GA ₃ 60 mg/l	5.22	5.45	5.57
3	T ₃ : GA ₃ 80 mg/l	5.83	5.91	5.99
4	T ₄ : NAA 30 mg/l	5.24	5.56	5.72
5	T ₅ : NAA 60 mg/l	5.52	5.60	5.68
6	T ₆ : NAA 90 mg/l	5.33	5.46	5.59
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	5.93	6.06	6.19
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	5.69	5.86	5.97
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	5.81	5.91	6.02
10	T ₁₀ : Control (water spray)	5.63	5.65	5.87
S.Em. ±		0.26	0.26	0.27
C.D. at 5%		NS	NS	NS
C.V. %		8.21	8.06	8.01

Table 4.2: Effect of plant growth regulators on tree spread (m) (N-S) direction different growth stages of custard apple cv. ‘Local’

Sr. No	Treatments	Tree spread (m) at (N-S) direction		
		Initial	30 DAT	Harvesting time
1	T ₁ : GA ₃ 40 mg/l	5.67	5.77	5.83
2	T ₂ : GA ₃ 60 mg/l	5.40	5.50	5.60
3	T ₃ : GA ₃ 80 mg/l	5.52	5.63	5.70
4	T ₄ : NAA 30 mg/l	4.90	5.05	5.16
5	T ₅ : NAA 60 mg/l	5.86	5.92	5.99
6	T ₆ : NAA 90 mg/l	5.77	5.89	5.98
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	5.91	6.01	6.09
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	5.27	5.38	5.48
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	4.96	5.03	5.15
10	T ₁₀ : Control (water spray)	5.50	5.53	5.62
S.Em. ±		0.23	0.23	0.23
C.D. at 5%		NS	NS	NS
C.V. %		7.18	7.01	7.07

Table 4.3: Effect of plant growth regulators on number of primary branches per

tree at different growth stages of custard apple cv. 'Local'

Sr. No.	Treatments	Number of primary branches/tree		
		Initial	30 DAT	Harvesting time
1	T ₁ : GA ₃ 40 mg/l	7.67	7.67	7.67
2	T ₂ : GA ₃ 60 mg/l	6.67	6.67	6.67
3	T ₃ : GA ₃ 80 mg/l	7.00	7.00	7.00
4	T ₄ : NAA 30 mg/l	7.67	7.67	7.67
5	T ₅ : NAA 60 mg/l	6.67	6.67	6.67
6	T ₆ : NAA 90 mg/l	5.67	5.67	5.67
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	8.00	8.00	8.00
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	7.67	7.67	7.67
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	7.00	7.00	7.00
10	T ₁₀ : Control (water spray)	6.00	6.00	6.00
S.Em. ±		0.54	0.54	0.54
C.D. at 5%		NS	NS	NS
C.V. %		13.38	13.38	13.38

Table 4.4: Effect of plant growth regulators on number of secondary branches per tree at different growth stages of custard apple cv. ‘Local’

Sr. No.	Treatments	Number of secondary branches/tree		
		Initial	30 DAT	Harvesting time
1	T ₁ : GA ₃ 40 mg/l	22.33	22.33	22.33
2	T ₂ : GA ₃ 60 mg/l	22.67	22.67	22.67
3	T ₃ : GA ₃ 80 mg/l	23.00	23.00	23.00
4	T ₄ : NAA 30 mg/l	23.67	23.67	23.67
5	T ₅ : NAA 60 mg/l	22.67	22.67	22.67
6	T ₆ : NAA 90 mg/l	22.67	22.67	22.67
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	23.00	23.00	23.00
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	23.67	23.67	23.67
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	23.67	23.67	23.67
10	T ₁₀ : Control (water spray)	22.00	22.00	22.00
S.Em. ±		1.69	1.69	1.69
C.D. at 5%		NS	NS	NS
C.V. %		12.79	12.79	12.79

Table 4.5: Effect of plant growth regulators on girth of primary branch (cm) at

different growth stages of custard apple cv. 'Local'

Sr. No	Treatments	Girth of primary branch (cm)		
		Initial	30 DAT	Harvesting time
1	T ₁ : GA ₃ 40 mg/l	27.17	27.25	27.31
2	T ₂ : GA ₃ 60 mg/l	25.33	25.37	25.46
3	T ₃ : GA ₃ 80 mg/l	24.83	24.90	24.98
4	T ₄ : NAA 30 mg/l	24.67	24.73	24.81
5	T ₅ : NAA 60 mg/l	24.83	24.87	24.96
6	T ₆ : NAA 90 mg/l	26.50	26.56	26.68
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	25.00	25.07	25.17
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	22.33	22.37	22.45
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	23.67	23.74	23.85
10	T ₁₀ : Control (water spray)	21.00	21.09	21.15
S.Em. ±		1.58	1.66	1.65
C.D. at 5%		NS	NS	NS
C.V. %		11.16	11.66	11.59

4.2 EFFECT ON YIELD PARAMETERS

Data recorded during the study on effect of plant growth regulators on yield parameters of custard apple *viz.*, days to first flower initiation, days to peak flowering, number of flower clusters per branch, number of fruits set per branch, number of fruits per tree, fruit weight (g), fruit yield (kg/tree) and fruit volume (cc) are presented as under.

4.2.1 Days to first flower initiation

The mean data on days to first flower initiation after application of plant growth regulators are presented in Table 4.6 and also depicted in Fig.4.1. The result revealed that effect of plant growth regulators on first flower initiation was found significant.

It is seen from the data (Table 4.6) that minimum days required to first flower initiation (20.00) was recorded in the treatment T₇ (GA₃ 20 + NAA 15 mg/l) and it remained at par with treatments T₁ (GA₃ 40 mg/l), T₃ (GA₃ 80 mg/l), T₄ (NAA 30 mg/l), T₅ (NAA 60 mg/l), T₆ (NAA 90 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l). While, maximum days taken to first flower initiation (27.00) was observed in the treatment T₁₀ *i.e.* control (water spray).

4.2.2 Days to peak flowering

Result regarding the days to peak flowering as influenced by plant growth regulators have been presented in Table 4.6 and also depicted graphically in Fig.4.1.

It is seen from the data (Table 4.6) that minimum days taken to peak flowering (28.00 days) were obtained in treatment T₇ (GA₃ 20 + NAA 15 mg/l) which was at par with treatments T₄ (NAA 30 mg/l), T₅ (NAA 60 mg/l), T₆ (NAA 90 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l). While, maximum days taken for peak flowering (36.67) was taken by the treatment T₁₀ *i.e.* control (water spray).

Table 4.6: Effect of plant growth regulators on days to first flower initiation and days to peak flowering of custard apple cv. 'Local'

Sr. No	Treatments	Days to first flower initiation	Days to peak flowering
1	T ₁ : GA ₃ 40 mg/l	23.67	33.67
2	T ₂ : GA ₃ 60 mg/l	24.33	34.67
3	T ₃ : GA ₃ 80 mg/l	24.00	34.00
4	T ₄ : NAA 30 mg/l	22.00	30.67
5	T ₅ : NAA 60 mg/l	23.00	32.33
6	T ₆ : NAA 90 mg/l	21.33	29.33
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	20.00	28.00
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	22.67	31.33
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	26.67	35.33
10	T ₁₀ : Control (water spray)	27.00	36.67
S.Em. ±		1.38	1.76
C.D. at 5%		4.11	5.22
C.V. %		10.21	9.34

4.2.3 Number of flower clusters per branch

The result pertaining to number of flower clusters per branch as influenced by the plant growth regulators are presented in Table 4.7 and graphically illustrated in Fig. 4.2. It is seen from the result that number of flower clusters per branch was significantly influenced by the different treatments.

Maximum number of flower clusters per branch (3.69) was observed in the treatment T₇ (GA₃ 20 + NAA 15 mg/l), which remained at par with the treatments T₂ (GA₃ 60 mg/l), T₅ (NAA 60 mg/l), T₆ (NAA 90 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l). While, minimum number of flower clusters per branch (2.09) was observed in treatment T₁₀ *i.e.* control (water spray).

4.2.4 Number of fruits set per branch

Data pertaining to the effect of various treatments on number of fruits set per branch are presented in Table 4.7 and graphically depicted in Fig.4.2. The perusal of the data revealed that number of fruits set per branch was significantly affected.

It is evident from the data that the treatment T₇ (GA₃ 20 + NAA 15 mg/l) recorded significantly maximum number of fruits set per branch (5.20) as compared to control and it remained at par with the treatments T₂ (GA₃ 60 mg/l), T₅ (NAA 60 mg/l), T₆ (NAA 90 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l). Treatment T₁₀ *i.e.* control (water spray) registered the lowest number of fruits set per branch (3.86). It was significantly the lowest treatment as compared to the treatments T₅, T₆ and T₇.

4.2.5 Number of fruits per tree

The effect of various treatments on number of fruits per tree are presented in Table 4.8 and also depicted in Fig.4.3. The result clearly indicated that an application of plant growth regulators significantly influenced the number of fruits per tree.

It is obvious from the data that significantly maximum number of fruits per tree (118.33) was recorded in the treatment T₇ (GA₃ 20 + NAA 15 mg/l) and it remained at par with the treatments T₂ (GA₃ 60 mg/l), T₅ (NAA 60 mg/l), T₆ (NAA 90

mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l). While, minimum number of fruits per tree (84.67) was recorded in the treatment T₁₀ *i.e.* control (water spray).

4.2.6 Fruit yield per tree (kg)

The data pertaining to the influence of various treatments on the fruit yield per tree are presented in Table 4.8 and also depicted in Fig.4.4. The data revealed that fruit yield per tree was significantly influenced due to the application of plant growth regulators.

It is quite apparent from the data (Table 4.8) that the maximum fruit yield per tree (26.94 kg) was recorded in the treatment T₇ (GA₃ 20 + NAA 15 mg/l) as compared to control and it remained at par with the treatments T₂ (GA₃ 60 mg/l), T₅ (NAA 60 mg/l), T₆ (NAA 90 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l). While, the treatment T₁₀ *i.e.* control (water spray) gave the minimum fruit yield per tree (17.79 kg) and remained at par with the treatments T₁, T₃, T₄ and T₉.

4.2.7 Average fruit weight (g)

Results pertaining to the effect of various treatments on average fruit weight are presented in Table 4.9 and graphically depicted in Fig.4.5. The perusal of the data revealed that average fruit weight was significantly affected due to various treatments.

It is evident from the data (Table 4.9) that the treatment T₇ (GA₃ 20 + NAA 15 mg/l) recorded significantly higher average fruit weight (227.67 g) as compared to control and treatments T₁, T₃, T₄ and T₉ and it remained at par with the treatments T₂ (GA₃ 60 mg/l), T₅ (NAA 60 mg/l), T₆ (NAA 90 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l). While, the treatment T₁₀ *i.e.* control (water spray) registered significantly the lowest average fruit weight (209.97 g) as compared to all the treatments, except treatments T₁, T₃, T₄ and T₉.

4.2.8 Fruit volume (cc)

The mean data pertaining to fruit volume as influenced by the plant growth regulators are presented in Table 4.9. The data on fruit volume was found non-significant. However, maximum fruit volume was recorded in the treatment T₇ (134.00 cc) while minimum in the control treatment (120.67 cc).

Table 4.7: Effect of plant growth regulators on number of flower clusters per branch, number of fruits set per branch of custard apple cv. ‘Local’

Sr. No .	Treatments	Number of flower clusters per branch	Number of fruits set per branch
1	T ₁ : GA ₃ 40 mg/l	2.20	3.93
2	T ₂ : GA ₃ 60 mg/l	2.99	4.58
3	T ₃ : GA ₃ 80 mg/l	2.30	4.04
4	T ₄ : NAA 30 mg/l	2.80	4.12
5	T ₅ : NAA 60 mg/l	3.37	4.98
6	T ₆ : NAA 90 mg/l	3.57	5.14
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	3.69	5.20
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	3.16	4.62
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	2.50	4.10
10	T ₁₀ : Control (water spray)	2.09	3.86
S.Em. ±		0.25	0.31
C.D. at 5%		0.75	0.93
C.V. %		15.36	12.21

Table 4.8: Effect of plant growth regulators on number of fruits per tree and fruit yield per tree (kg) of custard apple cv. 'Local'

Sr. No	Treatments	Number of fruits per tree	Fruit yield (kg/tree)
1	T ₁ : GA ₃ 40 mg/l	87.33	18.44
2	T ₂ : GA ₃ 60 mg/l	102.33	22.84
3	T ₃ : GA ₃ 80 mg/l	92.33	19.63
4	T ₄ : NAA 30 mg/l	96.67	20.94
5	T ₅ : NAA 60 mg/l	112.67	25.35
6	T ₆ : NAA 90 mg/l	116.33	26.36
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	118.33	26.94
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	107.33	23.96
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	94.67	20.48
10	T ₁₀ : Control (water spray)	84.67	17.79
S.Em. ±		6.45	1.41
C.D. at 5%		19.17	4.18
C.V. %		11.03	10.94

Table 4.9: Effect of plant growth regulators on average fruit weight (g) and fruit volume (cc) of custard apple cv. 'Local'

Sr. No.	Treatments	Average fruit Weight (g)	Fruit volume (cc)
1	T ₁ : GA ₃ 40 mg/l	211.28	133.33
2	T ₂ : GA ₃ 60 mg/l	223.00	126.00
3	T ₃ : GA ₃ 80 mg/l	212.30	122.33
4	T ₄ : NAA 30 mg/l	216.67	128.33
5	T ₅ : NAA 60 mg/l	225.00	130.33
6	T ₆ : NAA 90 mg/l	226.67	124.67
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	227.67	134.00
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	224.33	131.33
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	216.33	129.33
10	T ₁₀ : Control (water spray)	209.97	120.67
S.Em. ±		3.09	4.16
C.D. at 5%		9.18	NS
C.V. %		2.44	5.62

4.3. EFFECT ON QUALITY PARAMETERS

The results on various quality parameters *viz.*, days taken for ripening of fruits, total soluble solids (%), ascorbic acid (mg/100g pulp), reducing sugar (%), non-reducing sugar (%), total sugars (%), seed-aril ratio, peel (%) and organoleptic test as influenced by plant growth regulators are presented as under.

4.3.1 Days taken for ripening of fruits

The result data pertaining to the effect of various treatments on days taken for ripening of fruits are presented in Table 4.10. The data indicated that the effect of plant growth regulators on days taken for ripening was found non-significant. However, treatment T₁₀ *i.e.* control (water spray) took maximum days (5.33) for ripening of fruits. While, treatment T₅ (NAA 60 mg/l) took minimum days (4.00) for ripening of fruits.

4.3.2 Total soluble solids (%)

Data regarding the TSS as influenced by application of plant growth regulators are presented in Table 4.10. The data indicated that the effect of plant growth regulators on total soluble solids was found non-significant. However, treatment T₈ (GA₃ 30 + NAA 30 mg/l) numerically recorded maximum TSS (20.67 %). While, treatment T₁₀ *i.e.* control (water spray) resulted in minimum TSS (16.00 %).

4.3.3 Ascorbic acid (mg/100 g pulp)

The mean data pertaining to ascorbic acid as influenced by the plant growth regulators are presented in Table 4.10 and graphically depicted Fig. 4.6.

Significantly maximum ascorbic acid (22.80 mg/100 g pulp) was recorded in the treatment T₈ (GA₃ 30 + NAA 30 mg/l) which remained at par with the treatments T₇ (GA₃ 20 + NAA 15 mg/l) and T₉ (GA₃ 40 + NAA 45 mg/l). Whereas minimum ascorbic acid (15.48 mg/100 g pulp) was recorded in the treatment T₁₀ *i.e.* control (water spray).

Table 4.10: Effect of plant growth regulators on days taken for ripening of fruits, total soluble solids (%), ascorbic acid (mg/100g pulp) of custard apple cv. 'Local'

Sr. No	Treatments	Days taken for ripening of fruits	Total soluble solids (%)	Ascorbic acid (mg/100g pulp)
1	T ₁ : GA ₃ 40 mg/l	4.33	18.00	17.79
2	T ₂ : GA ₃ 60 mg/l	5.30	18.67	18.83
3	T ₃ : GA ₃ 80 mg/l	4.87	17.67	19.97
4	T ₄ : NAA 30 mg/l	4.83	16.50	18.43
5	T ₅ : NAA 60 mg/l	4.00	17.67	21.06
6	T ₆ : NAA 90 mg/l	4.73	17.33	17.19
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	5.00	19.33	21.83
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	4.83	20.67	22.80
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	4.67	19.00	21.24
10	T ₁₀ : Control (water spray)	5.33	16.00	15.48
S.Em. ±		0.28	1.01	0.53
C.D. at 5%		NS	NS	1.57
C.V. %		10.00	9.70	4.71

4.3.4. Reducing sugar (%)

The mean data pertaining to reducing sugar as influenced by the plant growth regulators are presented in Table 4.11 and graphically depicted Fig. 4.7.

It is quite apparent from the data that significantly maximum reducing sugar (20.08 %) was recorded in the treatment T₉ (GA₃ 40 + NAA 45 mg/l) and it remained at par with T₁ (GA₃ 40 mg/l). While, minimum reducing sugar (12.40 %) was recorded in treatment T₁₀ *i.e.* control (water spray).

4.3.5. Non-reducing sugar (%)

The mean data pertaining to non reducing sugar as influenced by the plant growth regulators are presented in Table 4.11 and graphically depicted in Fig. 4.8.

It is quite apparent from the data (Table 4.11) that significantly maximum non reducing sugar (2.01%) was recorded in the treatment T₉ (GA₃ 40 + NAA 45 mg/l) and it remained at par with the treatment T₁ (GA₃ 40 mg/l). The minimum non reducing sugar (1.37 %) was recorded in the treatment T₁₀ *i.e.* control (water spray).

4.3.6. Total sugars (%)

The mean data pertaining to total sugars as influenced by the plant growth regulators are presented in Table 4.11 and graphically depicted in Fig. 4.9.

Significantly maximum total sugars (22.09%) was recorded in treatment T₉ (GA₃ 40 + NAA 45 mg/l) and it remained at par with T₁ (GA₃ 40 mg/l). While, minimum total sugars (13.77 %) was observed in treatment T₁₀ *i.e.* control (water spray).

4.3.7. Seed-aril ratio

Data regarding the seed-aril ratio as influenced by application of plant growth regulators are presented in Table 4.12. It was observed that the effect of plant growth regulators on seed-aril ratio was non-significant.

However, it was minimum in the treatments T₆ (NAA 90 mg/l) and T₁₀ *i.e.* control (water spray) (0.17). While, it was the highest (0.22) in the treatment T₅ (NAA 60 mg/l).

4.3.8. Peel (%)

The results pertaining to the effect of various treatments on peel per cent was presented in Table 4.12. The effect of plant growth regulators on peel per cent was found non-significant. However, it was maximum in the treatment T₈ (GA₃ 30 + NAA 30 mg/l) (55.82). While, it was minimum (45.82) in the treatment T₆ (NAA 90 mg/l).

4.3.9. Organoleptic test

The mean data pertaining to organoleptic test including taste, texture, color, appearance and overall as influenced by the plant growth regulators are presented in table 4.13. It was observed that the effect of plant growth regulators on taste, texture, color, appearance and overall was non-significant. However, in case of overall test, it was maximum in the treatment T₅ (NAA 60 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l) (8.00) as against minimum in the control treatment (7.13).

Table 4.11: Effect of plant growth regulators on reducing sugar (%), non reducing sugar (%) and total sugars (%) of custard apple cv. 'Local'

Sr. No	Treatments	Reducing sugar (%)	Non reducing sugar (%)	Total sugars (%)
1	T ₁ : GA ₃ 40 mg/l	19.30	1.88	21.18
2	T ₂ : GA ₃ 60 mg/l	16.98	1.54	18.52
3	T ₃ : GA ₃ 80 mg/l	14.15	1.42	15.57
4	T ₄ : NAA 30 mg/l	13.81	1.38	15.19
5	T ₅ : NAA 60 mg/l	16.65	1.69	18.34
6	T ₆ : NAA 90 mg/l	16.04	1.59	17.63
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	15.20	1.53	16.73
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	15.15	1.61	16.76
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	20.08	2.01	22.09
10	T ₁₀ : Control (water spray)	12.40	1.37	13.77
S.Em. ±		0.57	0.06	0.61
C.D. at 5%		1.68	0.17	1.81
C.V. %		6.15	6.11	6.00

4.4. Economics:

The regional adaptability of any cultivation practices in any crop is completely based on the highest economic value of a treatment. Therefore, it is necessary to work out economics of different treatments for valid comparison of operational practices because of sometimes the most effective treatment may become poorer when tested on the basis of economics.

The mean data on the cost of cultivation incurred with gross realization and CBR of custard apple as affected by plant growth regulators are presented in Table 4.14 and also graphically illustrated in fig 4.10. The details of cost incurred in the treatment application and income worked out which is presented in Appendix-II.

Perusal of the data presented in Table 4.14 revealed that maximum fruit yield (10.78 t/ha) was obtained with the treatment T₇ (GA₃ 20 + NAA 15 mg/l) followed by treatment T₆ (10.54 t/ha) as compared to control T₁₀ *i.e.* control (7.12 t/ha). Similarly the highest net realization (₹ 3, 36, 786 ha⁻¹) was obtained by the treatment T₇ (GA₃ 20 + NAA 15 mg/l) followed by T₆ (NAA 90 mg/l) (₹ 3, 31, 314 ha⁻¹) as compared to rest of the treatments including control T₁₀ *i.e.* control (water spray). However, the highest CBR (9.81) was recorded in treatment T₆ (NAA 90 mg/l) as compared to treatments T₇ and rest of the treatments. This might be due to lower cost of the treatment.

Table 4.12: Effect of plant growth regulators on seed-aril ratio and peel (%) of custard apple cv. ‘Local’

Sr. No.	Treatments	seed-aril ratio	peel (%)
1	T ₁ : GA ₃ 40 mg/l	0.19	48.52
2	T ₂ : GA ₃ 60 mg/l	0.21	54.39
3	T ₃ : GA ₃ 80 mg/l	0.18	53.36
4	T ₄ : NAA 30 mg/l	0.20	49.70
5	T ₅ : NAA 60 mg/l	0.22	51.56
6	T ₆ : NAA 90 mg/l	0.17	45.82
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	0.20	51.23
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	0.21	55.82
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	0.18	50.06
10	T ₁₀ : Control (water spray)	0.17	48.68
S.Em. ±		0.01	1.94
C.D. at 5%		NS	NS
C.V. %		9.93	6.59

Table 4.13: Effect of plant growth regulators on organoleptic test of custard apple cv. ‘Local’

Sr. No.	Treatments	Taste	Texture	Color	Appearance	Overall
1	T ₁ : GA ₃ 40 mg/l	7.25	7.50	7.33	7.75	7.58
2	T ₂ : GA ₃ 60 mg/l	7.25	7.08	7.67	7.50	7.63
3	T ₃ : GA ₃ 80 mg/l	7.25	7.08	7.08	7.33	7.21
4	T ₄ : NAA 30 mg/l	7.42	7.33	7.58	7.83	7.83
5	T ₅ : NAA 60 mg/l	8.00	7.67	7.67	8.00	8.00
6	T ₆ : NAA 90 mg/l	7.33	7.42	7.75	7.67	7.50
7	T ₇ : GA ₃ 20 + NAA 15 mg/l	6.83	7.17	7.50	7.33	7.33
8	T ₈ : GA ₃ 30 + NAA 30 mg/l	7.67	7.33	7.83	7.67	8.00
9	T ₉ : GA ₃ 40 + NAA 45 mg/l	7.00	6.83	7.42	7.75	7.50
10	T ₁₀ : Control (water spray)	6.67	6.75	7.08	7.00	7.13
S.Em. ±		0.32	0.28	0.31	0.32	0.25
C.D. at 5%		NS	NS	NS	NS	NS
C.V. %		10.92	9.51	10.01	10.38	8.04

Table 4.14: Economics of custard apple cv. ‘Local’ as influenced by various treatments

Tr. No.	Fruit yield (t/ha)	Gross realization (₹/ha)	Total cost of cultivation (₹/ha)	Net realization (₹/ha)	CBR
T ₁	7.38	2,58,300	44,172	2,14,128	5.85
T ₂	9.14	3,19,900	48,012	2,71,888	6.66
T ₃	7.85	2,74,750	51,852	2,22,898	5.30
T ₄	8.38	2,93,300	36,857	2,56,443	7.96
T ₅	10.14	3,54,900	37,222	3,17,678	9.53
T ₆	10.54	3,68,900	37,586	3,31,314	9.81
T ₇	10.78	3,77,300	40,514	3,36,786	9.31
T ₈	9.58	3,35,300	42,617	2,92,683	7.87
T ₉	8.19	2,86,650	44,719	2,41,931	6.41
T ₁₀	7.12	2,49,200	36,492	2,12,708	6.83

Selling price of custard apple fruit per kg @ ₹ 35.00

Cost of PGR's

GA₃ @ ₹ 120 g⁻¹

NAA @ ₹ 7.6 g⁻¹

T₁: GA₃ 40 mg/l

T₂: GA₃ 60 mg/l

T₃: GA₃ 80 mg/l

T₄: NAA 30 mg/l

T₅: NAA 60 mg/l

T₆: NAA 90 mg/l

T₇: GA₃ 20 + NAA 15 mg/l

T₈: GA₃ 30 + NAA 30 mg/l

T₉: GA₃ 40 + NAA 45 mg/l

T₁₀: Control (water spray)

V. DISCUSSION

The demand of custard apple fruit is continuously increasing, but the production of fruits is low in Gujarat, due to improper management practices. Plant growth regulators play an important role in growth, yield and quality of custard apple. Therefore, the present investigation on the “Effect of plant growth regulators on growth, yield and quality of custard apple (*Annona squamosa* Linn.) cv. Local” was carried out at Horticultural Research Farm, Department of Horticulture, B.A.C.A., A.A.U., Anand. The effects of various treatments were recorded and the results obtained during the course of investigation are discussed in this chapter. The entire discussion has been divided into following heads.

5.1 Effect on growth parameters

5.2 Effect on yield parameters

5.3 Effect on quality parameters

5.4 Economics

5.1 EFFECT ON GROWTH PARAMETERS

Custard apple exhibits indeterminate growth habit. The plant growth is the function of photosynthetic activity and their capacity to utilize available nutrients.

The response of plant growth regulators on various growth parameters of custard apple such as tree spread (E-W) (Table 4.1), tree spread (N-S) (Table 4.2), number of primary branches (Table 4.3), number of secondary branches (Table 4.4) and girth of primary branch (Table 4.5) were found to be non-significant. These results were controversy with the findings of Babu and Lavania (1985) in lemon, Kassem *et al.* (2010) in persimmon tree, Wahdan *et al.* (2011) in mango and Goswami *et al.* (2013) in pomegranate.

5.2 EFFECT ON YIELD PARAMETERS

The effect of plant growth regulators on yield parameters of custard apple, viz., days to first flowering initiation, days to peak flowering (Table 4.6), number of flower clusters per branch, number of fruits set per branch (Table 4.7), number of fruits per tree, fruit yield per tree (Table 4.8) and average fruit weight (Table 4.9) were found to be significant, while fruit volume (Table 4.9) was found to be non-significant.

An appraisal of data presented in Table 4.6 indicated that among all the treatments, significantly the earliest flower initiation was noted under the treatment T₇ (GA₃ 20 + NAA 15 mg/l). The higher concentration of plant regulators viz., GA₃ and NAA in combined treatment, delayed the period of first flower initiation and maximum days taken for peak flowering because the higher concentration might be having toxic effect on yield parameters. Similarly the minimum days taken for peak flowering was also observed with same treatment (T₇). This might be due to the C: N ratio, which helps in balanced management of vegetative and reproductive phases and thereby promote early flowering. The results of the present study are in controversy with the results obtained by Goswami *et al.* (2013) in pomegranate.

It is clear from the results (Table 4.7) that treatment T₇ (GA₃ 20 + NAA 15 mg/l) recorded significantly maximum number of flower clusters per branch (3.69) as compared to control. The increased in number of flower clusters per branch might be due to supply of nutrients and growth promoting substances. The results of the present study are in controversy with the results obtained by Goswami *et al.* (2013) in pomegranate.

The data presented in Table 4.7 showed that increase in number of fruits set per branch (5.20) was obtained with treatment T₇ (GA₃ 20 + NAA 15 mg/l). The increase in number of fruits set per branch might be due to supply of nutrients and

growth promoting hormones right from starting of the experimentation to the harvesting of the fruits. The production and supply of photosynthesis at critical stage induces the more flowering as well as fruits set. These results are in accordance with the findings of Oosthuysen (1993) and Nkansah *et al.* (2012) in mango, Singh *et al.* (2007) in aonla.

An appraisal of data presented in Table 4.8 indicate that among all treatments, significantly maximum number of fruits per tree (118.33) and fruit yield per tree (26.94 kg) was noted under the treatment T₇ (GA₃ 20 + NAA 15 mg/l) as compared to control. This might be due to effect of gibberellic acid cell enlargement, cell division and increasing the number and size of fruits which ultimately has resulted in higher fruit yield. While as NAA increasing in photosynthetic activity, fruit set by reducing fruit drop and thereby higher number of fruits and ultimately the higher fruit yield. These findings are in accordance with the results obtained by Singh *et al.* (2007) and Srivastava *et al.* (2009) in aonla and Nkansah *et al.* (2012) in mango.

The treatment T₇ (GA₃ 20 + NAA 15 mg/l) recorded significantly the highest average fruit weight (227.67 g). This might be due to the use of plant growth regulators GA₃ and NAA which accelerated rate of fruit growth. The exogenous application of gibberellic acid promoted cell enlargement and cell division. Similarly increase in fruit weight might be due to the application of NAA i.e. auxin which promotes cell division, cell expansion and increased volume of intercellular spaces in the mesocarpic cells. These findings are in accordance with the results obtained by Singh *et al.* (2007) in aonla and Nkansah *et al.* (2012) in mango.

The data presented in Table 4.9 indicated that fruit volume was non-significantly changed due to the treatments of plant growth regulators viz., GA₃ and NAA.

5.3 EFFECT ON QUALITY PARAMETERS

The data presented in Table (4.10) indicated that effect of plant growth regulators on days taken for ripening of fruits and TSS were found non- significant.

In case of ascorbic acid content, treatment T₈ (GA₃ 30 + NAA 30 mg/l) recorded maximum ascorbic acid (22.80 mg/100 g pulp) (Table 4.10). The increase in ascorbic acid content may be due to perpetual synthesis of glucose -6- phosphate throughout the growth and development of fruits, which is thought to be the precursor of vitamin C. These results are conformity with the findings of Srivastava *et al.* (2009) in aonla.

The response of plant growth regulators on reducing sugar content differed significantly (Table 4.11). The results revealed that significantly maximum reducing sugar (20.08 %) was recorded in the treatment T₉ (GA₃ 40 + NAA 45 mg/l). Plant growth regulators may increase the activity of the enzymes such as amylases, which hydrolyse the complex polysaccharides in to simple sugars. Auxin and GA₃ has been reported to accelerate the translocation of metabolites from other parts of the plant towards developing fruits. These findings are supported by the results obtained by Singh *et al.* (2007) in aonla.

It is clear from the result (Table 4.11) that treatment T₉ (GA₃ 40 + NAA 45 mg/l) recorded significantly the highest non reducing sugar (2.01%). This might be due to plant growth regulators may increase the activity of the enzymes such as amylases, which hydrolyse the complex polysaccharides in to simple sugars. These results controversy reported by Srivastava *et al.* (2009) in aonla.

The results pertaining to total sugars (Table 4.11) showed significant response to the application of plant growth regulators over control. Further, significantly the highest total sugars (22.09%) were recorded under the treatment T₉ (GA₃ 40 + NAA

45 mg/l). Plant growth regulators may increase the activity of the enzymes such as amylases, which hydrolyse the complex polysaccharides in to simple sugars. Auxin as well as GA₃ has been found to accelerate the translocation of metabolites from other parts of the plant towards developing fruits. These findings are also supported by the results obtained by Singh *et al.* (2007) in aonla.

The data presented in Table (4.12) indicated the effect of plant growth regulators on seed-aril ratio and peel per cent were found non-significant.

The results pertaining to organoleptic test (Table 4.13) such as taste, texture, color, appearance and overall showed non-significant response to application of plant growth regulators.

5.4 Economics

Economics of the treatments was worked out on the basis of gross realization and total cost of cultivation. The data presented in Table 4.14 indicated that highest net realization (₹ 3,36,786 ha⁻¹) was obtained in the treatment T₇ *i.e.* GA₃ 20 + NAA 15 mg/l followed by T₆ *i.e.* NAA 90 mg/l. This might be due to the increase in fruit yield due to increase in fruit set, number of fruits and fruit weight due to GA₃ and NAA with their appropriate concentration before initiation of flowering.

VI. SUMMARY AND CONCLUSION

6.1 SUMMARY

The present investigation on “**Effect of plant growth regulators on growth, yield and quality of custard apple (*Annona squamosa* Linn.) cv. Local**” was carried out during *Kharif-rabi* season of the year 2012-13 at Horticultural Research Farm, Department of Horticulture, B.A. College of Agriculture, Anand Agricultural University, Anand. The experiment was laid out in a Randomized Block Design with 10 treatments viz. T₁: GA₃ 40 mg/l, T₂: GA₃ 60 mg/l, T₃: GA₃ 80 mg/l, T₄: NAA 30 mg/l, T₅: NAA 60 mg/l, T₆: NAA 90 mg/l, T₇: GA₃ 20 + NAA 15 mg/l, T₈: GA₃ 30 + NAA 30 mg/l, T₉: GA₃ 40 + NAA 45 mg/l and T₁₀: control (water spray) with three replications.

The results presented and discussed in the preceding chapters have been summarized under following major heads.

6.1.1 Effect of plant growth regulators on growth parameters

The growth parameters like tree spread (E-W and N-S), number of primary branches per tree, number of secondary branches per tree and girth of primary branch were non significant by effected by plant growth regulators.

6.1.2 Effect of plant growth regulators on yield parameters

Minimum days taken to first flower initiation (20 days) after application of plant growth regulators was obtained by the treatment T₇ (GA₃ 20 + NAA 15 mg/l), which remained at par with the treatments T₁, T₃, T₄, T₅, T₆ and T₈. While the maximum days taken for appearance of first flower initiation (27 days) was noted in the treatment T₁₀ *i.e.* control (water spray).

Minimum days required for peak flowering (28 days) was recorded in the treatment T₇ (GA₃ 20 + NAA 15 mg/l), which remained at par with the treatments T₄,

T₅, T₆, and T₈. While, the maximum days required for peak flowering (36.67 days) was seen in the treatment T₁₀ *i.e.* control (water spray).

Maximum number of flower clusters per branch (3.69) was recorded by the treatment T₇ (GA₃ 20 + NAA 15 mg/l), which remained at par with the treatments T₂, T₅, T₆ and T₈. While, minimum number of flower clusters per branch (2.09) was observed in the treatment T₁₀ *i.e.* control (water spray).

Maximum number of fruits set per branch (5.20) was recorded with the treatment T₇ (GA₃ 20 + NAA 15 mg/l), which remained at par with the treatments T₂, T₅, T₆ and T₈. While, minimum number of fruits set per branch (3.86) was found in the treatment T₁₀ *i.e.* control (water spray). It was significantly minimum as compared to the treatments T₅, T₆ and T₇.

Maximum number of fruits per tree (118.33) was recorded in treatment T₇ (GA₃ 20 + NAA 15 mg/l) which remained at par with the treatments T₂, T₅, T₆ and T₈. While, minimum number of fruits per tree (84.67) was recorded in the treatment T₁₀ *i.e.* control (water spray).

The highest fruit yield per tree (26.94 kg) was obtained in the treatment T₇ (GA₃ 20 + NAA 15 mg/l), which remained at par with the treatments T₂, T₅, T₆ and T₈. While, minimum fruit yield per tree (17.79 kg) was recorded in the treatment T₁₀ *i.e.* control (water spray) and remained at par with the treatments T₁, T₃, T₄ and T₉.

Maximum weight of average fruit (227.67 g) was recorded in the treatment T₇ (GA₃ 20 + NAA 15 mg/l), which remained at par with the treatments T₂, T₅, T₆ and T₈. While, minimum weight of average fruit (209.97 g) was found in the treatment T₁₀ *i.e.* control (water spray) as compared to all the treatments, except treatments T₁, T₃, T₄ and T₉.

The fruit volume was not significantly changed by the application of plant growth regulators. However, maximum fruit volume was recorded in the treatment T₇ (134.00 cc) and minimum in the control treatment (120.67 cc).

6.1.3 Effect of plant growth regulators on quality parameters

The number of days for the ripening of fruits was not significantly affected by the application of plant growth regulators. However, treatment T₁₀ *i.e.* control (water spray) took maximum days (5.33) for ripening of fruits. While, treatment T₅ (NAA 60 mg/l) took minimum days (4.00) for ripening of fruits.

The TSS was not significantly affected by the application of plant growth regulators. However, treatment T₈ (GA₃ 30 + NAA 30 mg/l) took maximum TSS (20.67 %). While, treatment T₁₀ *i.e.* control (water spray) took minimum TSS (16.00 %).

The content of ascorbic acid (22.80 mg/100 g pulp) was recorded maximum with the treatment T₈ (GA₃ 30 + NAA 30 mg/l), which remained at par with the treatments T₇ and T₉. While, minimum ascorbic acid (15.48 mg/100 g pulp) was observed in T₁₀ *i.e.* control (water spray).

The reducing sugar was significantly the highest (20.08 %) in the treatment T₉ (GA₃ 40 + NAA 45 mg/l) as compared to control. However, it was statistically at par with the treatments T₁. Treatment T₁₀ *i.e.* control (water spray) recorded significantly the lowest reducing sugar (12.40 %) as compared to rest of the treatments.

The highest non reducing sugar (2.01%) was recorded by the treatment T₉ (GA₃ 40 + NAA 45 mg/l) followed by treatment T₁. While, minimum non reducing sugar (1.37 %) was observed in T₁₀ *i.e.* control (water spray).

Maximum total sugars (22.09%) were recorded by the treatment T₉ (GA₃ 40 + NAA 45 mg/l) followed by treatment T₁. While, minimum total sugars (13.77 %) recorded in T₁₀ *i.e.* control (water spray).

The seed-aril ratio was not significantly affected by treatments of plant growth regulators. However, it was minimum in treatments T₆ (NAA 90 mg/l) and T₁₀ *i.e.* control (water spray) *i.e.* 0.17. While, it was the highest in the treatment T₅ (NAA 60 mg/l) (0.22) as compared to rest of the treatments.

Peel percent was not significantly affected by the different treatment of plant growth regulators. However, it was maximum in the treatment T₈ (GA₃ 30 + NAA 30 mg/l) (55.82) and minimum in the treatment T₆ (NAA 90 mg/l) (45.82) among the treatments.

The result of organoleptic test (taste, texture, color, appearance and overall) was found non-significant response to the application of different concentration of plant growth regulators. However, in case of overall test it was maximum in the treatments T₅ (NAA 60 mg/l) and T₈ (GA₃ 30 + NAA 30 mg/l) (8.00) as against minimum in the control (7.13).

6.1.4 Economics

The highest net realization ($\text{` 3, 36, 786 ha}^{-1}$) was obtained by the treatment T₇ (GA₃ 20 + NAA 15 mg/l) as compared to rest of the treatments. While treatment T₆ (NAA 90 mg/l) recorded maximum CBR (9.81) may be due to lower cost of the treatment. The lowest net realization ($\text{` 2, 12, 708 ha}^{-1}$) was obtained in T₁₀ *i.e.* control (water spray). While, minimum CBR value (5.30) was recorded by treatment T₃ (GA₃ 80 mg/l) due to higher cost of the treatment.

6.2 CONCLUSION

In the light of the results obtained from this investigation, it can be inferred that spraying of GA₃ 20 + NAA 15 mg/l twice i.e. before flowering (second fortnight of may) and one month after the first spray is beneficial for getting higher fruit yield and net realization in custard apple cv. 'Local', under middle Gujarat Agro-climatic Conditions.

BIBLIOGRAPHY

- Ahmad M. and Zargar G.H (2005). Effect of trunk girdling, flower thinning, GA₃ and ethephon application on quality characteristics in grape cv. Perlette under temperate Kashmir valley conditions. *Indian J. Hort.*, **62** (3):285-287.
- Anonymous (2012). (a) National Horticulture Board.
- Anonymous (2012). (b) Directorate of Horticulture, Gujarat State Gandhinagar.
- Babu Ratna, G.H.V. and Lavania, M.L. (1985). Vegetative growth and nutritional status as influenced by auxin and gibberellic acid, and their effect on fruit yield in lemon. *Scientia Horticulture*, **26**: 25-33.
- Bal J.S. and Randhawa J.S. (2007). Effect of NAA on fruit drop and quality of ber. *Haryana J. Hort. Sci.*, **36** (3&4): 231-232.
- Bankar, G.J and Prasad, R.N. (1990). Effect of Gibberellic acid and NAA on fruit set and quality of fruit in ber cv. Gola. *Progressive Horticulture*, **22** (1-4): 60-62.
- Bhat Anju, Kher Ravi and Gupta S.P. (2006). Effect of growth regulators and nutrients on fruit cracking and fruit quality in lemon. *Haryana J. hort. Sci.*, **35** (3&4): 267.
- Bhati Bheroo Singh and Yadav Pramod Kumar (2003). Effect of foliar application of urea and NAA on quality of ber (*Zizyphus mauritiana* L.) cv. Gola. *Haryana J. Hort. Sci.*, **32** (1&2): 32-33.
- Bhati Bheroo Singh and Yadav Pramod Kumar (2004). Effect of foliar application of urea and NAA on the yield parameters of ber

(*Zizyphus mauritiana* L.) cv. Gola. *Haryana J. Hort. Sci.*, **33** (3&4): 189-190.

Bhowmick Nilesh and Banik B.C. (2011). Influence of pre-harvest foliar application of growth regulators and micronutrients on mango cv. Himsagar. *Indian J. Hort.*, **68** (1): 103-107.

Biswar, B.; Ghosh, S.K.; Ghosh, B. and Mitra, S.K. (1988). Effect of growth substances on fruit weight, size and quality of guava cv. L-49. *Indian Agric.*, **32** (4): 245-248.

*Brahmachari, V.S.; Mandal, A.K.; Rajesh Kumar and Rani, R. (1995). Effect of growth substances on fruit set and physiological characters of Sardar Guava. *Hort. J.*, **9** (1): 1-7.

Brahmachari V.S., Naresh Kumar and Rajesh Kumar (1997). Effect of foliar feeding of calcium, potassium and growth substance on yield and quality of guava (*Psidium guajava* L.). *Haryana J. Hort. Sci.*, **26** (3-4): 169-173.

Brahmachari V.S. and Rani Ruby (2000). Effect of growth substances on fruit drop, yield and physio-chemical composition of Litchi fruits. *Progressive Horticulture*, **32** (1): 50-55.

Chaudhary A.S., Singh Moti and Singh G.N. (1992). Effect of plant growth regulators on Loquat var. Herds Mammoth. *Punjab Hort. J.*, **32** (1-4): 99-102.

- Dutta P., Kundu S. and Ahmed B. (2008). Effect of plant bio-regulators on fruit quality and mineral composition of ripe mango cv. Himsagar. *Indian Agric.*, **52** (3&4): 107-111.
- Garasiya V.R., Patel N.M., Bhadauria H.S and Wankhade V.R. (2013). Studies of plant growth substances on the yield component of winter season guava cv. L-49 (Sardar). *International Journal of Agricultural Sciences*, **9** (1): 114-116.
- Ghosh S.N., Bera B., Roy S. and Kundu A. (2009). Effect of plant growth regulators in yield and fruit quality in pomegranate cv. Ruby. *J. Hortl. Sci.*, **4** (2): 158-160.
- Gill P.P.S. and Bal J.S. (2009). Effect of growth regulator and nutrients spray on control of fruit drop, fruit size and quality of ber under sub-montane zone of Punjab. *J. Hortl. Sci.*, **4** (2): 161-163.
- Goswami J.D., Patel N.M., Bhadauria H.S. and Wankhade V.R. (2013). Effect of plant growth substances on growth, fruit setting and yield of pomegranate cv. Sinduri. *International Journal of Agricultural Sciences*. **9** (1): 332-334.
- Jackson, M.L. (1973). "Soil Chemical Analysis" Prentice Hall of India Pvt. Ltd., New Delhi, **pp.** 183-192.
- Jain M.C. and Dashora L.K. (2011). Effect of plant growth regulators on physico-chemical characters and yield of guava cv. Sardar under high density planting system. *Indian J. Hort.*, **68** (2): 259-261.

- Kassem H.A., Amal M. El-Kobbia, Hend A.Marzouk and Mohamed M.El-Sebaiey (2010). Effect of foliar sprays on fruit retention, quality and yield of Costata persimmon trees. *Emir. J. Food Agric.*, **22**(4): 259-274.
- Katyal S. L., Krishnamurti S., Singh Sham (1963). Chemical properties of custard apple tree. *Fruit Culture in India* Page no.-239-246.
- Keskar, B.G., Bhore, D.P. and Masalekar, S.R. (1986). Effect of NAA and mulch on yield of custard apple. *J. MAU.*, **11**(2): 235-236.
- Kulkarni S.S., Desai U.T., Masalkar S.D. (1995). Fruit set studies in Custard Apple under semi-arid conditions of western Maharashtra. *J. Maharashtra agric. Univ.*, **20** (2): 317-318.
- Nkansah G.O., Ofosu-Anim J. and Mawuli A. (2012). Gibberellic acid and Naphthalene acetic acid affect fruit retention, yield and quality of Keitt Mango in the Coastal Savanna Ecological Zone of Ghana. *American Journal of Plant Physiology*, **7** (6): 243-251.
- *Oosthuyse, S.A. (1993). Effect of spray application of KNO₃, urea and growth regulators on the yield of Tommy Atkins mango.
- *Pandey, V. (1999). Effect of NAA and GA₃ spray on fruit retention, growth, yield and quality of ber (*Zizyphus mauritiana* L.) cv. Banarasi Karaka. *Orrisa J.Hort.*, **27** (1): 69-73.
- Panse, V.G. and Sukhatme, P.V. (1985). "Statistical Methods for Agricultural Workers". I.C.A.R., New Delhi.

- Patel N.M., Patel D.K., Verma L.R and Patel M.M. (2010). Effect of cultural and chemical treatments on fruit set and fruit yield of custard apple (*Annona squamosa* Linn.) cv. Sindhan. *The Asian Journal of Horticulture*, **5** (2): 498-502.
- Paull, R.E. (1982). Post harvest variation in composition of soursop (*Annona muricata* L.) fruit in relation to respiration and ethylene production. *J. Amer. Soc. Hort. Sci.*, **107** (4): 582-585.
- *Piper, C.S. (1950). Soil and Plant Analysis. Interscience publishing Inc., New York, pp. 368.
- Rajput C.B.S. and Singh J.N. (1983). Effects of urea and GA₃ sprays on the growth, flowering and fruiting characters of mango. *Prog. Hort.*, **15** (3):174-177.
- Rakesh Kumar, Parshant Bakshi, J.N. Srivastava and S. Sarvanan (2012). Influence of plant growth regulators on growth, yield and quality of strawberry (*Fragaria xananassa* Duch) cv. Sweet Charlie. *The Asian Journal of Horticulture*, **7** (1): 40-43.
- Ranganna, S. (1979). Hand Book of Analysis and Quality Control for Fruit and Vegetable Products (II Edn.) Tata McGrew Hill Publishing. Co. Ltd., New Delhi.
- Ray, D.P.; Samanta, P.K.S.; Dora, D.K.; Sahu, P. and Das, B.K. (1991). Effect of plant growth regulators on fruit set, retention, development and quality of Sapota (*Achras sapota* L.) cv. Cricket ball. *Indian Agriculturist*, **36** (1): 9-13.

- Reddy P. and Prasad Manohar D. (2011). Effect of plant growth regulators on fruit characters and yield of pomegranate (*punica granatum* L.) cv. Ganesh. *Internation J. of plant, animal and environmental sciences*, **2** (2): 91-93.
- *Shinde, B. B.; Ingle, H. V.; Dhawale, D. U.; Hajare, A. R. and Dhobe, S. G. (2008). Effect of plant growth regulators on size, yield and quality of acid lime. *J. Soils and Crops*, **18** (1): 117-120.
- Singh A. K. and Rajput C. B. S. (1991). Effect of GA₃, BA and Calcium on flowering, fruiting and fruit quality of Mango (*Mangifera Indica* L.) cv. Langra. *The Punjab Horticultural Journal*. 45-52.
- Singh J. K., Prasad J. and Singh H.K. (2007). Effect of micro-nutrients and plant growth regulators on yield and physico-chemical characteristics of aonla fruits in cv. Narendra Aonla-10. *Indian J. Hort.*, **64** (2): 216-218.
- Singh J.P., Suneel Kumar, Katiyar P.N and Dwivedi A.K. (2011). Effect of calcium nitrate, GA₃ and ethrel on fruiting, ripening and chemical traits of phalsa (*Grewia Subinaequalis* D.C.). *Annals of Horticulture*, **4** (1): 72-76.
- Singh M.I. and Chohan G.S. (1984). Effect of various plant growth regulators on Granulation in citrus cv. Dancy Tangerine. *Indian J. Hort.*, **41**(3-4): 221-224.
- Singh, S. P. (1992). Fruit crop for wasteland. Published by Scientific Publishers, Jodhpur. pp. 49-64.

- Singh, S.P., Singh, I.B. and Singh, V.N. (1987). A note on effect of Gibberellic Acid on fruit setting, fruit retention and quality of Jujube (*Ziziphus Mauritiana* Lamk) cv. Banarasi Karaka. *Prog. Hort.*, **19** (1-2): 61-64.
- Singh, R.; Godara, N. R. and Ahlawat, V. P. (2002). Qualitative attributes as affected by foliar sprays of nutrients and growth regulators in ber (*Zizyphus mauritiana* L.) cv. Umran. *Haryana J. Hort. Sci.*, **31** (1&2): 23-25.
- Singh Rajpal, Godara N.R., Singh Rajbir and Dahiya S.S. (2001). Responses of foliar application of growth regulators and nutrients in Ber (*Zizyphus mauritiana* L.) cv. Umran. *Haryana J. Hort. Sci.*, **30** (3&4): 161-164.
- Srivastava C.P., Singh H.K., Vishwanath and Bhanu Pratap (2009). Efficacy of foliar feeding of plant growth regulators along with urea on yield and quality of aonla (*Emblica Officinalis* Gaertn.) cv. NA-7 fruits. *Annals of Horticulture*, **2** (1): 77-79.
- Sundararajan S., Shanmugavelu, K.G. and Muthuswamy, S. (1968). Effect of plant growth regulators on custard apple (*Annona squamosa* L.). *South Indian Hort.* **16** (3&4): 63-64.
- Wahdan, M. T., Habib, S. E, Bassal, M. A. and Qaoud, E. M. (2011). Effect of some chemicals on growth, fruiting, yield and fruit quality of “Succary Abiad” mango cv. *Journal of American Science*, **7** (2): 651-658.

Yadav S., Bhati S.K.; Godara R.K and Rana G. S. (2001). Effect of growth regulators on the yield and quality of winter season Guava cv. L-49. *Haryana J. Hort. Sci.*, **30** (1&2): 1-2.

APPENDIX -I

Appendix-I: Mean weekly weather parameters during the experiment period from May 2012 to December 2012

Month	Std. Week	Date	Temperature (°C)		Mean RH (%)	Bright sunshine (hrs/day)	Rainfall (mm)
			Max.	Min.			
May 2012							
	20	13-19	39.0	25.3	56.1	10.47	0.0
	21	20-26	39.9	25.7	57.2	10.81	0.0
	22	27-02	39.6	26.3	56.3	10.32	0.0
	23	03-09	37.7	27.8	61.6	7.65	0.0
June 2012							
	24	10-16	37.5	27.6	69.9	7.87	4.1
	25	17-23	37.9	27.8	64.0	8.62	0.0
	26	24-30	37.5	27.6	64.0	9.22	2.6
July 2012							
	27	01-07	34.6	27.0	77.8	2.94	76.8
	28	08-14	32.8	25.8	84.4	5.25	131.4
	29	15-21	33.5	27.1	80.6	4.94	46.3
	30	22-28	32.0	26.7	80.6	1.38	2.2
	31	29-04	31.6	26.3	81.3	1.14	5.2
Aug 2012							
	32	05-11	31.7	25.9	83.2	1.77	15.1
	33	12-18	29.9	24.7	90.5	1.94	255.2
	34	19-25	31.8	24.8	83.4	3.57	30.6
	35	26-01	32.6	25.9	88.1	2.95	68.9

Month	Std. Week	Date	Temperature (°C)		Mean RH (%)	Bright sunshine (hrs/day)	Rainfall (mm)
			Max.	Min.			
Sept 2012							
	36	02-08	31.9	25.4	91.2	2.25	160.2
	37	09-15	29.8	25.1	92.1	1.92	54.3
	38	16-22	32.3	24.6	82.8	5.3	0.0
	39	23-29	32.3	24.0	79.1	6.54	29.8
Oct 2012							
	40	30-06	36.3	24.7	72.6	8.46	0.0
	41	07-13	35.8	21.5	68.2	8.45	0.0
	42	14-20	36.1	19.6	65.1	9.58	0.0
	43	21-27	35.6	19.1	61.1	9.74	0.0
	44	28-03	33.5	16.2	52.1	8.8	0.0
Nov 2012							
	45	04-10	32.6	13.9	57.9	9.64	0.0
	46	11-17	33.2	15.5	61.7	9.52	0.0
	47	18-24	31.4	12.4	59.5	9.5	0.0
	48	25-01	31.1	13.3	65.5	9.59	0.0
Dec 2012							
	49	02-08	30.5	16.0	63.3	8.83	0.0
	50	09-15	31.0	13.8	69.1	8.87	0.0
	51	16-22	29.7	14.2	67.3	8.59	0.0
	52	23-29	28.6	10.3	62.0	9.31	0.0

APPENDIX -II

APPENDIX-II: Cost of cultivation of custard apple and other economical details

Sr. No.	Particulars	Cost (₹ ha ⁻¹)
I Common cost		

A.	Land Preparation	
1.	Tractor cultivation (4 hrs @ ` 200.00 hr ⁻¹)	800
2.	Digging in ring (14 L)	1,680
B.	Manures and Fertilizers	
1.	Urea @ 435 g/tree	1,044
2.	Single Super Phosphate @ 625 g/tree	995
3.	Murate of Potash @ 83 g/tree	153
4.	Farm Yard Manure @ 10 kg/tree	3,120
5.	Fertilizer and plant growth regulators application (15 L)	1,800
C.	Irrigation	
1.	Total 7 irrigations @ 4 hrs/irrigation ha ⁻¹ (cost @ ` 450.0 ha ⁻¹ + 8 L)	4,110
D.	Cares after	
1.	Hand weeding 2 times (12+12 = 24 L)	5,760
E.	Picking (138 L)	16,560
F.	Land revenue for 8 months @ ` 700 ha ⁻¹	470
	Total of A to F Cost	36,492.00

Note L = Labour @ ` 120 day⁻¹

Fertilizer and organic manures price:-

Urea	@ ` 6 kg ⁻¹
Single Super phosphate	@ ` 3.98.kg ⁻¹
Murate of Potash	@ ` 4.62 kg ⁻¹
Farm yard manure	@ ` 0.78 kg ⁻¹

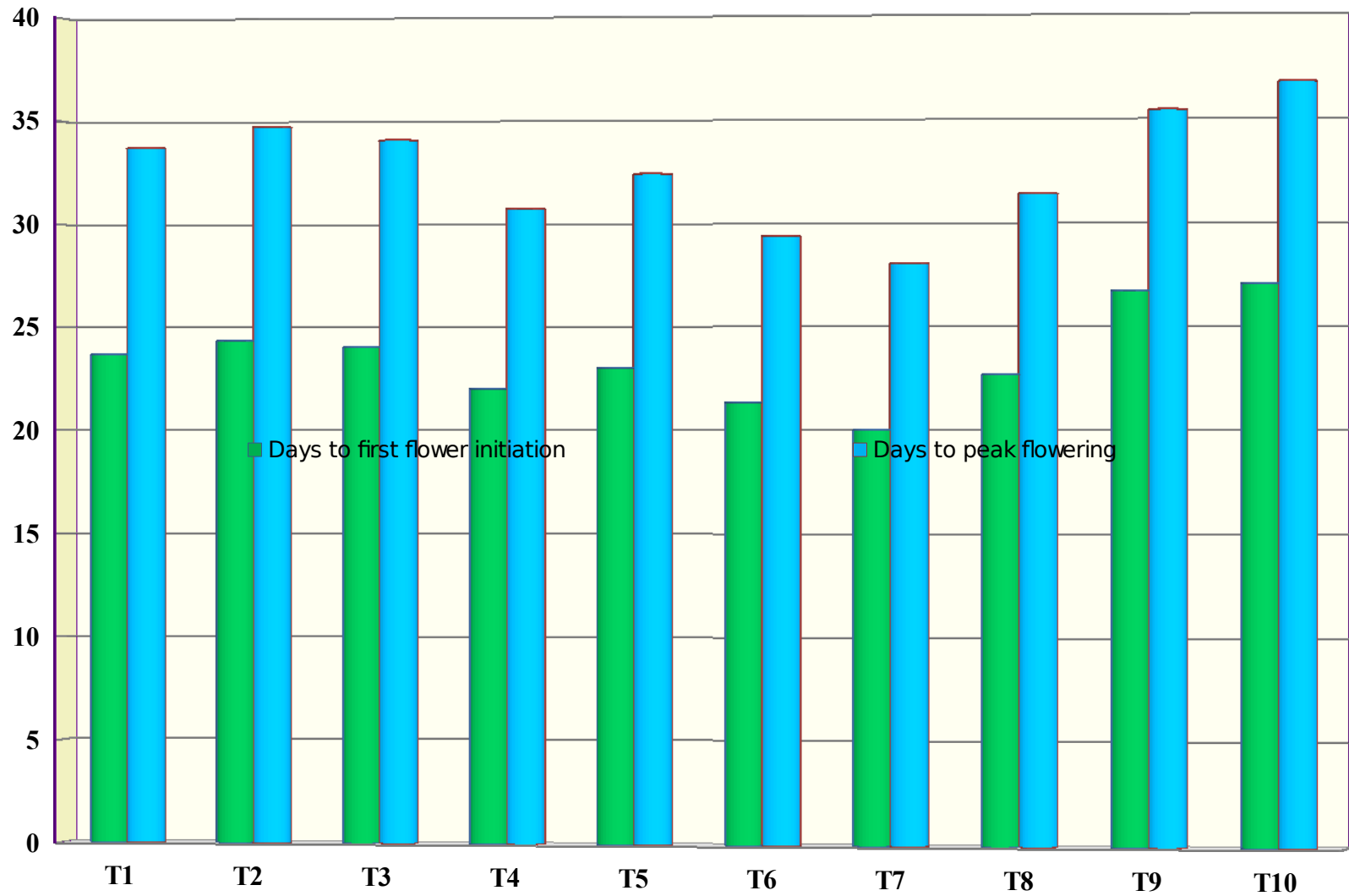


Fig 4.1: Effect of plant growth regulators on days to first flower initiation and days to peak flowering of custard apple cv. 'Local'

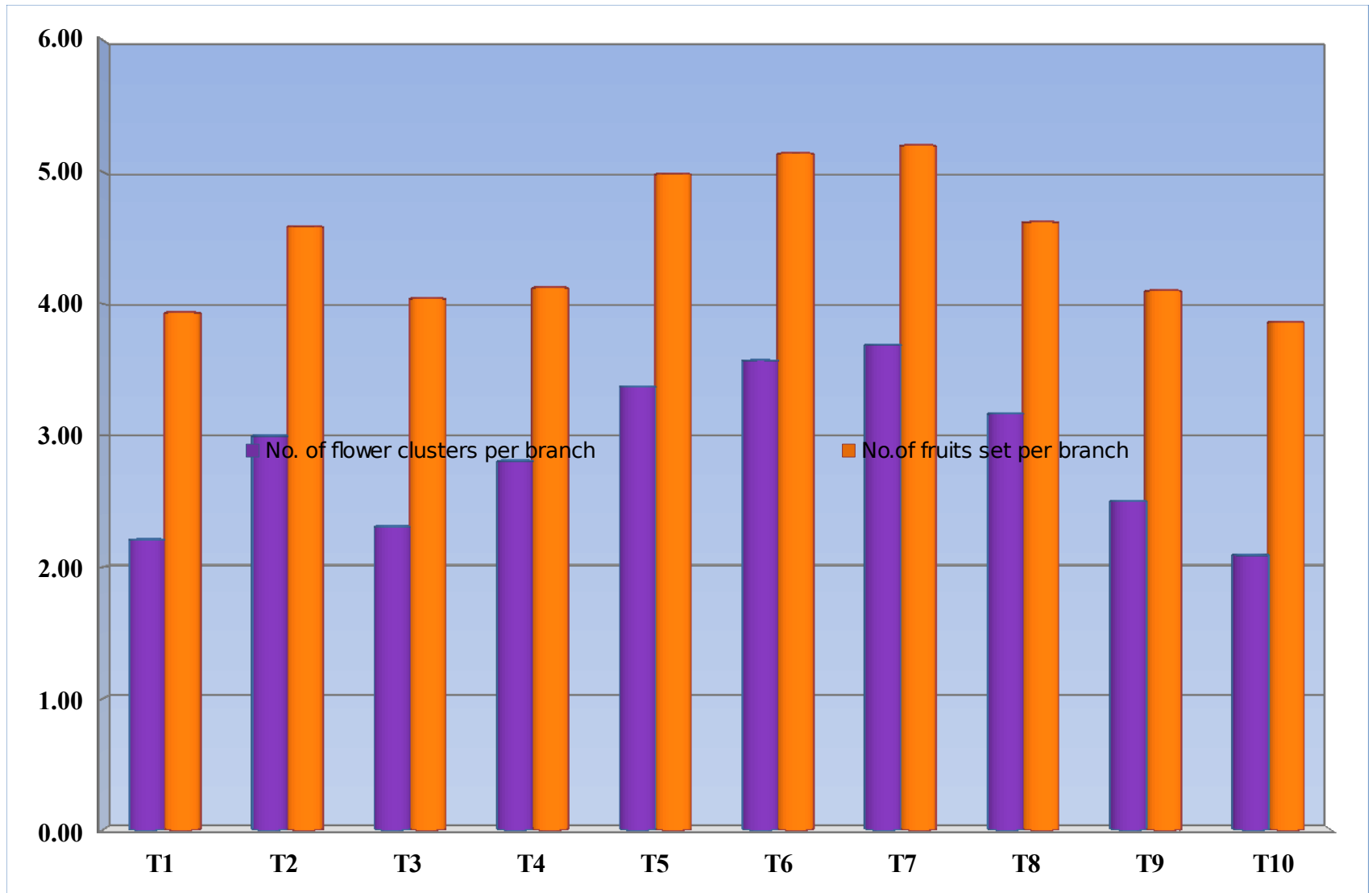


Fig 4.2: Effect of plant growth regulators on number of flower clusters per branch and number of fruits set per branch of custard apple cv. 'Local'

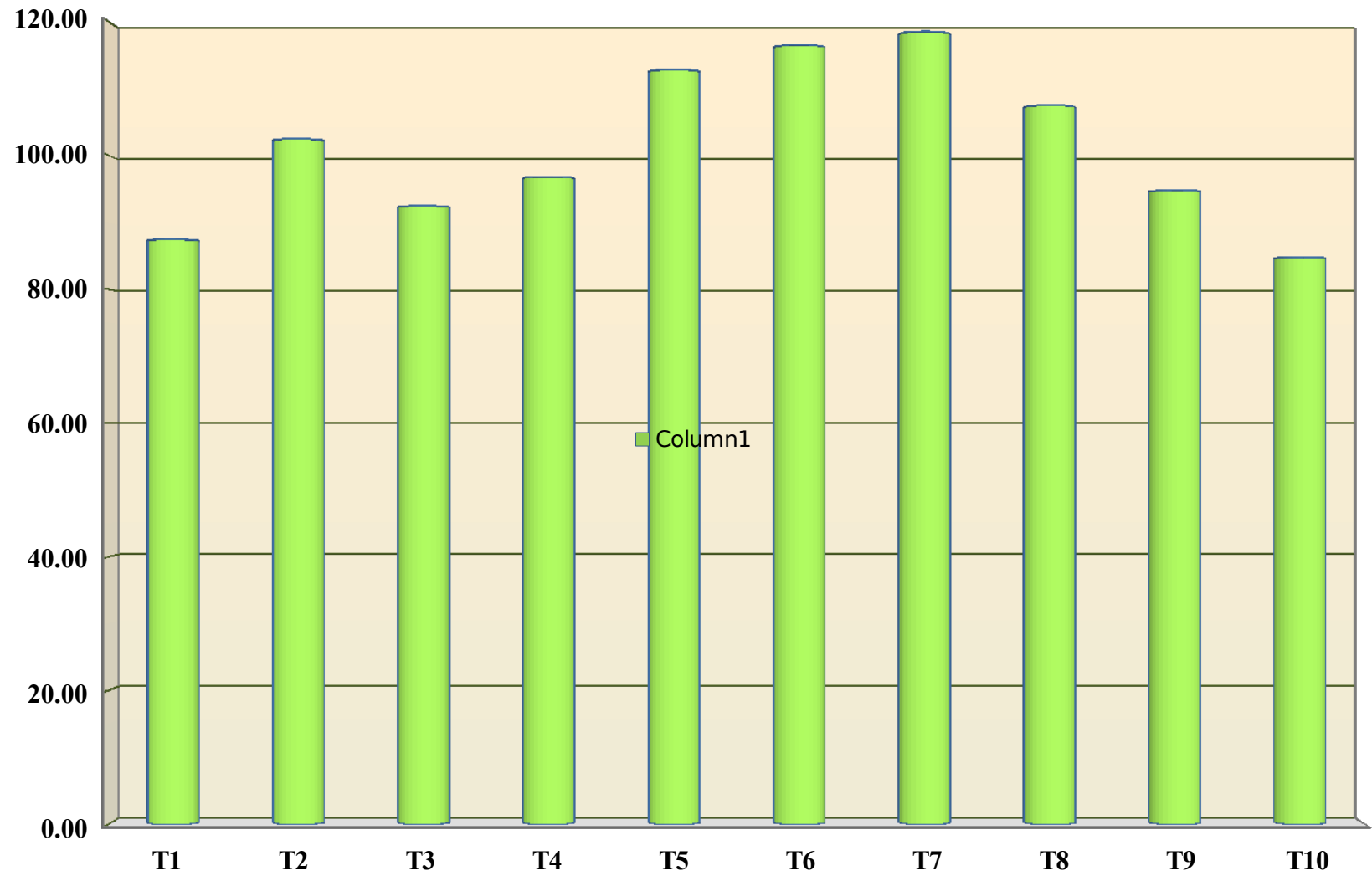


Fig 4.3: Effect of plant growth regulators on number of fruits per tree of custard apple cv. 'Local'

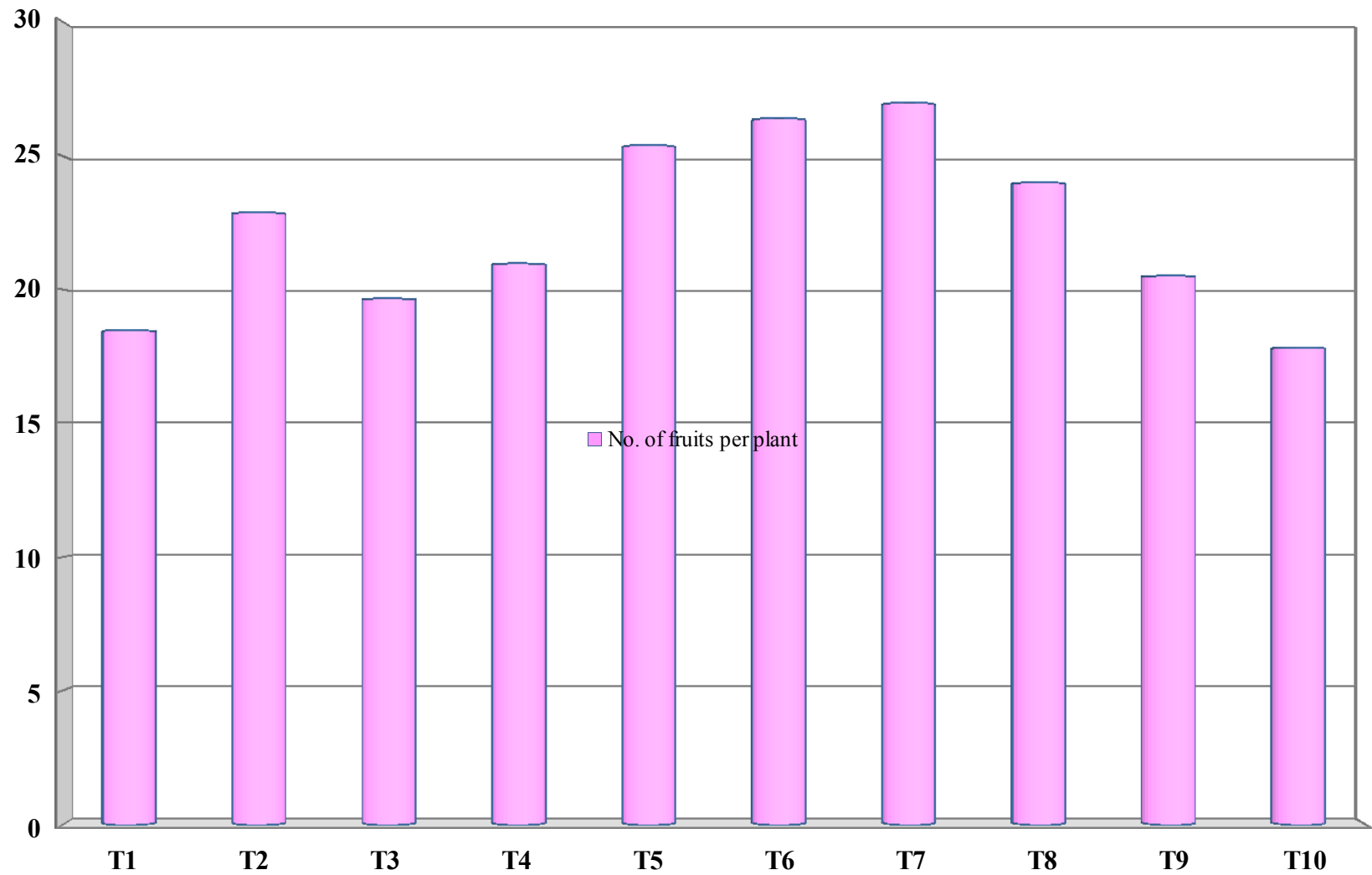


Fig 4.4: Effect of plant growth regulators on fruit yield per tree (kg) of custard apple cv. 'Local'

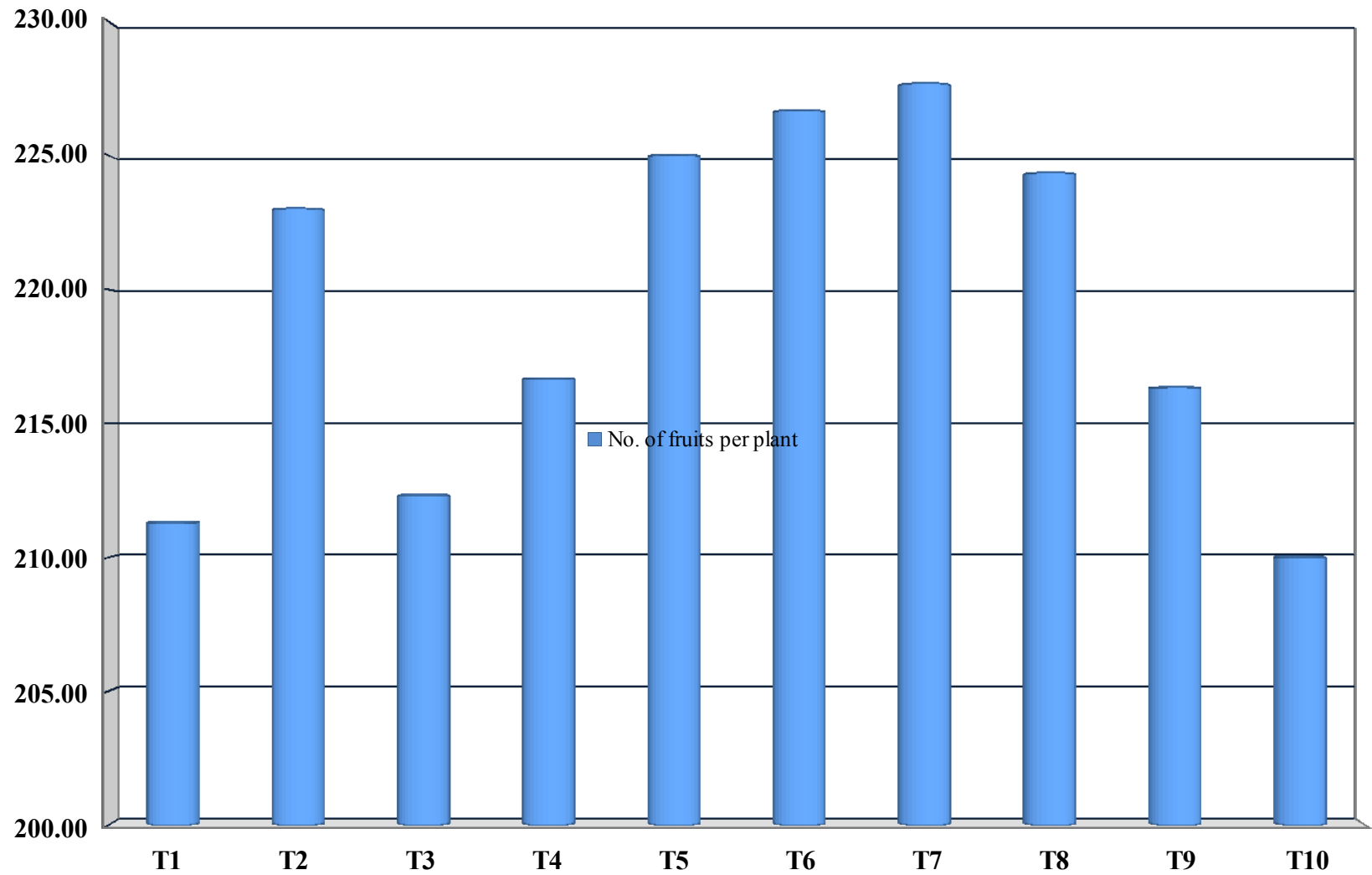


Fig 4.5: Effect of plant growth regulators on average fruit weight (g) of custard apple cv. 'Local'

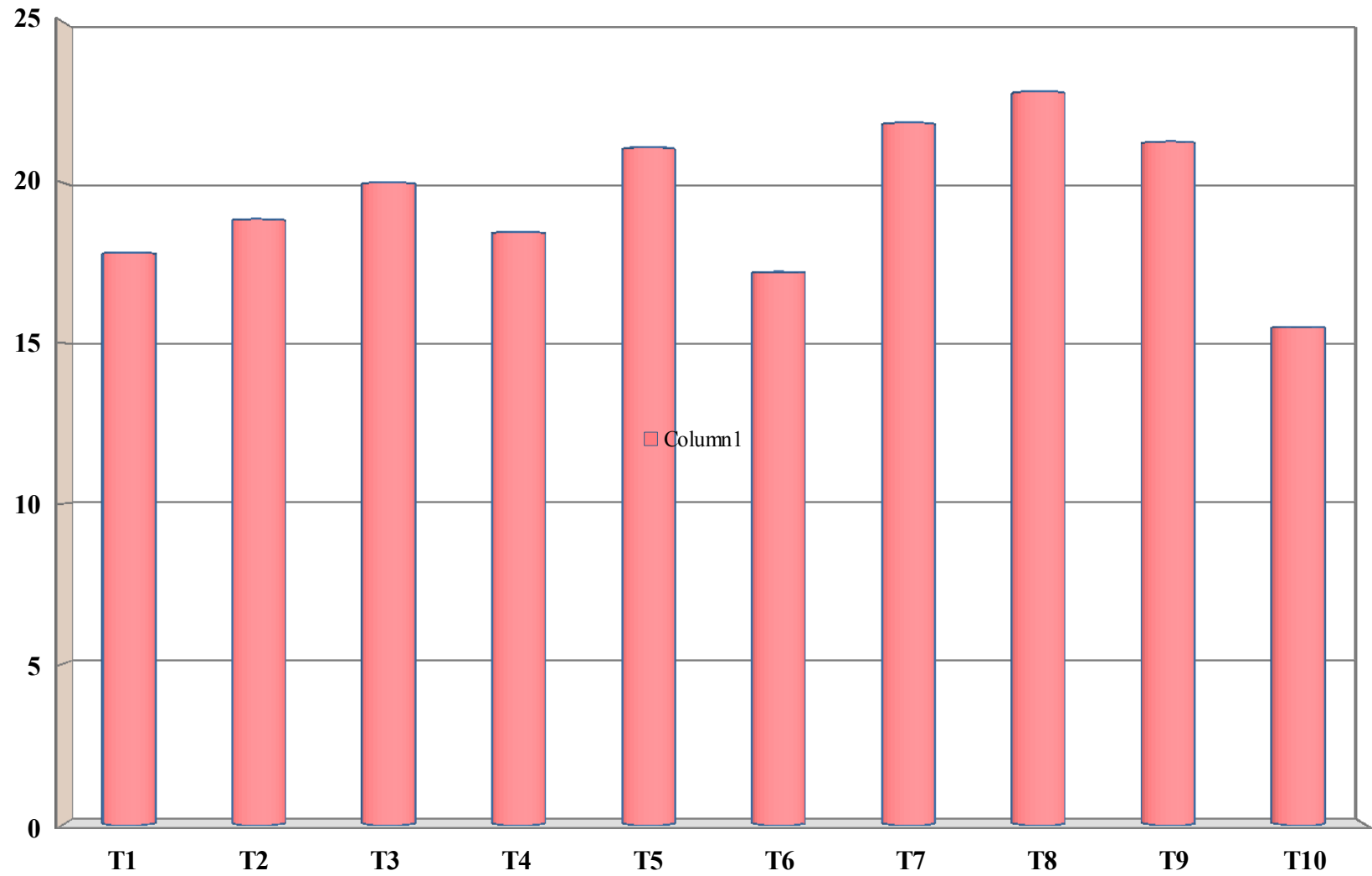


Fig 4.6: Effect of plant growth regulators on ascorbic acid (mg/100 g pulp) of custard apple cv. 'Local'

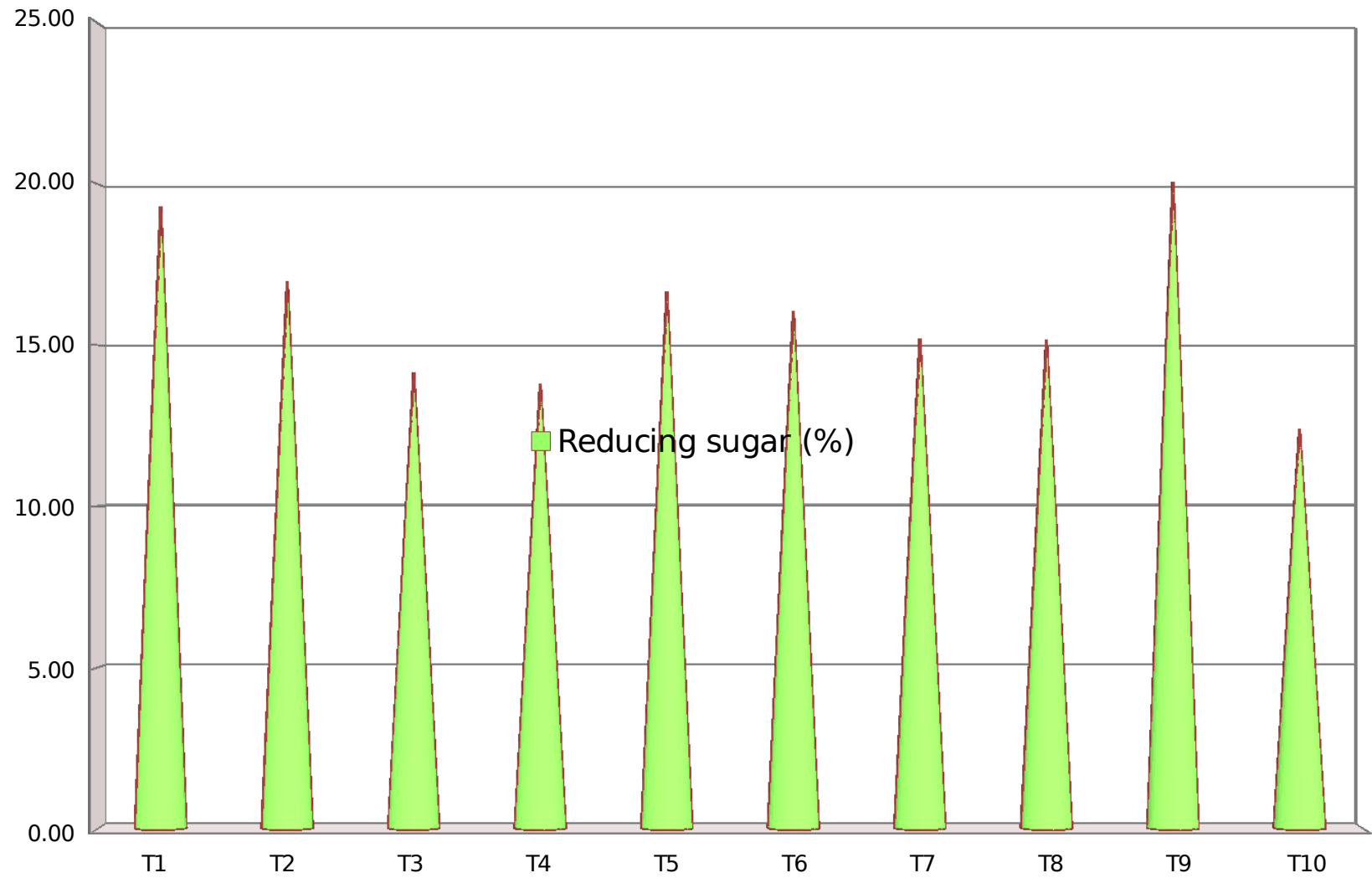


Fig 4.7: Effect of plant growth regulators on reducing sugar (%) of custard apple cv. 'Local'

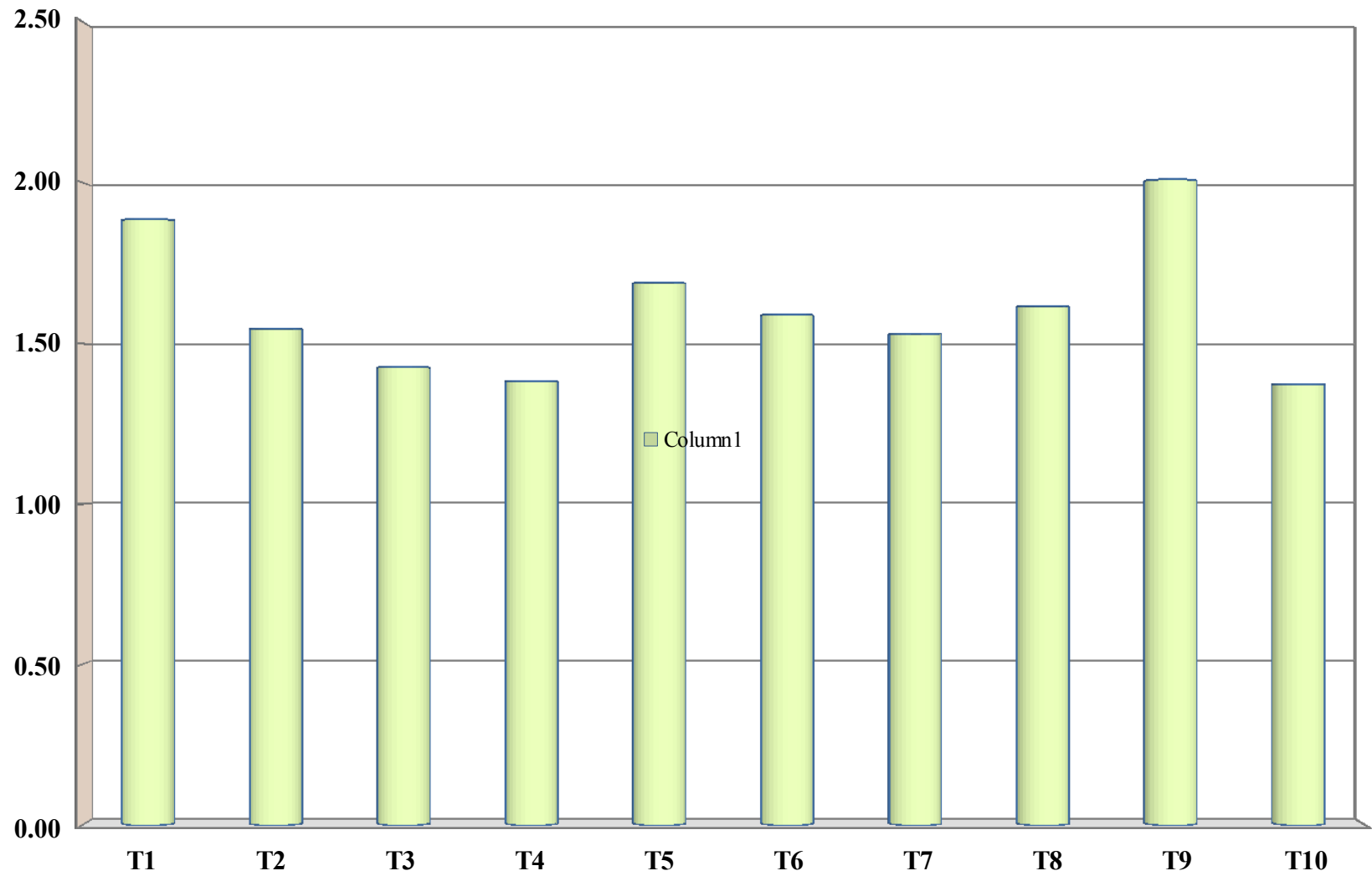


Fig 4.8: Effect of plant growth regulators on non reducing sugar (%) of custard apple cv. 'Local'

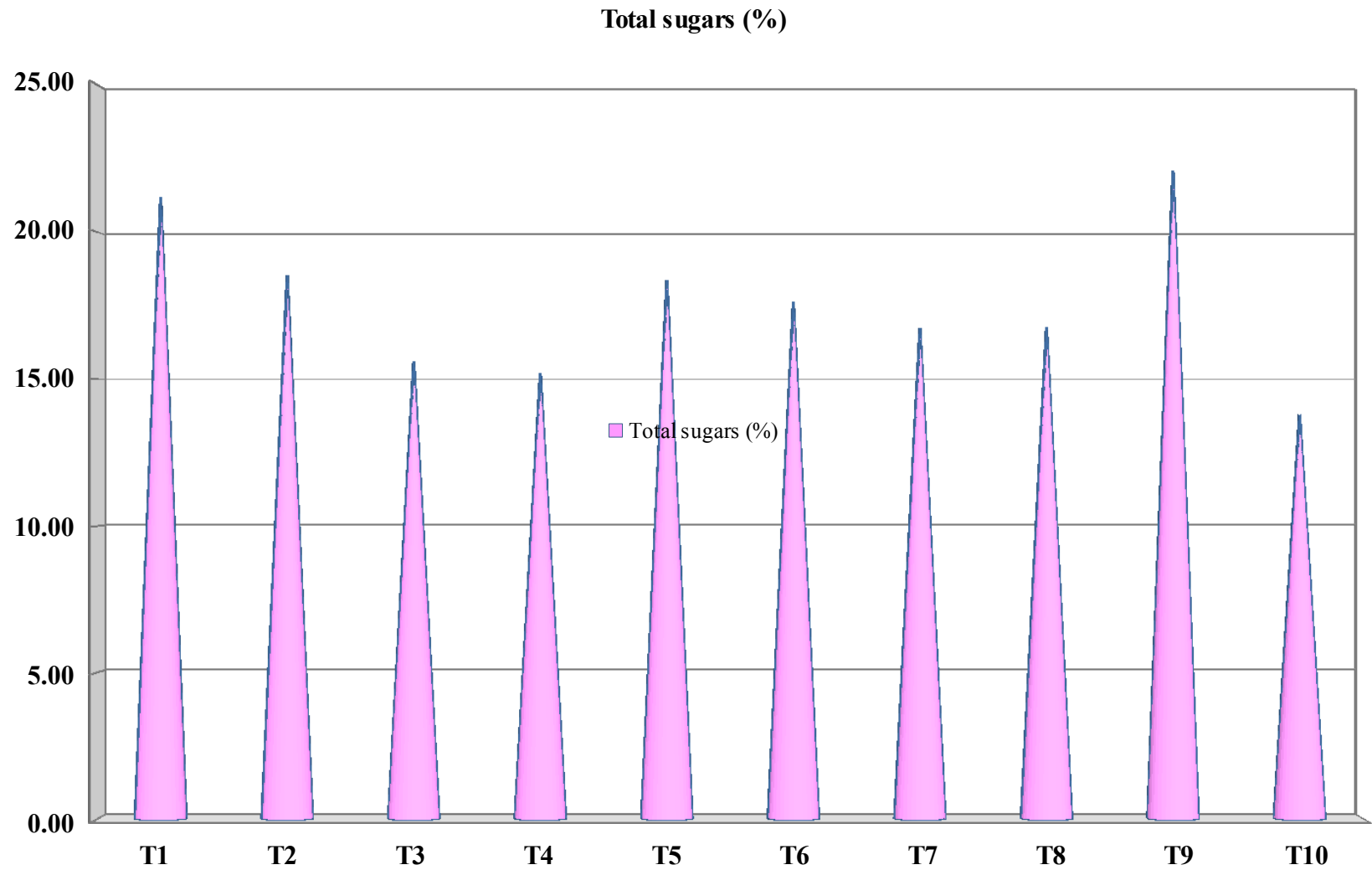


Fig 4.9: Effect of plant growth regulators on total sugars (%) of custard apple cv. 'Local'

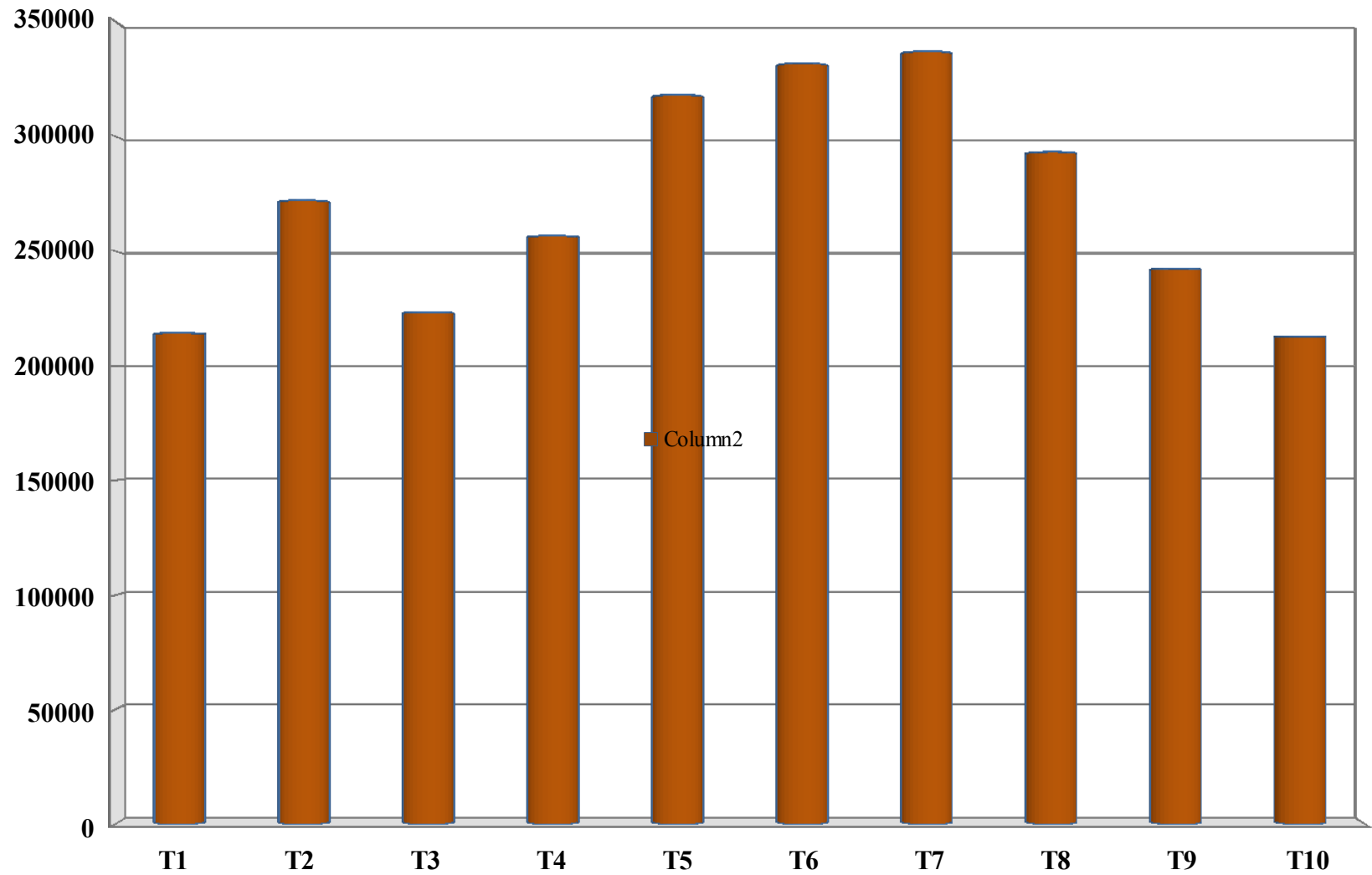


Fig 4.10: Economics of custard apple cv. 'Local' as influenced by various treatments



Plate 1: General view of an experimental field of custard apple cv. 'Local'



T₇ : GA₃ 20 + NAA 15 mg/l



T₁₀ : Control (water spray)

Plate 4 : Effect of T₇ (GA₃ 20 + NAA 15 mg/l) v/s T₁₀ Control (water spray) on average fruit weight (g) of custard apple cv. 'Local'