"EFFECT OF FERTILIZER LEVELS AND GROWTH REGULATORS ON YIELD AND QUALITY OF SAPOTA (*Manilkara achras* (MILL.) FORSBERG) CV. KALIPATTI"

By

Mr. SIDDANTH JAIN K.

B. Sc. (Hort.)

DEPARTMENT OF HORTICULTURE,
FACULTY OF AGRICULTURE,
Dr. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH,
DAPOLI- 415 712, DIST. RATNAGIRI (M.S.) – 415 712

May, 2019

"EFFECT OF FERTILIZER LEVELS AND GROWTH REGULATORS ON YIELD AND QUALITY OF SAPOTA (*Manilkara achras* (MILL.) FORSBERG) CV. KALIPATTI"

A thesis submitted to the

Dr. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH,
DAPOLI, (Agricultural University)
DIST. RATNAGIRI (M.S.), INDIA

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (HORTICULTURE)

in

FRUIT SCIENCE

by

Mr. SIDDANTH JAIN K.
B. Sc. (Hort.)

DEPARTMENT OF HORTICULTURE,
FACULTY OF AGRICULTURE,
Dr. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH,
DAPOLI - 415 712, DIST. RATNAGIRI (M.S.) – 415 712

May, 2019

"EFFECT OF FERTILIZER LEVELS AND GROWTH REGULATORS ON YIELD AND QUALITY OF SAPOTA (*Manilkara achras* (MILL.) FORSBERG) CV. KALIPATTI"

A thesis submitted to the

Dr. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI
(Agricultural University)
Dist. Ratnagiri (Maharashtra State)

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

(HORTICULTURE)

in

FRUIT SCIENCE

by

Mr. SIDDANTH JAIN K.
B. Sc. (Hort.)
Reg. No. : HDPM/17/0129

APPROVED BY THE ADVISORY COMMITTEE

Chairman and Research Guide:

(K. V. Malshe)
Junior Horticulturist
Mango Research Sub-Center, Rameshwar,
Tal. Deogad Dist. Sindhudurg.

Members:

(R. G. Khandekar)
Professor
Department of Horticulture,
College of Agriculture, Dapoli.

(P. S. Sawant)
Associate Professor (CAS)
Department of Soil Science
and Agricultural Chemistry,
College of Agriculture, Dapoli.

(C. D. Pawar)
Professor
Department of Horticulture,
College of Agriculture, Dapoli.

May, 2019

Shri. K. V. Malshe
M. Sc. (Hort.)
Junior Horticulturist
Mango Research Sub-Center,
Rameshwar,
Tal. Deogad Dist. Sindhudurg.

CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF FERTILIZER LEVELS AND GROWTH REGULATORS ON YIELD AND QUALITY OF SAPOTA (*Manilkara achras* (MILL.) FORSBERG) CV. KALIPATTI"** submitted to Faculty of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, (Maharashtra state), in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **FRUIT SCIENCE,** embodies the results of a piece of bona-fide research carried out by **Mr. SIDDANTH JAIN K.** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

Place**:** Dapoli

Date : / May / 2019

(K. V. Malshe)
Chairman,
Advisory Committee
And
Research guide

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACKNOWLEDGEMENT

Yes!!! Now at the completion of my research work and manuscript, it's time to recall path and process of work and I feel it is an opportunity to convey my heartfelt sense of thankfulness and deep sense of gratitude towards all individuals who helped me directly and indirectly for completion of my degree program.

It is moment of great pleasure in recording my fervent sense of heartfelt gratitude and sincere feelings of indebtedness towards my honorable Research Guide and Chairman of my Advisory Committee, ***Prof. K.V. Malshe,*** *Jr. Horticulturist, Mango Research Sub-Centre, Rameshwar, for his valuable guidance at every step, constant encouragement, profound interest in research, constructive suggestions unfailing co-operation, hard work and helping mind throughout the course of my post-graduation gave me this unique experience of planning, conducting and presenting this research work.*

I am overwhelmed with sincere feelings of indebtedness to the Members of my Advisory Committee, ***Dr. R.G. Khandekar,*** *Professor, Department of Horticulture,* ***Dr. C.D. Pawar,*** *Associate Professor, Department of Horticulture, and* ***Dr. (Mrs.) Pooja S. Sawant,*** *Associate Professor (CAS), Dept. of Soil Science and Agricultural Chemistry, College of Agriculture, Dapoli for their valuable guidance, constant encouragement and moral support during the course of my post-graduation studies.*

It is my proud privilege to express my deep sense of appreciation and sincere thanks to ***Dr. B.R. Salvi,*** *Head, Department of Horticulture; I also convey my thanks to* ***Dr. P.B. Sanap, Prof. Y.R. Parulekar, Prof. M.M. Kulkarni, Prof. D.T. Kolekar and Prof S.B. Thorat.***

I convey my thanks to ***Mr. M.B. Sawant,*** *lab assistant,* ***Mr. Sanjay Warse,*** *field assistant, Priyanka Prashanth, Omkar, Ajith, and all non-teaching staff and labors of my department who helped me throught the period of my stay at Dapoli.*

I place on record my cordial thanks to, ***Dr. Sanjay Sawant*** *Honorable Vice -Chancellor Sir,* ***Dr. S. S. Narkhede,*** *Dean and Director of Instruction, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, and* ***Dr. U. V. Mahadkar,*** *Associate Dean, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, for the permission and all the necessary facilities in time, throughout the period of my post-graduation studies.*

I bow my back and place my head to the feet of my visible god, ***my parents Chandrashekar Shetty K, and Padmashree K,*** *without them I'm nothing but zero and with their blessings, my journey of life reached to this stage and I also show my affection for my sister* ***Seemitha K, Jain,*** *who loves and cares about me.*

I am sincerely thankful to my seniors ***Pathan sir, Hemanth sir, Praveen sir, Subbu sir, Prashanth sir, Bommesh sir, Devu sir, and Manju sir*** *for their unconditional care and affection towards me. Without them it would have been difficult to leap over those hurdles. I am also thankful my seniors* ***Kekan Sir, Omkar sir, Shivaji Mane sir, Sameer Sir, and Akshay Sir*** *who stood with me throughout my PG life.*

It is a friend who shares your secrets and who provides crutches to the crumbling house of confidence. The words at command are inadequate to convey the depth of my heartfelt thanks to my friends, ***Jayanth, Naveen, Ambrish, Mallikarjun, Harshitha, Akshay N.R , Sagarika, Praveen (Gende) and Yoganand H.S.***

On a long journey such as this, one encounters a number of fellow travelers moving towards the same destination. This companies and enthusiasm and zest to the journey making it enjoyable. I was fortunate to travel the path of knowledge with my dear ones, ***Avdhuth, Omkar, Akshay Kulthe, Vinod, Rahul, Suraj, Sourabh, Jagan, Sneha More, Madhavi, Jayashree,*** *and all Sr. M.Sc., Jr. M.Sc. friends for their enthusiastic company and co-operation who helped me directly or indirectly and their excellent company and warm affection throughout my stay in this University. I felt elated to express my bountiful thanks to those who directly or indirectly helped me in successful completion of thesis work.*

Any omission in this brief acknowledgement does not mean lack of gratitude.

Place : Dapoli

Date : May, 2019 ***(Siddanth Jain K,)***

Dr. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI
DEPARTMENT OF HORTICULTURE COLLEGE OF AGRICULTURE, DAPOLI

Title of thesis	:	**"Effect of fertilizer levels and growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kalipatti"**
Name of the student	:	Mr. Siddanth Jain K.
Registration number	:	HDPM/17/0129
Name and designation of research guide	:	Mr. K. V. Malshe Junior Horticulturist Mango Research Sub-Center, Rameshwar. Tal. Deogad Dist. Sindhudurg
Year of submission	:	May, 2019

ABSTRACT

The present investigation entitled **"Effect of fertilizer levels and growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kalipatti"** was conducted at Department of Horticulture, College of Agriculture, Dapoli (M.S.) during 2017-19.

During investigation it was observed that all the treatments with different fertilizer doses exhibited non-significant effect on growth characteristics like tree height, spread and canopy volume. However, length of new shoot, number of leaves per shoot, flowering characters, fruiting parameters, yield and yield attributing characters, physical, chemical and storage parameters of fruits differed significantly.

The application of treatment 6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January (T_4) resulted in significantly maximum shoot length and number of leaves per shoot at 60 and 120 days after treatment (18.23 cm, 26.48 cm and 15.88, 21.12, respectively), number of

flowers per shoot (12.52), number of fruit set (3.52), fruit set per cent (29.69%), number of fruits retained at harvest (1.76), fruit retention percentage (47.28%) and shortest period for fruit development (214.96 days).

The significantly highest fruit yield was recorded (number of fruits per tree (429.46), fruit yield per tree (63.85 Kg) and yield per hectare (4.09 ton) in treatment T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January). The physico-chemical parameters were also superior in the same treatment with the maximum fruit length (6.20 cm), fruit diameter (6.08 cm), fruit weight (138.14 g), volume of fruit (132.34 cm^3), specific gravity of fruit (1.04), pulp weight (130.08 g), number of seeds per fruit (1.86), seed weight per fruit (1.51 g) and pulp/seed ratio (85.95), maximum TSS (24.98 ^{0}B), TSS/acidity ratio (187.01), reducing sugars (11.06%), non-reducing sugars (5.56%), total sugars (16.62%) and minimum fruit acidity (0.13%).Same treatment resulted in lowest PLW % on 2nd, 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 3.18%, 6%, 9.94%, 11.31% and 27.14% respectively),shrivelling and/or spoilage % on 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 0%, 8.80%, 12.00% and 29.60% respectively) and longest shelf life (8.2 days). The highest Benefit : Cost ratio (1.23) recorded in same treatment.

In the experiment on effect of growth regulators on yield and quality of sapota, the treatment application of NAA 200 ppm (T_7) significantly increased number of flowers per shoot (16.13), number of fruit set (2.37), fruit set per cent (14.68%), number of retained fruits (1.57), fruit retention per cent (66.28%) to the maximum extent.

The sapota trees sprayed with GA_3 150 ppm (T_4) significantly enhanced number of fruits per tree (301.00), fruit yield per tree (44.48 Kg) and yield per hectare (2.85 ton), maximum fruit length (6.16 cm), fruit diameter (5.81 cm), fruit weight (146.17 g), volume of fruit (138.77 cm^3), specific gravity of fruit (1.05), pulp

weight (138.00 g), pulp/seed ratio (99.28), maximum TSS (25.10 ^{0}B), TSS/acidity ratio (192.60), reducing sugars (11.58%), non-reducing sugars (5.65%), total sugars (17.23%) and shelf life (8.67 days) and same treatment also decreased period for fruit development (216.01 days), fruit acidity (0.13%), PLW % on 2nd, 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 3.11%, 6.29%, 9.98%, 11.55% and 28.45% respectively), shrivelling and/or spoilage % on 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 0%, 5.33%, 9.33% and 18.67% respectively). The highest Benefit : Cost ratio (1.69) recorded in treatment application of NAA 200 ppm (T_7).

From the results of the present study, it is evident that the fertilizer dose of 6.0 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January found superior for yield and quality improvement. The application of GA_3 150 ppm as well enhanced the yield and quality of sapota (cv. Kalipatti) fruits.

APPENDIX I

Abbreviations used

%	:	per cent
&	:	and
/	:	per
@	:	At the rate
°B	:	degree Brix
°C	:	degree Celsius
Anon.	:	Anonymous
BSS	:	Bright sunshine
C.D.	:	critical difference
cm	:	Centimeter (s)
Cv.	:	cultivar
DAT	:	Days after treatment
Dr.	:	doctor
et al.	:	and others
Epan		Pan evoporimeter
Fig	:	figure
g	:	gram
GA_3	:	Giberellic acid
ha	:	hectare
hrs		hours
i.e.	:	Id est (In other words)
kg	:	Kilogram (s)
Kmph	:	Kilometer per hour
L.	:	Linnaeus
m	:	Meter (s)
M.S.	:	Maharashtra
Max.	:	Maximum
mg	:	Milligram (s)
Min.	:	Minimum
ml	:	Milliliter (s)

mm	:	Millimeter (s)
MSL	:	Mean sea level
NAA	:	1-Naphthalene acetic acid
no.	:	Number
NS	:	Non-significant
ppm	:	Parts per million
R.H.	:	Relative humidity
RD	:	Rainy days
S.E.	:	Standard error
t	:	tones
TSS	:	Total soluble solids
var.	:	variety
viz.	:	Namely

APENDIX II

Weekly weather data

Period (01.01.2018-08.07.20118)	MW	Mean weekly temp. (°C)		Mean weekly RH (%)		Total weekly rain fall	Total weekly rainy days	Mean weekly B.S.S
		Max.	Min.	Morn.	Even.	mm	day	Hrs.
01.01.18 - 07.01.18	01	30.4	12.4	96.4	73.6	0.0	0.0	7.7
08.01.18 -14.01.18	02	31.5	15.2	96.6	69.4	0.0	0.0	7.8
15.01.18 - 21.01.18	03	33.8	14.8	96.3	64.7	0.0	0.0	8.0
22.01.18 - 28.01.18	04	30.4	12.5	95.3	78.9	0.0	0.0	8.7
29.01.18 - 04.02.18	05	33.1	12.2	96.0	64.3	0.0	0.0	9.2
05.02.18 - 11.02.18	06	32.1	14.4	95.1	65.9	0.0	0.0	5.5
12.02.18 - 18.02.18	07	32.2	14.3	92.0	65.0	0.0	0.0	7.5
19.02.18 - 25.02.18	08	33.9	15.4	96.6	68.6	0.0	0.0	6.4
26.02.18 - 04.03.18	09	36.1	15.3	94.7	61.7	0.0	0.0	8.0
05.03.18 - 11.03.18	10	33.6	17.1	94.3	63.6	0.0	0.0	8.3
12.03.18 - 18.03.18	11	34.6	18.9	92.6	58.0	0.0	0.0	6.4
19.03.18 - 25.03.18	12	31.7	15.4	91.1	69.4	0.0	0.0	10.3
26.03.18 - 01.04.18	13	33.6	19.9	96.4	88.3	0.0	0.0	8.1
02.04.18 - 08.04.18	14	32.5	19.8	92.1	88.1	0.0	0.0	7.6
09.04.18 - 15.01.18	15	34.7	20.0	91.0	68.7	0.0	0.0	8.8
16.04.18 - 22.04.18	16	33.8	21.3	90.3	69.1	0.0	0.0	9.0
23.04.18 - 29.04.18	17	34.1	19.5	90.3	67.4	0.0	0.0	10.6
30.04.18 - 06.05.18	18	33.0	21.1	91.4	69.6	0.0	0.0	10.6
07.05.18- 13.05.18	19	33.8	23.6	89.1	71.0	0.0	0.0	9.4
14.05.18 - 20.05.18	20	34.2	23.4	90.6	72.6	6.0	1.0	8.2
21.05.18 - 27.05.18	21	33.7	24.5	90.0	71.1	0.0	0.0	7.4
28.05.18 - 03.06.18	22	33.9	25.4	89.1	75.6	10.2	1.0	6.8
04.06.18 - 10.06.18	23	32.2	23.6	95.4	88.7	135.2	5.0	4.2
11.06.18 - 17.06.18	24	31.2	24.5	96.6	90.4	96.6	4.0	2.6
18.06.18 - 24.06.18	25	28.4	22.4	96.3	96.4	642.8	6.0	0.7
25.06.18 - 01.07.18	26	28.4	23.1	96.3	95.4	205.9	7.0	0.1
02.07.18 - 08.07.18	27	28.1	22.9	97.7	95.7	545.4	7.0	1.3

Period (09.07.2018-03.02.2019)	MW	Mean weekly temp. (ºC)		Mean weekly RH (%)		Total weekly rain fall	Total weekly rainy days	Mean weekly B.S.S
		Max.	Min.	Morn.	Even.	mm	day	Hrs.
09.07.18 - 15.07.18	28	27.7	23.6	98.7	95.1	316.9	7.0	0.0
16.07.18 - 22.07.18	29	27.7	23.7	97.6	95.0	203.4	7.0	0.4
23.07.18 - 29.07.18	30	28.0	24.2	94.1	93.7	33.2	6.0	0.2
30.07.18 - 05.08.18	31	28.3	24.1	93.4	90.4	100.6	6.0	0.6
06.08.18 - 12.08.18	32	28.1	23.9	96.3	90.1	92.0	7.0	0.9
13.08.18 - 19.08.18	33	26.7	23.1	97.4	94.1	194.4	7.0	0.0
20.08.18 - 26.08.18	34	27.1	22.8	95.9	92.4	205.6	7.0	1.0
27.08.18 - 02.09.18	35	28.0	22.6	92.3	91.6	129.8	7.0	1.5
03.09.18 - 09.09.18	36	28.3	22.0	91.4	85.4	52.2	6.0	3.8
10.09.18 - 16.09.18	37	29.5	20.8	86.7	80.9	0.0	0.0	8.0
17.09.18 - 23.09.18	38	29.8	22.1	88.7	78.9	49.2	2.0	3.6
24.09.18 - 30.09.18	39	31.1	22.5	93.0	76.9	15.4	2.0	5.2
01.10.18 - 07.10.18	40	34.1	21.7	90.9	64.3	28.2	3.0	5.1
08.10.18 - 14.10.18	41	33.2	22.5	90.1	72.6	0.0	0.0	5.8
15.10.18 - 21.10.18	42	33.4	21.0	90.4	68.9	8.8	1.0	6.3
22.10.18 - 28.10.18	43	33.9	19.5	89.1	60.4	0.0	0.0	7.9
29.10.18 - 04.11.18	44	33.6	17.0	85.6	60.4	0.0	0.0	8.9
05.11.18 - 11.11.18	45	34.6	19.6	85.0	67.9	0.0	0.0	8.7
12.11.18 - 18.11.18	46	34.6	15.2	90.4	64.9	0.0	0.0	8.9
19.11.18 - 25.11.18	47	33.5	18.4	88.3	65.3	0.0	0.0	7.2
26.11.18 - 02.12.18	48	33.2	14.0	89.9	66.1	0.0	0.0	8.4
03.12.18 - 09.12.18	49	33.1	15.7	91.0	65.9	0.0	0.0	6.1
10.12.18 - 16.12.18	50	31.4	13.2	83.6	62.6	0.0	0.0	6.7
17.12.18 - 23.12.18	51	30.9	12.0	87.7	65.3	0.0	0.0	7.0
24.12.18 - 30.12.18	52	32.1	12.3	88.0	66.1	0.0	0.0	8.5
31.12.18 - 06.01.19	01	32.2	9.9	89.6	61.6	0.0	0.0	8.8
07.01.19 - 13.01.19	02	32.1	10.5	87.0	59.9	0.0	0.0	8.6
14.01.19- 20.01.19	03	33.5	13.1	88.4	58.0	0.0	0.0	8.1
21.01.19 - 27.01.19	04	29.7	11.2	89.4	59.6	0.0	0.0	8.4
28.01.19 - 03.02.19	05	31.1	13.5	89.1	60.0	0.0	0.0	8.2

APPENDIX III

Economics of sapota

1. Effect of fertilizer levels on economics of sapota

Sr. No.	**Name of head**	**Name of sub-heads**	**T_1**	**T_2**	**T_3**	**T_4**
1	Input required	**Fertilizers and chemicals**				
		FYM = 2.5 Rs/Kg	16000	32000	48000	64000
		Urea= 5.36 Rs/kg	1115	2230	3362	4460
		SSP= 7.76 Rs/kg	4654	9312	13906	18624
		MOP= 19.60 Rs/kg	3136	6272	9408	12544
		Insecticides	505	505	505	505
2	Labours	weeding (tractor and manual)	2005	2005	2005	2005
		FYM application	1005	1005	1005	1005
		Spraying of insecticides	402	402	402	402
	Input Cost		**28822**	**53731**	**78593**	**103545**
3	Depreciation on implementation and machinery		1000	1000	1000	1000
4	Land revenue and other cesses		50	50	50	50
5	Interest on working capital (@ 6 % for 12 months)		1729.32	3223.86	4715.58	6212.7
6	Interest on fixed capital		1000	1000	1000	1000
7	Rental value of land (1/6 of the gross value)		11000.00	18233.33	26000.00	34083.33

8	Supervision charges (@ 10 % input cost)	2882.2	5373.1	7859.3	10354.5
9	Amortization value	9649	9649	9649	9649
	Total Cost	**56132.52**	**92260.29**	**128866.88**	**165894.53**
10	Yield and gross returns				
	Main product	1320	2188	3120	4098
	Gross returns	**66000**	**109400**	**156000**	**204500**
11	Net profit at:-				
	Input Cost	37178	55669	77407	100955
	Total Cost	**9867.48**	**17139.71**	**27133.12**	**38605.47**
12	Input output ratio	2.29	2.04	1.98	1.97
13	**Benefit cost ratio**	**1.18**	**1.19**	**1.21**	**1.23**
14	Cost per kg	42.52	42.17	41.30	40.48
15	selling price per kg	50	50	50	50

2. Effect of growth regulators on economics of sapota

Sr. No.	Name of head	Name of sub-heads	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1	Input required	Fertilizers :							
		FYM = 2.5 Rs/Kg	16000	16000	16000	16000	16000	16000	16000
		Urea= 5.36 Rs/kg	2230	2230	2230	2230	2230	2230	2230
		SSP= 7.76 Rs/kg	9312	9312	9312	9312	9312	9312	9312
		MOP= 19.60 Rs/kg	6272	6272	6272	6272	6272	6272	6272
		Insecticides	505	505	505	505	505	505	505
		Growth regulator	0	3120	6240	9360	408	612	816
2	Labours	weeding (tractor and manual)	2005	2005	2005	2005	2005	2005	2005
		FYM application	1005	1005	1005	1005	1005	1005	1005
		Spraying of insecticides	402	402	402	402	402	402	402
	Input Cost		**37731**	**40851**	**43971**	**47091**	**38139**	**38343**	**38547**
3	Depreciation on implementation and machinery		1000	1000	1000	1000	1000	1000	1000
4	Land revenue and other cesses		50	50	50	50	50	50	50
5	Interest on working capital (@ 6 % for 12 months)		2263.86	2451.06	2638.26	2825.46	2288.34	2300.58	2312.82
6	Interest on fixed capital		1000	1000	1000	1000	1001	1002	1003
7	Rental value of land (1/6 of the gross value)		11833.33	16666.67	20083.33	23750.00	17791.67	18916.67	22083.33
8	Supervision charges (@ 10 % input cost)		3773.1	4085.1	4397.1	4709.1	3813.9	3834.3	3854.7
9	Amortization value		9649	9649	9649	9649	9650	9651	9652
	Total Cost		**67300.29**	**75752.83**	**82788.69**	**90074.56**	**73733.91**	**75097.55**	**78502.85**
10	Yield and gross returns								
	Main product		1420	2000	2410	2850	2135	2270	2650
	Gross returns		**71000**	**100000**	**120500**	**142500**	**106750**	**113500**	**132500**
11	Net profit at:-								
	Input Cost		33269	59149	76529	95409	68611	75157	93953
	Total Cost		**3699.71**	**24247.17**	**37711.31**	**52425.44**	**33016.09**	**38402.45**	**53997.15**
12	Input output ratio		1.88	2.45	2.74	3.03	2.80	2.96	3.44
13	**Benefit cost ratio**		**1.05**	**1.32**	**1.46**	**1.58**	**1.45**	**1.51**	**1.69**
14	Cost per kg		47.39	37.88	34.35	31.61	34.54	33.08	29.62
15	selling price per kg		50	50	50	50	50	50	50

CHAPTER-I
INTRODUCTION

Sapota [*Manilkara achras* (Mill.) Forsberg. Syn *Acharas sapota* L.] is a prominent tropical fruit, belongs to family Sapotaceae, popularly known as 'chiku' in India. The chromosome number of sapota is 2n=26. It comprises 40 genera and about 600 species, distributed in the tropics (Sutaria, 1966). It is native to tropical America, most probably to South Mexico or Central America. It is widely cultivated throughout tropics for its delicious fruits (Bose and Mitra, 1990). Sapota is an evergreen tree usually growing up to 10 m height. Being a hardy crop, it can be grown on wide range of soil and climatic conditions (Dutton, 1976). In India, sapota cultivation was taken up for the first time in Maharashtra in 1898 in a village named Gholwad (Cheema *et al.*, 1954). In India, sapota ranks fifth in both production and consumption next to mango, banana, citrus and grape. India is the largest producer of sapota followed by Mexico, Guatemala and Venezuela (Pawar *et al.,* 2010). In India it was cultivated under 99 thousand ha area with a production of 1236 thousand MT and the productivity 12.48 MT/ha (Anon. 2017). The major sapota growing states are Maharashtra, Gujarat, Tamil Nadu, Andra Pradesh, Karnataka, West Bengal, Uttar Pradesh, Punjab and Haryana. In Maharashtra, it was grown under 17.91 thousand hectare area with a production of 156.47 thousand MT and the productivity 8.7 t/ha. (Anon. 2017).

Sapota fruit is a fleshy berry, variable in shape, size and weight (75 to 150 g). The fruit when fully ripen is delicious and eaten as dessert fruit. The pulp is sweet and melting. The fruit skin can also be eaten since it is richer than the pulp in nutritive value. The sapota fruits are a good source of sugar which ranges between 12 to 14 per cent. Composition of fruits indicates moisture (73.7 g), carbohydrates (21.49 g), protein (0.7 g), fat (1.1 g), calcium (28.0 mg), phosphorus

(27.0 mg), Iron (2.0 mg) and ascorbic acid (6.0 mg) per 100 g of edible portion of fruits as reported by Bose and Mitra (1990). Sapota fruits are used for making jams, jellies, osmo-dehydrated slices and squash (Reddy, 1959). Products like sweet chutney, dried sapota pieces, sapota milk shake, nectar, blended sapota drinks, pickle, preserve and candy can also be prepared with good sensory quality (Sawant, 1989). Chickle, the gum latex obtained from bark of the tree, was for many years the principle ingredient of chewing gum. The unripe fruit and bark yield milky white latex which solidifies on exposure to air and this forms the base for making chickle. Chickle is commercially produced in South East Mexico, Guatemala and British Honduras (Ahmed *et al.,* 2011).

Sapota is one of the most important fruit in southern and western part of country due to its wide range of adaptability, low production cost and reasonable economic returns with very low pest and disease susceptibility. Sapota needs warm (10 to 38°C) and humid (70 % relative humidity) climate where it flowers and fruits throughout the year. However, if it is grown in subtropics or places of higher elevation like Punjab and Haryana, it gives only one crop in summer season even in moisture stress it produces one crop only. The costal climate with an annual rainfall of 125-250 cm, optimum temperature between 11-34°C is best suited. High temperature above 41°C during summer causes flower drop and fruit scorching (Bose and Mitra, 1990).

There are about three dozen varieties of sapota grown in different parts of the India. Some common cultivars grown are Kalipatti, Chatri, Dhola, Diwani, Jingar, Venjet, Pala, Kirti bharti, Dwarapudi, Jhonnavalasa round, Cricket ball, Oval, Culcutta round (Ganjyal *et al.,*2005) and out of these 'Kalipatti' is the leading variety of Maharashtra, Gujarat and North-Karnataka states (Chundawat and Bhuva, 1982) having dark green leaves, spreading habit and oval fruit of outstanding quality. The fruit is fleshy berry, variable in shape, size

and weight (75-150g) with 1 or 2 seeds per fruit. The skin is thin, rusty brown somewhat scurfy looking like Iris potato and the pulp soft, melting, crumbling with a sandy or granular texture. Immature fruits are astringent, while ripe fruits are sweet and tasty.

Nutrients and their managements is one of the most important aspects of fruit production and accounts for thirty per cent of the total cost of cultivation. However, in Indian fruit industry, poor nutrition is one of the major causes of low orchard efficiency resulting in poor productivity. The information on nutrient management in fruit crops has not been generated, but responses and requirement of nutrient of perennial fruit crops vary with soil and climatic conditions and also depend on growth, bearing habit, age, rootstock and management techniques. These are further influenced by quantity, source, rate, method and time of application of nutrients. However, indiscriminate use of chemical fertilizers are hazardous to environment coupled with adverse effects on quality of produce and soil health.

The application of organic and inorganic sources of nutrient may be helpful in increasing the vegetative as well as reproductive growth of sapota, which may ultimately result in better production of good quality fruits. Being an irrigated crop, the split application of fertilizers may be helpful for improving nutrient use efficiency and expected yield.

Sapota produces a large number of flowers throughout the year in different flushes. But flowers and fruits tends to drop in different stages of development right from its setting to maturity. However, incompatibility, low fertility and low fruit set drastically reduce the yield.

The exogenous application of Gibberellic acid (GA_3) increases cell size and intercellular spaces coupled with accumulation of water and nutrients in greater amount thus it would be increased the growth, yield, fruit quality and shelf life of sapota fruits (Agrawal and Dikshit, 2010). The application of GA_3 at flowering also results in

parthenocarpic fruit development which reduces the number of seed and weight. Thus, this hormone overcomes the problem of infertility also.

The foliar application of NAA (1-Napthalene Acetic Acid) at flowering stage increases cell elongation by enlargement of vacuoles and loosening of cell wall after increasing its plasticity. So it improves the physical and qualitative characters of sapota fruits (Agrawal and Dikshit, 2010). It also limits the fruit drop in many fruit crops (Delvadia *et al.*, 1994 in sapota, Brahmachari *et al.*, 1996 in guava, Nambisan *et al.*, 2007 in sapota and Bhowmick and Banik, 2011 in mango).

In recent years considerable attention has been given to increase fruit set, yield and qualitative characters of many fruit crops with the help of plant growth regulators. Different groups of plant growth regulators like auxins, gibberellins and growth retardants at different concentrations have been reported to influence flowering, fruit set, retention, development and quality characters of several fruit crops. (Ray *et al.*, 1991 in sapota, Tiwari *et al.*, 1992 in guava and Singh *et al.*, 2011 in phalsa).

Scanty research has been conducted on these aspects in Konkan Agro-climatic conditions of Maharastra. Keeping this fact in view the present experiment entitled **"Effect of fertilizer levels and growth regulators on yield and quality of sapota [*Manilkara achras* (Mill.) Forsberg] Cv. Kalipatti."** was conducted with following objectives:

1. To study the effect of graded doses of fertilizers on yield and yield attributes of sapota.
2. To study the effect of graded doses of fertilizers on physico – chemical properties of sapota.
3. To study the effect of NAA and GA_3 on yield and yield attributes of sapota.
4. To study the effect of NAA and GA_3 on physico – chemical properties of sapota.

5. CHAPTER-II

6. REVIEW OF LITERATURE

7. The present investigation entitled **"Effect of fertilizer levels and growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kalipatti"** was conducted at Department of Horticulture, College of Agriculture, Dapoli (M.S.) during 2017-19.

8. Sapota is an evergreen tree in continuous state of growth and production under warm and humid tropics. Therefore, health of sapota tree assumes special significance for the sustenance of vegetative growth and optimum production of high quality fruit. Like any other plants sapota also requires different nutrient elements for proper growth and yield and use of growth regulators also enhances the yield and quality of the fruits. Application of inorganic fertilizers along with farm yard manure has resulted in beneficial effects on growth, yield and quality of fruit crops. Spraying of different growth regulators enhances the yield and quality of fruits. The relevant information on effect of different levels inorganic fertilizers with FYM and different doses of growth regulators like NAA and GA_3 on growth, yield and quality of sapota as well as on other fruit crops has been reviewed and presented in this chapter under appropriate headings and subheadings.

9. 2.1 Effect of fertilizer levels on growth, yield and yield attributing characters

10. Bhuva *et al.* (1990) conducted trials in 1982-84 with sapodilla trees planted in 1970 at a spacing of 9 × 9 m. they reported that the best tree growth, the highest yields and the best quality were obtained with the IW:CPE ratio of 0.50 (10-11 irrigations, each with 80 mm water applied at 32-day intervals in the winter and at 18-day intervals in the summer) and with the intermediate NPK rate (1000 g N, 500 g P_2O_5 and 500 g K_2O/tree).

11. Teran *et al.* (1996) found significant differences in number of guava fruits per plant with application of different levels of nitrogen, but no significant responses were observed to different levels of potash as well as combined application of nitrogen and potash. The application of 200 g N gave the best results. However, it was statistically at par with other treatments. Therefore, the lower dose of nitrogen (150g /plant) + potassium (50 g/plant) is recommended. Similar beneficial effect of NPK in combination with FYM to increase growth and yield was recorded by Muhammad *et al.* (2000) in guava
12. Gawande *et al.* (1998) recorded the maximum fruit yield in 20- year old sapota plants, which were treated with 3:2:2 kg NPK and 50 kg FYM inoculated with 100 earthworms per tree per year under Rahuri conditions.
13. Boora and singh (2000) carried out a field experiment with sapota (*M. achras* [*M. zapota*]) cv. Cricket Ball was carried out on clay loam soil in Kaithal, Haryana, India, during 1995-96. The treatments consisted of 3 levels of N (400, 800 and 1200 g/tree), and 2 levels each of P and K (200 and 400 g/tree). Half dose of N and full doses of P and K were applied in the first week of March and the remaining half of N was applied in the last week of July. Tree growth in terms of plant height increased with the increasing levels of N. The number of fruits increased significantly by higher level of N over lower level. The maximum number of fruits (203.08/tree) was recorded with 1200 g N/tree, whereas 800 g N/tree gave 194.68 fruits, which did not differ significantly from 1200 g. The lowest level of N (400 g) gave the minimum number of fruits (174.32). However, the difference between 800 and 1200g N levels was found non-significant.
14. Mahalle *et al.* (2001) observed that the vegetative growth in respect to number of leaves was significantly influenced by application of 375 g nitrogen, 187.5 g phosphorus and 187.5 g potassium in custard apple.
15. Dalal *et al.* (2004) observed significantly maximum fruit yield per tree in terms of number (2230.50) and weight (204.48 kg/tree) in sapota when treated with 75 kg FYM + 1500 g N + 100 g P_2O_5 + 500 g K_2O + 12.5 g PSB per tree under Akola conditions.
16. Hiwarale *et al.* (2004) observed that the fruit yield of acid lime in terms of number and weight of fruit per plant were significantly increased

with the application of neem cake @ 7.5 kg + 100 % recommended dose of NPK.

17. Madhavi *et al.* (2005) reported the maximum fruit yield (23.63 kg plant^{-1}) in guava cv. 'Sardar' by the application of full dose of chemical fertilizers (i.e., 500 g N + 200 g P2O5 + 500 g K2O /tree/year) whereas, the minimum yield was obtained in control (13.12 kg/plant).
18. Patil *et al.* (2005) revealed that application of 562.5+ 150+ 525 g NPK + 25 kg FYM 5 kg vermicompost recorded significantly higher number of fruits (193.60) and fruit yield (40.04 kg) per tree in mango under rainfed conditions of Dharwad.
19. Hebbara *et al.* (2006) in their field experiment conducted on integrated nutrient management in sapota using vermicompost at Agricultural Research Station, Gangavati, Karnataka, recorded highest fruit yield (18.4 kg fruits plant^{-1}) with 100% RDF + vermicompost application.
20. Kumar *et al.* (2008) studied various combinations of NPK on fruiting, yield and fruit quality in guava, over two years. Treatments with higher nitrogen level attained maximum yield and fruiting compared to treatments with lower nitrogen levels, in combination with phosphorus and potassium. Maximum yield of 22.66, 26.35 kg per plant and fruit set of 34.73%, 35.65% were recorded with 150 g N, 50 g P_2O_5 and 75 g K_2O per plant per year in both the years, respectively.
21. Ahmad *et al.* (2009) reported that application of FYM and NPK fertilizers improved yield and fruit quality of guava cv. Larkana Surahi in winter crop. The maximum yield per plant (63.78 kg) was obtained by guava plants when applied with 40 kg FYM + 1 kg each of N- P_2O_5 - K_2O per plant during August- September for winter season from 10-12 year old plants.
22. Hiwale *et al.* (2010) conducted an experiment on effect of nutrient replenishment through organic fertilizers in sapota cv. Kalipatti at CHES, Vejalpur (Gujrat) and recorded the maximum plant height (4.73 m), highest number of fruits per shoot (60%) and maximum fruit yield (92 kg/ plant) in treatment combination of 50 kg FYM + 500:250:250 g NPK per plant.
23. Musmade *et al.* (2010) reported that plant growth, fruit yield and quality of acid lime were significantly improved due to combined application of neem cake and FYM along with inorganic fertilizers.

Significantly higher yield (147.65 kg plant^{-1}) with better quality fruits were obtained from the 10 year old trees receiving 600:300:300 g NPK + 15 g each of FYM and neem cake plant^{-1} year^{-1} with maximum monetary returns.

24. Ganeshamurthy *et al.* (2011) obtained that high rate of K is needed to achieve not only highest total fruit production but also the greatest percentage of fruit production suitable for marketing, good in quality, high in mineral content and good in keeping quality of fruits like banana and grapes.
25. Baviskar *et al.* (2011) conducted an experiment to study the effect of different combinations of organic, inorganic manures and biofertilizers on yield and quality of sapota at Department of Horticulture, Panjabrao Deshmukh Krishi Vidyapeeth, Akola during year 2010-11. The fruit yield in terms of number of fruits harvested per plant (1569.33), fruit yield (197.53 Kg/plant) was recorded maximum in plants which were treated with (1125:750:375 g NPK + 15 kg vermicompost + 250 g Azotobacter + 250 g PSB/plant).
26. Gautam *et al.* (2012) studied the effect of INM in mango cv. Sunderja and reported that the treatment combination of 500:250:250 g NPK/tree + 50 kg FYM + 10 kg vermicompost registered the maximum plant height, canopy height, plant spread as well as tree volume.
27. Shivakumar, *et al.* (2012) carried out two years field experiment and revealed that application of FYM equivalent to 100% recommended dose of nitrogen (RDN) (154.3 t/ha) gave significantly higher fruit yield of 173.9 t/ha as compared to control with RDF and other organic manure treatments in papaya cv. Surya at Dharwad conditions of Karnataka state.
28. Varu (2012) recorded the greatest tree height (7.26 m), tree spread (8.11 m in N-S and 8.13 m in E-W directions), fruit weight (63.65 g), number of fruits per tree (2627.56) and fruit yield per tree (163.30 kg) were obtained in sapota cv. Kalipatti with the application of 900 g N/tree in the form of urea under Jungad conditions.
29. Dhomane and Kadam (2013) conducted an experiment on influence of different sources of nitrogen in guava and recorded the maximum weight of fruit (243.80 g), maximum yield per tree (58.1 kg) and yield

per hectare (23.26 tonnes) in treatment combination of 75% N through urea + 25% N through neem cake of RDF.

30. Kumar and Kumar (2013) carried out an experiment at Horticulture Research Centre, Patharchatta, GBPUAT, Pantnagar on 18 years old mango trees of cv. Deshehari and revealed that the maximum number of fruits (840.00, 366.67) and fruit yield (127.43, 52.37 kg) per tree with application of 75 kg of vermicompost per tree during both the years of 2007-08.
31. Mustafa *et al.* (2013) carried out an investigation to optimize dose of the nutrient requirement of aonla cv. NA-7 through integrated use of organic manure, inorganic fertilizer, vermi-compost, neem cake and micronutrient in the form of different combinations. Observation revealed that application of 25kg FYM+ ½ NPK+ $ZnSO_4$ + $CuSO_4$ + $FeSO_4$ produced maximum fruit yield (47.75Kg), fruit size as well as nutrient content also. Fertility of experimental soil restores due to application of 25kg FYM+ ½ NPK+ $ZnSO_4$ + $CuSO_4$ + $FeSO_4$.
32. Garhwal *et al.* (2014) revealed that combined application of 80 kg FYM and 750 g nitrogen per plant led to significant increase in plant height (15.20%), spread (N-S, 18.03%; E-W, 18.99%) and canopy volume (81.81%) of Kinnow mandarin in sandy soils of hot arid region.
33. Satisha *et al.* (2014) conducted a field experiment for three consecutive years to study the effect of various combinations of nitrogenous fertilizer (in the form of urea), vermicompost and FYM on yield and soil-available nutrients in sapota. Largest number of fruits (4820 $tree^{-1}$) and maximum fruit yield (31 tons ha^{-1}) were recorded with 10 kg vermicompost + 350:50:450g NPK $tree^{-1}$, and was at par with application of 40kg FYM + 350:50:450g NPK $tree^{-1}$. The net profit and yield trend over the years showed that application of 10kg vermicompost + 350:50:450g NPK per tree was more suitable for meeting nutrient requirement for enhanced yield in sapota. Application of organics (irrespective of source) showed positive, significant effect on organic matter content of the soil after three years. Highest build-up of organic matter in the soil was recorded with 10kg vermicompost alone, which was at par with 40kg FYM alone.
34. Meena (2016) carried out two year field experiment on integrated nutrient management on sapota cv. Kalipatti and revealed that

application of 750:375:375g NPK + 50 Kg FYM + 250g *Azospirillum* + 250 g *Azotobacter* per plant was better with respect to flowering, yield and fruit quality parameters i.e. less number of days required for flowering (19.24 days), highest number of flowers per shoot (12.75), fruit set per cent (31.50%), fruit retention (48.03%), number of fruits per plant (327.88), yield (29.03 Kg tree^{-1} and 4.54 t ha $^{-1}$).

35.

36. Cheena *et al.* (2018) conducted the field experiment to study the effect of integrated nutrient management on growth and yield of sapota (*Achras sapota* L.) during the year 2011-2015 at JVR Horticulture Research Station, Malyal, Mahabubabad district Sri Konda Laxman Telangana State Horticulture University, Rajendranagar, Hyderabad. The highest plant height and plant spread were recorded in treatment - 40 kg FYM + 350 g N/Plant (4.79 m) and treatment - 10 kg Vermicompost + 350 g N/Plant, however lowest was noticed in treatment - 40 kg FYM alone (3.83 m) and treatment 10 kg Vermicompost respectively. The highest fruit weight and no fruits were recorded in treatment - 10 kg Vermicompost + 350 g N/Plant (112.16 g) and treatment - 40 kg FYM + 300 g N/Plant (384.21), however lowest was observed in treatment - 40 kg FYM + 200 g N/Plant (96.72 g) and treatment - 10 kg Vermicompost (269.35) respectively. The highest average fruit yield per tree (42.91 kg/tree) and hectare (6.69 t/ha) were recorded in treatment 40 kg FYM + 350 g N/Plant, however lowest fruit yield per tree (28.27 kg) and yield per hectare (4.40 t/ha) recorded in treatment 40 kg FYM alone.

37. Maskar *et al.* (2018) conducted research on Effect of Bio-fertilizers and Inorganic Fertilizers on Growth and Yield of Sapota cv. Kalipatti, and recorded that the application of *Azospirillum* and PSB with 100 percent chemical fertilizers reported the highest plant growth in respect to days required for sprouting of new shoots (24.30), length of shoot (12.64 cm), Girth of shoots (2.06 cm), No. of leaves per shoots (9.67), leaf area (19.48 cm^2), number of flowers per shoot (9.67), fruit set (44.11%), number of fruits per shoot (4.24), number of fruits per tree (635.67), yield per tree (53.33 kg), and also reduced the maturity days for harvesting of fruits.

38.

39.

40.

41. **2.2 Effect of fertilizer levels on fruit quality**

42. 2.2.1 Physical characteristics

43. Boora and Singh (2000) reported that weight of fruit (63.48 g) increased with application of 800 g N per plant in sapota cv. 'Cricket Ball' and ascorbic acid and reducing sugars were increased significantly by the application of higher levels of N.

44. Dudi *et al.* (2004) recorded the maximum length and weight in 'Kinnow' mandarin fruits with the application of 1.650 kg urea and 100 kg FYM per plant.

45. Hebbara *et al.* (2006) in their field experiment conducted on integrated nutrient management in sapota using vermicompost at Agricultural Research Station, Gangavati, Karnataka, and recorded maximum fruit weight (60.0 g fruit^{-1}) with 50 per cent RDF + vermicompost application.

46. Ahmad *et al.* (2009) reported that application of FYM and NPK fertilizers improved yield and fruit quality of guava cv. Larkana Surahi in winter crop. The maximum single fruit weight (193.52 g), pulp weight (190.04 g), fruit size (length x diameter = 9.74 x 7.63 cm), number of seeds (200.80/fruit) and TSS (11.35 ^{0}B) were obtained by guava plants when applied with 40 kg FYM + 1 kg each of N- P_2O_5 - K_2O per plant during August- September for winter season from 10-12 year old plants.

47. Patel and Naik (2010) carried out different pre harvesting treatments of organic manures and inorganic fertilizers to study the post-harvest shelf life of sapota at Fruit Research Station, Gandevi (Gujarat) and found that highest fresh weight, fruit volume of sapota fruit was obtained when plants received treatment of 400:60:300 g NPK + 5 kg vermicompost tree^{-1}.

48. Baviskar *et al.* (2011) recorded superior fruit quality traits of sapota like fruit weight (125.87g), fruit length (4.36cm), fruit breadth (5.26cm) fruit volume (117.20cc), pulp weight (101.66g) and peel weight (22.50g), in plants which were treated with (1125:750:375 g NPK + 15 kg vermicompost + 250 g Azotobacter + 250 g PSB/plant).

49. Ganeshamurthy *et al.* (2011) reported that applied K influences fruit size, appearance, and colour and consumer acceptance like fruit recovery, aroma, and taste.
50. Varu (2012) recorded highest fruit length (5.21cm) and fruit girth (4.80 cm) was found the highest in sapota with the treatment 900 g N (where 50% from castor cake + 50% from urea).
51. Garhwal *et al.* (2014) recorded the maximum average fruit weight (118.22 g), fruit diameter (5.96 cm), fruit length (5.58 cm), volume of fruit (129.71 cc), peel weight (32.95 g), weight of sacs (85.27 g) and juice percentage (48.30%) with application of 80 kg FYM per plant in kinnow mandarin orchard.
52. Meena (2016) carried out two year field experiment on integrated nutrient management on sapota cv. Kalipatti and revealed that application of 750:375:375g NPK + 50 Kg FYM + 250g *Azospirillum* + 250 g *Azotobacter* per plant was better with respect to fruit quality parameters i.e. fruit length (6.20 cm), fruit diameter (5.67 cm), fruit weight (100.17 g fruit^{-1}), pulp/ seed ratio (93.09) and fruit firmness (4.96 kg/cm^2)

53. 2.2.2 Chemical and storage characteristics

54. Mitra and Bose (1985) applied different doses of N, P and K in 3 years old trees of guava cv. 'L-49'. The TSS increased with K but N application at higher rates decreased TSS, whereas, P had no effect on TSS. In a nutritional trial in guava cv. 'Sardar' for two years,
55. Biswas *et al.* (1989) observed that acidity declined with higher level of N and K as compared to control (untreated) in papaya. The highest acidity was recorded in untreated (control) fruits.
56. Gawande *et al.* (1998) recorded the lowest acidity (0.020%) in sapota fruits from the plants which were treated with 3:2:2 kg NPK + 50 kg FYM per tree per year.
57. Pereira and Mitra (1999) reported that application of 30 kg FYM per plant exhibited better quality of fruit of guava cv. 'Lucknow-49' in terms of higher TSS/acid ratio (29.3).
58. Ram *et al.* (1999) in a nutritional trial in guava cv. 'Sardar' for two years observed that total soluble solids in freshly harvested fruits ranged from 11.7° B to 14.8° B. The maximum TSS was recorded (14.8° B and 14.7° B in year 1993 and 1994, respectively) with 600 g

neem coated urea. Non-significant effect on acidity of fruit was recorded at different nutrition treatment.

59. Lal and Sen (2001) reported that TSS and TSS / acid ratio content of guava fruit cv. 'Allahabad Safeda' harvested from fifteen-year-old grafted plant increased linearly with the application of N, Zn and Mn.
60. Mahalle *et al.* (2001) recorded maximum TSS (24.33 ºB) in custard apple by the treatment of NPK levels at 250 g N, 187.5 g P_2O_5 and 187.5 g K_2O. Similar results were also reported by Sen and Chauhan (1983) in pomegranate.
61. Singh *et al.* (2003) reported the maximum total soluble solids (19.3°B) with the application of 800 g N/tree on 7-year-old 'Cricket Ball' cultivar of sapota.
62. Madhavi *et al.* (2005) obtained highest TSS (8.2%) by the application of 250 g N + 250 g P_2O_5 + 250 g K_2O with 5 kg neem cake per tree per year in 3 year old guava cv. 'L-49'. Similarly, Ram *et al.* (2005a) recorded maximum TSS of 13.5 per cent at 250 g N + 100 g P_2O_5+ 250 g K_2O and 10 kg FYM inoculated with *Azotobacter* treatment followed by 500 g N (neem coated urea) + 100 g P_2O_5+ 500 g K_2O treated guava cv. 'Sardar' (13.0%).
63. Rathore and Dhyani (2005) recorded significant improvement in the fruit quality of guava in terms of TSS by the application of N (500 g plant^{-1}) + P (500 g / plant) consisting of poultry manure and plant chemical fertilizers.
64. Tarai and Ghosh (2006) recorded that fruit quality in sweet orange (*Citrus sinensis* Osbeck) cv. 'Mosambi' improved by application of neem cake and inorganic fertilizers. Similarly, higher TSS (9.60 ºB) The minimum acidity (0.36 %) with maximum TSS: Acid ratio (32.0) was recorded in fruits harvested from the plant receiving 2 kg neem cake + N, 200: P, 75: K, 150 g. Similar, decrease in acidity, increase in juice content and TSS was also noted by Borah *et al.* (2001) in 'Khasi Mandarin' due to application of neem cake and inorganic fertilizers.
65. Mitra *et al.* (2010) reported higher total soluble solids and lower acidity in both rainy and winter seasons were found superior in fruit of guava plants receiving 50 g N, 40 g P_2O_5 and 50 g K_2O /plant/ year along with 5 kg of neem cake /tree/ year.

66. Patel and Naik (2010) revealed that, different combinations involving the use of organic nutrition with the chemical fertilizers had significant effect on fruit quality of sapota. The treatment consists of 400:60:300 g NPK + 5 kg vermicompost per tree recorded maximum TSS (22.85 ºB) as well as maximum reducing, total sugar and maximum shelf life under Gujarat conditions.
67. Kumar *et al.* (2012) reported the maximum acidity content (5.76 %) with treatment 210 g N + 140 g P + 210 g K + 15 kg vermicompost + 5 kg neem cake in spring flush of lemon cv. Pant lemon.
68. Varu (2012) recorded the maximum TSS (18.40 ºB), reducing sugar (5.02%) and total sugar (7.10%) content in sapota with the treatment 900 g N (75% from castor cake + 25% from urea).
69. Dutta Ray *et al.* (2014) was conducted an experiment to increase the production and quality of pomegranate with suitable nutrient management. Four levels of nitrogen (1000g, 400g, 300g and 200g per plant) in the form of urea and neem cake (1kg per plant) and in combinations, along with a common dose of 100g phosphorus (Single super phosphate) and 100g potassium (Murate of potash) were applied. The fruits of the plants treated with 300g nitrogen + 1kg neem cake per plant recorded highest total soluble solids (12.29 ºBrix and significantly minimum acidity (0.39%).
70. Garhwal *et al.* (2014) reported the maximum TSS (12.11 °B) and significantly minimum juice acidity (0.79%) with application of 80 kg FYM per plant in Kinnow mandarin orchard in sandy soils of hot arid region.
71. Meena (2016) carried out two year field experiment on integrated nutrient management on sapota cv. Kalipatti and revealed that application of 750:375:375 g NPK + 50 Kg FYM + 250 g *Azospirillum* + 250 g *Azotobacter* per plant was better with respect to high TSS (20.05 ºB), minimum acidity (0.166%), highest TSS/acid ratio (121.29%), ascorbic acid content (11.86 mg/100g pulp), reducing sugars (5.11%), total sugars(7.33%).
72. Mehul *et al.* (2017) conducted experiment on Effect of integrated nutrient management on quality parameters of sapota cv. Kalipatti and they recorded improved fruit quality in terms of maximum total soluble solids (24.50 ^{0}B), reducing sugar (10.52%), non-reducing sugar

(12.01%), total sugars (22.53 %), shelf life (8.05 days) and minimum acidity (0.21 %), physiological loss in weight on 2nd and 4th day after harvest (3.03 % and 5.24% respectively) of fruits in trees which were treated with 75% NPK + Vermicompost 15 kg + AAU Bio NPK 10 ml/tree.

73. 2.3 Effect of fertilizers on soil nutrient status

74. Madhavi *et al.* (2008) revealed that soil nutrient status was improved by the application of organic manures and bio fertilizers in mango. They recorded highest N (216.2 kg ha^{-1}), (P_2O_5 911.6 kg ha^{-1}) and K_2O (366 kg ha^{-1}) when plants were treated with 500:500:500 g NPK+ 30 kg FYM + 250 g *Azospirillium* $plant^{-1}$ under Andhra Pradesh conditions.
75. Srivastava *et al.* (2008) carried out an experiment to find out effect of different INM based treatments on the changes in soil fertility in citrus under Maharashtra conditions and reported highest level of available N (144.3 mg kg^{-1} soil) and P (15.4 mg kg^{-1} soil) under the treatment of 300:75:37.5 g NPK + green manuring + bio inoculant.
76. Shivakumar, *et al.* (2012) carried out two years field experiment and revealed that analysis of the soil after harvest of papaya crop did not show any significant difference on organic carbon, DTPA-extractable Cu and Mn content among the treatments. Available major nutrients (NPK) were significantly higher with the application of FYM equivalent to 100% RDN and DTPA extractable Zn and Fe in combination with FYM and vermicompost each equivalent to 50% RDN as compared to control comprising chemical fertilizer as RDF.
77. Garhwal *et al.* (2014) revealed that combined application of 80 kg FYM and 750 g nitrogen per plant led to significant increase in soil nitrogen at different depths (0 to 15 cm, 41.78%; 15 to 30 cm, 51.36% and 30 to 60 cm, 27.71%) over initial level.
78. Singh *et al.* (2014) reported that the soil properties in terms of pH and EC declined whereas hydraulic conductivity, organic carbon increased from their initial values with the application of various organic sources of nutrient in different combinations.

79. 2.4 Effect of NAA on growth and yield characters

80. Ray *et al.* (1991) evaluated the performance of NAA at 200, 300 and 400 ppm on sapota cv. Cricket Ball at Bhubaneswar. Among the various doses of NAA applied at just before the flowering and one

month after first spray, the significantly maximum fruit set (27.1 %) and fruit retention (3.89 %) with the foliar application of 200 ppm NAA was observed over control.

81. Tiwari *et al.* (1992) conducted a field experiment on guava cv. Allhabad Safeda to determine the effect of NAA @ 600, 800 and 1000 ppm applied at flowering stage at pantnagar. The significantly maximum no. of flower buds 20.6/branch. The significantly maximum fruit set (74.5 %) was recorded with the application of 600 ppm NAA, whereas minimum fruit drop (32.3 %) was observed with the spray of 800 ppm NAA. The significantly maximum yield (49.6 kg/tree) was recorded with the application of NAA 1000 ppm.
82. Delvadia *et al.* (1994) observed that foliar application of NAA at 100 ppm gave the significantly maximum increased No. of flowers/shoot 8.15, fruit set 41.60 %, fruit retention 13.00 % and minimum fruit drop 85.64 %, maximum increased No. of fruits/tree 538.3 and yield 38.23 kg/tree in chiku.
83. Brahmachari *et al.* (1996) studied the effects of NAA sprays as before flowering and after fruit set on Six years old guava cv. 'Sardar'. Among different doses of NAA, spraying of 100 ppm NAA increased significantly maximum fruit set, fruit retention and minimum fruit drop over to control.
84. Singh and Reddy (1997) observed that foliar application of NAA 400 ppm significantly increased fruit set upto 39.33 % and total yield 65.73 kg/tree in guava.
85. Parihar *et al.* (1999) observed the effect of NAA @ 10, 20 and 30 ppm on various growth parameters of phalsa. They revealed the maximum average shoot length (267.0 cm) was observed with NAA 30 ppm.
86. Bhat *et al.* (2000) reported that foliar application of NAA @ 20 ppm in 'Eureka' lemon significantly increased yield (25.74 kg/tree), juice content (49.05 %) and rind thickness (1.87 mm).
87. Singh *et al.* (2005) reported that foliar application of NAA at 2.5 ppm decreased fruit drop (86.86 %) over control in litchi, whereas significantly increased fruit set (0.72 %) and fruit retention (7.88 %) were recorded with the application of NAA 5 ppm.
88. Sharma *et al.* (2005) evaluated the performance of NAA at 2.5 and 5 ppm on litchi cv. Dehradun at Jammu. The foliar application of NAA

2.5 ppm at flowering significantly increased maximum fruit set up to (74.25 fruits/panicle).

89. Gupta and Kaur (2007) revealed that foliar application of NAA at 10 ppm significantly increased fruit retention (19.58 %) and decreased total fruit drop (80.42 %), increased fruit weight (42.27 g/fruit) and yield (14.35 kg/tree) over control in plum cv. Satlaj Purple over control in plum cv. Satlaj Purple.
90. Nagargoje *et al.* (2007) conducted an experiment during 1999-2000 at Parbhani, Maharashtra, India, to evaluate the effect of NAA on flower drop, fruit set, fruit drop and fruit retention in sapota (*Manilkara zapota*) cv. Kalipatti. NAA was applied at concentrations of 50 and 100 ppm at 50% flowering and at the pea stage of fruit development on uniformly selected branches. Control plant received water sprays. Results revealed that application of 100 ppm NAA at 50% flowering and at the pea stage of fruit development in August-September was significantly superior to 50 ppm NAA and control in reducing flower and fruit drop as well as in increasing fruit set and fruit retention.
91. Nambisan *et al.* (2007) reported that among the various doses of NAA at 10, 20 and 30 ppm, NAA 30 ppm gave significantly maximum flowers (13.6/shoot), fruits (1.7/shoot), fruit set (12.5 %) fruits retained (0.6/shoot) and fruit retention (33.12 %), maximum yield (57.73 fruits/100 shoots) in sapota cv. Kalipatti.
92. Kacha (2008) carried out an investigation on phalsa to see the effect of NAA (100, 150 and 200 ppm), GA3 (50, 100 and 150 ppm) and ethrel (500, 750 and 1000 ppm) at Junagadh. He revealed that among the different concentrations of NAA the maximum height of bush (177.33 cm) and length of shoot (99.17 cm) was increased with NAA 200 ppm over to control.
93. Bhowmick and Banik (2011) conducted a field trial on mango cv. Himsagar to determine the effect of NAA at 20, 40 and 60 ppm for two years. Among different concentrations, NAA at 40 ppm significantly increased the fruit retention (7.25 %) and decreased fruit drop (92.75 %)
94. Bhujbal *et al.* (2013) reported that pre harvest spray of NAA @ 200 ppm at 21 day before harvest found maximum fruit set % (45.02%), fruit retention % (17.39%), minimum days required for fruit maturity

(245.08 days) and maximum number of fruits per tree (2480.20) to all other growth regulators like GA_3 and CCC at different concentrations in sapota cv. Kalipatti.

95. Garhwal (2015) conducted an experiment "Effect of SADH, NAA and GA_3 on growth, yield and quality of sapota [*Manilkara achras* (Mill.) Forsberg] cv. Kalipatti" at College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh during two consecutive years i.e. 2012-13 and 2013-14, with ten treatments T_1 (SADH - 50 ppm), T_2 (SADH - 100 ppm), T_3 (SADH - 150 ppm), T_4 (NAA - 200 ppm), T_5 (NAA - 300 ppm), T_6 (NAA - 400 ppm), T_7 (GA_3 - 50 ppm), T_8 (GA_3 - 100 ppm), T_9 (GA_3 - 150 ppm) and T_{10} (control). He revealed that NAA 400 ppm will give significantly minimum fruit drop (79.69 %), while NAA 300 ppm resulted in maximum cost benefit ratio (3.91).

96. Kavyashree *et al.* (2018) conducted an experiment in the 35 year old sapota orchard at Mudigere (Karnataka) during 2014-15 to asses the Effect of plant growth regulators on yield and quality of sapota (*Achras zapota* L.) through crop regulation under hill zone of Karnataka. Three growth regulators viz., NAA (250, 300 and 350 ppm), 2, 4-D (40, 50 and 60 ppm) and Ethephon (350, 400 and 450 ppm) at varied concentrations were sprayed at pea nut stage. The results of the experiment showed that, the foliar application of NAA at 350 ppm gave significantly maximum yield per tree (108.47 kg) and yield per hectare (10.85 t).

97. 2.5 Effect of NAA on fruit quality

98. 2.5.1 Physical characteristics

99. Ray *et al.* (1991) evaluated the performance of NAA at 200, 300 and 400 ppm on sapota cv. Cricket Ball at Bhubaneswar. Among the various doses of NAA applied at just before the flowering and one month after first spray, the significantly maximum fruit length (3.56 cm), fruit diameter (3.90 cm) and fruit weight (108.7 g) were obtained with the application of NAA 300 ppm.

100. Rema and Sharma (1991) observed that spray of 150 ppm NAA at full bloom stage significantly increased the fruit weight, fruit volume, seed weight and fruit yield in phalsa.

101. Singh and Reddy (1997) observed that foliar application of NAA 400 ppm significantly increased fruit weight 135.00 g, fruit length 6.06 cm, fruit diameter 6.28 cm in guava.

102. Sharma *et al.* (2005) evaluated the performance of NAA at 2.5 and 5 ppm on litchi cv. Dehradun at Jammu. The foliar application of NAA 2.5 ppm at flowering significantly increased maximum fruit length (3.18 cm) over control. While, application of 5 ppm NAA significantly increased fruit weight (15.25 g) and diameter (2.95 cm)

103. Chavan *et al.* (2009) studied the effect of pre harvest foliar spray of NAA @ 150 ppm at flower initiation, pea stage and lag phase of fruit development in sapota fruits cv. Kalipatti. They recorded maximum fruit weight (82.36 g),

104. Agrawal and Dikshit (2010) reported that foliar application of 100 ppm NAA at flowering increased significantly fruit length (15.60 cm), diameter (86.21 cm), weight (88.50 g), volume (81.23 cc), pulp weight (69.75 g), peel weight (13.31 g), pulp thickness (2.87 cm) and decreased no. of seeds (4. 16/fruit) and seed weight (3.16 g/fruit) in sapota cv. Cricket Ball.

105. Bhowmick and Banik (2011) conducted a field trial on mango cv. Himsagar to determine the effect of NAA at 20, 40 and 60 ppm for two years. Among different concentrations, NAA at 40 ppm significantly increased the no. of fruits (790.17/tree), yield (20.67 tonnes /ha), fruit length (8.91 cm), fruit breadth (7.01 cm), fruit weight (263.38 g/fruit). The significantly increased pulp (75.65 %) was recorded with the application of NAA 60 ppm. While, significantly maximum peel (14.64 %) was observed with the spray of NAA 20 ppm.

106. Patil *et al.* (2011) studied the pre-harvest spray of different level of NAA (50,100 and 150 ppm) on sapota cv. Kalipatti. They observed that application of NAA @ 150 ppm at flowering stage increased fruit length (6.39 cm), fruit diameter (4.47 cm) and fruit weight (82.36 g).

107. Sharma and Tiwari (2015) observed the effect of pre-harvest spray of NAA @ 100 ppm on 20 August and after 30 days of first spray in guava cv. Chittidar. They recorded maximum fruit weight (223.37 g), fruit diameter (5.74 cm), fruit volume (220.60 cc).

108. Kavyashree *et al.* (2018) reported that, the foliar application of NAA at 350 ppm gave significantly maximum fruit weight (110.23 g),

fruit length (6.07 cm), fruit diameter (58.30 mm), volume of fruit (106.87 cc) yield per tree (108.47 kg), yield per hectare (10.85 t) and extended shelf life (10.58 days) with minimum physiological loss in weight (6.10 %, 8.11 % and 10.22 % at 3, 6 and 9 days during storage respectively) compared to all other treatments tried.

109. 2.5.2 Chemical and storage characteristics

110. Ray *et al.* (1991) evaluated the performance of NAA at 200, 300 and 400 ppm on sapota cv. Cricket Ball at Bhubaneswar. Among the various doses of NAA applied at just before the flowering and one month after first spray, the maximum TSS (20.5 %), pectin (1.11 %) total sugar (18.56%), reducing sugar (9.72 %), non-reducing sugar (8.83 %), and ascorbic acid (9.43 mg/100 g of pulp) and decreased acidity (0.051 %) were observed with the foliar application of 200 ppm NAA over control.

111. Kumar and Kumar (1994) conducted an experiment on effect of growth regulators sprays on yield and quality of litchi fruits at Pantnagar. Among different treatments NAA 20 ppm increased TSS 18.70 % and total sugars 12.31%.

112. Singh and Reddy (1997) observed that foliar application of 600 ppm NAA significantly increased TSS 9.83 ^{0}Brix, ascorbic acid 263.96 mg/100 g and minimum acidity 0.30 % in guava.

113. Bhat *et al.* (2000) reported that foliar application of NAA @ 20 ppm in 'Eurekha' lemon significantly decreased acidity (2.99 %).

114. Yadav *et al.* (2001) carried out an experiment to see the effect of foliar application of growth regulators, i.e. NAA (20, 40 and 60 ppm), GA (50, 100 and 150 ppm) and Ethrel [Ethephon] (50, 75 and 100 ppm) on 15th years old guava trees cv. 'L-49'. Total Soluble Solids and ascorbic acid (189 mg/100g pulp) was found significantly maximum with NAA 60 ppm, whereas all growth regulators significantly increased in total sugars over control.

115. Bhati and Yadav (2003) studied the effect of foliar application of NAA (0, 10, 20 and 30 ppm) on the fruit quality of eight years old plants of ber (*Zyziphus mauritiana* cv. 'Gola') at flowering. The application of 20 ppm NAA significantly increased maximum TSS (19.44 0B), ascorbic acid (168.7 mg/100 g pulp), reducing sugar (4.2

%), total sugar (10.69 %) and significantly decreased acidity (0.200 %) as compared to other doses.

116. Kher *et al.* (2005) conducted an experiment at Udheywalla, Jammu to evaluate the effects of pre harvest application of plant growth regulators on the quality of guava cv. 'Sardar' fruits. The significantly maximum TSS content (11.6 %) was noted with application of NAA 60 ppm, whereas significantly maximum total sugar (7.63 %) was recorded with application of NAA 80 ppm.

117. Sharma *et al.* (2005) evaluated the performance of NAA at 2.5 and 5 ppm on litchi cv. Dehradun at Jammu. The foliar application of NAA 2.5 ppm at flowering significantly increased maximum total sugar (17.53 %), reducing sugar (9.80 %), non-reducing sugar (7.34 %) and ascorbic acid (39.76 mg/100 g flesh weight) over control. While, significantly increased TSS (19.00 %) was observed with the application of 5 ppm NAA.

118. Gupta and Kaur (2007) revealed that foliar application of NAA at 10 ppm significantly increased TSS (14.02 %) and decreased acidity (0.93 %) over control in plum cv. Satlaj Purple.

119. Chavan *et al.* (2009) studied the effect of pre harvest foliar spray of NAA @ 150 ppm at flower initiation, pea stage and lag phase of fruit development in sapota fruits cv. Kalipatti. They recorded maximum fruit weight (82.36 g), T.S.S (20.15 ^{o} Brix) and minimum acidity content (0.21 %) as compared to NAA @ 50 ppm and 100 ppm.

120. Agrawal and Dikshit (2010) recorded that foliar application of 100 ppm NAA at flowering significantly increased TSS (19.63 ^{0}B), ascorbic acid (11.80 mg/100 g of pulp), reducing sugar (9.03 %), non-reducing sugar (6.60 %), total sugar (15.63 %) and decreased acidity (0.10 %) in sapota cv. Cricket Ball.

121. Bhowmick and Banik (2011) conducted a field trial on mango cv. Himsagar to determine the effect of NAA at 20, 40 and 60 ppm for two years. Among different concentrations, NAA at 40 ppm significantly increased the ascorbic acid (42.42 mg/100 g pulp). The significantly increased reducing sugar (4.59 %) and decreased stone (12.65 %) were reported with the application of NAA 60 ppm. While, significantly maximum TSS (19.43 ^{0}B), total sugars (15.76 %), non-

reducing sugar (11.32 %), TSS: acid ratio (103.38 %) and minimum acidity (0.188 %) were observed with the spray of NAA 20 ppm.

122. Bhujbal *et al.* (2013) reported that pre harvest spray of NAA @ 200 ppm at 21 days before harvest found maximum TSS (21.86^{0}B) to all other growth regulators like GA_3 and CCC at different concentrations in sapota cv. Kalipatti.

123. Meena *et al.* (2013) found that pre-harvest spray of NAA @ 75 ppm at pea stage and second spray after 20 days of first spray recorded maximum TSS (0.73 ° Brix) and minimum physiological loss in weight (8.66 %) in ber cv. Gola.

124. Kavyashree *et al.* (2018) reported that, the foliar application of NAA at 350 ppm gave significantly extended shelf life (10.58 days) with minimum physiological loss in weight (6.10 %, 8.11 % and 10.22% at 3, 6 and 9 days during storage respectively) compared to all other treatments tried.

125. 2.6 Effect of GA_3 on growth and yield characters

126. Pramanik and Bose (1974) observed that GA_3 at 50 and 100 ppm increased fruit set of ber, while, GA_3 at 100 ppm and 2,4,5-T (100) in high concentration reduced fruit drop Rajput *et al.* (1977) concluded a positive correlation between vegetative characters at the concentration of 30 ppm GA_3 proved better than rest of the treatments in all growth characters of guava.

127. Sundarrajan *et al.* (1988) found that the spraying of GA_3 at 200 ppm on guava at the time of flowering followed by the second spray after 15 days gave a significant response. The percentage of fruit set varied from 40 (control) to 80 by the application of GA_3 200 ppm alone.

128. Ray *et al.* (1991) evaluated the performance of GA_3 at 50, 100 and 150 ppm on growth, yield and fruit quality of sapota cv. Cricket Ball at Bhubaneswar. Among the various doses of GA_3 applied at just before the flowering and one month after first spray significantly maximum fruit set (26.2 %) and fruit retention (3.24) were obtained with the application of 100 ppm GA_3.

129. Delvadia *et al.* (1994) observed that foliar application of GA_3 at 50 ppm gave the significantly maximum increased number of flowers/shoot 8.20, fruit set 37.53 %, fruit retention 12.37 %,

maximum increased no. of fruits/tree 504.8 and yield 35.28 kg/tree in sapota.

130. Kaur *et al.* (1997) observed that foliar applications of GA_3 at 15 ppm reduced fruit drop up to 51.43 % from 63.04 % i.e. control Kinnow mandarin.

131. Bhat *et al.* (2000) reported that foliar application of GA_3 at 20 ppm significantly increased yield (27.85 kg/tree) in 'Eureka' lemon.

132. Singh *et al.* (2005) reported that foliar application of GA_3 at 5 ppm gave significantly increased aril proportion (70.31 %), fruit retention (11.04 %) and decreased fruit cracking (8.30 %) and fruit drop (85.24 %), while application of 10 ppm GA_3 significantly increased fruit set (0.91 %) over control in litchi cv. Dehradun.

133. Yadav and Chaturvedi (2005) studied the influence of GA_3 and trace elements on growth of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarsi Karaka. They reported that GA_3 increased the growth characters and GA_3 at 30 ppm minimized fruit drop and increased fruit retention.

134. Kachave and Bhosale (2007) studied the effect of plant growth regulators and micronutrients on fruiting and yield parameters of Kagzi lime (*Citrus aurantifolia* Swingle) fruits. The results revealed that GA_3 + micronutrient mixture 1 % spray was the best treatment for reducing fruit drop, increasing fruit retention, number of fruits per tree.

135. Nambisan *et al.* (2007) reported that among the various doses of GA_3 at 10, 20 and 30 ppm, GA_3 30 ppm gave significantly increased maximum flowers (12.1/shoot) and fruit set (13.9 %) and maximum fruits (1.7/shoot) in sapota cv. Kalipatti. While, the significantly maximum fruit retention (29.40 %) and maximum yield (46.66 fruits/100 shoots) was observed with the spray of GA_3 10 ppm.

136. Kacha (2008) carried out an investigation on phalsa to see the effect of NAA (100, 150 and 200 ppm), GA_3 (50, 100 and 150 ppm) and ethrel (500, 750 and 1000 ppm) at Junagadh. He revealed that among the different concentrations of GA_3, the maximum height of bush (170.11 cm) and length of shoot (91.48 cm) was increased with GA_3 100 ppm over to control.

137. Bhowmick and Banik (2011) conducted a field trial on mango cv. Himsagar to determine the effect of GA_3 at 20, 40 and 80 ppm for two years. Among different concentrations, GA_3 at 40 ppm significantly increased the fruit retention (7.00 %), increased the no. of fruits (776.67/tree) and yield (21.73 tonnes /ha).

138. Singh *et al.* (2011) reported that foliar application of GA_3 40 ppm, significantly increased number of leaves (1842.94/bush) and harvest span (16.95 days) in plum under Kanpur conditions. While, maximum average shoot length (157.28 cm) was recorded with the application of GA_3 60 ppm. They also reported that foliar application of GA_3 50 ppm significantly increased the fruit set (69.35 %).

139. Garhwal (2015) observed that application of GA_3 150 ppm gave the maximum increase over to initial in plant height (5.73 %); plant spread N-S (9.99 %) and E-W (10.74 %) and canopy of plant (8.88 %).

140. Khawle (2016) conducted an experiment entitled, Effect of growth regulators on yield and quality of sapota *(Manilkara achras* (Mill.) Forseberg). cv. Kalipatti was carried out in Dept. of Horticulture. V. N. M. K. V, Parbhani during 2015-16, with treatments viz. T_1 (GA_3 75 ppm), T_2 (GA_3 100 ppm), T_3 (GA_3 125 ppm), T_4 (CPPU 2 ppm),T_5 (CPPU 4 ppm),T_6 (CPPU 125 ppm),T_7 (Brassinosteroid 0.5ppm), T_8 (Brassinosteroid 1ppm), T_9 (Brassinosteroid 1.5 ppm), and T_{10} (control). He recorded that GA_3 at 125 ppm significantly increased yield characters like number of fruits per tree (1551) and yield per tree (126.45 Kg / tree).

14.7 Effect of GA_3 on fruit quality

2.7.1 Physical characteristics

141. Pandey *et al.* (1980) found maximum fruit weight and diameter of fruit with GA_3@ 100 ppm on Dashehari mango.

142. Ray *et al.* (1991) evaluated the performance of GA_3 at 50, 100 and 150 ppm on growth, yield and fruit quality of sapota cv. Cricket Ball at Bhubaneswar. Among the various doses of GA_3 applied at just before the flowering and one month after first spray resulted significantly maximum fruit length (3.95 cm), fruit diameter (4.13 cm) and fruit weight (108.7) were obtained with the application of 100 ppm GA_3.

143. Kumar *et al.* (1998) studied the effect of gibberellic acid on yield and yield attributing characters of guava cv. 'Allahabad Safeda' for two years grown in an acidic soil. Application of 150 ppm GA_3 significantly improved the fruit size, fruit weight, fruit volume, specific gravity and yield and decreased no. of seeds and seed weight during both the consecutive years of study.

144. Bhat *et al.* (2000) reported that foliar application of GA_3 at 20 ppm significantly increased juice content (49.70 %) and rind thickness (1.88 mm) in 'Eurekha' lemon.

145. Sharma *et al.* (2005) evaluated the performance of GA_3 at 5 and 10 ppm on litchi cv. Dehradun at Jammu. The foliar application of GA_3 10 ppm at flowering significantly increased fruit weight (17.21 g) and diameter (3.43 cm) over control.

146. Kachave and Bhosale (2007) reported that GA_3 + micronutrient mixture 1 % spray was the best treatment for increasing weight of individual fruit, fruit length, diameter, volume, specific gravity, yield per tree, reduced no. of seeds and seed weight.

147. Agrawal and Dikshit (2010) recorded that foliar application of 50 ppm GA_3 at flowering increased significantly fruit length (15.50 cm), diameter (84.54 cm), weight (6.10 g), volume (79.39 cc), pulp weight (69.23 g), peel weight (11.49 g) and pulp thickness (2.83 cm) and decreased number of seeds (4.61/fruit) and seed weight (4.33g/fruit) in sapota cv. Cricket Ball.

148. Syamal *et al.* (2010) revealed that GA_3 (100 and 150 ppm) increased the plant height, fruit weight, volume, specific gravity and yield of papaya plant significantly over control.

149. Bhowmick and Banik (2011) conducted a field trial on mango cv. Himsagar to determine the effect of GA_3 at 20, 40 and 80 ppm for two years. Among different concentrations, GA_3 at 40 ppm significantly increased fruit length (9.28 cm), fruit breadth (7.31 cm), fruit weight (283.38 g/fruit), peel (14.42 %) and the significantly increased pulp (75.59 %).

150. Patil *et al.* (2011) studied that pre-harvest spray of different level of GA_3 (50, 100 and 150 ppm) on sapota cv. Kalipatti. They observed that application of GA_3 @ 150 ppm at flowering stage increase

fruit length (6.64 cm), fruit diameter (4.75 cm) and fruit weight (87.23 g).

151. Bhujbal *et al.* (2013) reported that pre harvest spray of GA_3 @ 150 ppm at 21 days before harvest produced maximum fruit weight (88.66 g), minimum number of seed (1.420) and minimum seed weight (1.181 g) in sapota cv. Kalipatti.

152. Jagtap *et al.* (2013) studied on the effect of foliar application of plant growth regulators and micronutrients on yield and quality of acid lime cv. Kagzi (*Citrus aurantifolia* S.). They observed that foliar application of 50 ppm GA_3 significantly increased the fruit weight (47.40 g), fruit volume (47.90 cc) and fruit diameter (4.54 cm).

153. Lal *et al.* (2013) reported that the pre-harvest spray of GA_3 @ 50 ppm at before flowering observed maximum fruit length (9.8 cm), fruit girth (10.20 cm), fruit weight (182 g) and fruit volume (178.3 cc) in guava cv. Allahabad Safeda

154. Garhwal (2015) reported that Maximum length of fruit (6.79 cm), diameter of fruit (6.98 cm), fruit weight (94.78 g), fruit volume (83.27 cc), specific gravity (1.07), pulp weight (93.23 g) and minimum seed: pulp ratio (0.0168 g) and seed weight (1.55 g) were recorded with the foliar application of GA_3 150 ppm over control

155. Desai (2016) recorded maximum fruit weight and fruit volume (89.85 g and 79.30 cc, respectively) in sapota fruits. With the spraying of GA_3 @ 100 mg/l.

156. Khawle (2016) reported that GA_3 at 125 ppm resulted significantly maximum length of fruit (6.61 cm), width of fruit (4.73 cm), fruit weight (81.53 g) and pulp weight (71.54).

157. 2.7.2 Chemical and storage characteristics

158. Singh and Singh (1976) reported maximum TSS, sugars, ascorbic acid and minimum acidity in mango at 200 ppm concentration of GA_3. The quality of fruits was adversely affected at higher GA_3 concentration.

159. Singh (1977) applied GA_3 at 0 to 250 ppm on mango cv. Banarasi Langra and observed that total soluble solids, sugars and ascorbic acid content were enhanced whereas, acidity was reduced by application of GA_3 up to 200 ppm. However, appreciable effect was

observed in respect of fruit quality in case of Banganpalli mango sprayed four times with GA_3 at 10, 20 and 40 ppm.

160. Chakrawar and Singh (1978) reported that, the fruit quality of Kaula Mandarin was influenced to some extent by the application of growth regulators. The GA_3 (10 and 20 ppm) improved the quality as like total soluble solids, vitamin-'C', reducing sugar and non-reducing sugars.

161. Daulta (1982) found that foliar application of GA_3 40 ppm significantly increased TSS in grape. However titrable acidity was not affect significantly over control.

162. Sandhu *et al.* (1985) reported that application GA_3 75 and 60 ppm at fruit set stage was found to be most effective for increasing total soluble solid of grape cv. 'Thompson Seedless' and 'Perlette', respectively.

163. Singh and Rajput (1986) reported that the chemical composition of mango fruits in terms of total soluble solids, sugars (reducing and non-reducing) and ascorbic acid was significantly improved by application of 150 ppm GA_3 as compared to control.

164. Chattopadhyay and Jana (1988) observed that GA_3 at 10, 25 and 50 ppm were found to be more effective in increasing the total soluble solids and sugar content in Cavendish banana in comparison to control.

165. Ray *et al.* (1991) evaluated the performance of GA_3 at 50, 100 and 150 ppm on growth, yield and fruit quality of sapota cv. Cricket Ball at Bhubaneswar. Among the various doses of GA_3 applied at just before the flowering and one month after first spray significantly maximum reducing sugar (16.52 %), ascorbic acid (9.10 mg/100 g of pulp) and pectin (1.31 %) were obtained with the application of 100 ppm GA_3. The significantly increased TSS (20.1 %) and decreased acidity (0.044 %) was observed with the application of GA_3 150 ppm. The significantly increased total sugar (17.48 %) and non-reducing sugar (7.04 %) were recorded with the foliar application of GA_3 50 ppm over to control.

166. Kumar and Singh (1993) found that, GA_3 @ 30 or 75 ppm pre-harvest sprays in mango cv. Amrapali significantly improved fruit quality (total soluble solids, sugar and ascorbic acid contents) and

reduced spoilage losses during harvest without causing a marked increase in pre-harvest fruit drop as compared to control.

167. Tsadik and Zelleke (1993) sprayed GA_3 0, 25, 50 and 100 ppm on Grape cv. 'Kai Dube' for two years at Ethiopia. They reported that increased doses of GA_3 (0 to 100 ppm) significantly increased TSS 17.83 ^{0}Brix and decreased acidity up to 0.73 % with application of GA_3 100 ppm.

168. Bhanja and Lenka (1994) conducted an experiment on effect of pre and postharvest treatments on storage life of sapota fruits cv. Oval at Bhubaneswar. They revealed that a pre-harvest spray application of GA_3 at 100 ppm extended shelf life up to 36 days (compared with 8 days in the water-sprayed control), and reduced physiological weight loss and rotting percentage.

169. Singh *et al.* (1995) observed that, GA_3 and Ethrel (Ethephon) were sprayed on mango fruits cv. Amrapali in the first week of June 1990 to enhance the ripening and to improve the storage life of Amrapalli mango fruits. GA_3 at 75 and 50 ppm improved the quality of fruits.

170. Kumar *et al.* (1996) evaluated the performance of GA_3 at 12.5, 25 and 50 ppm on fruit quality of strawberry cv. Tioga. The significantly maximum TSS (6.23 ^{0}B), reducing sugar (4.08 %) and total sugars (4.29 %) were observed with the spray of GA_3 12.5 ppm.

171. Yadav *et al.* (2001) observed the effect of foliar application of growth regulators, i.e. NAA (20, 40 and 60 ppm), GA_3 (50, 100 and 150 ppm) and Ethrel (50, 75 and 100 ppm), made on 15 years-old guava trees cv. L-49. They reported that all the treatments increased the total sugar contents.

172. Sharma *et al.* (2002) conducted the experiments in HAU, Haryana to evaluate the effects of pre harvest application of plant growth regulators on the quality of winter guava cv. 'Sardar' fruits and reported that the maximum ascorbic acid (mg/100g) was recorded with spraying of 50 ppm GA_3.

173. Saraswathi *et al.* (2003) observed the effect of pre harvest spray of GA_3 @ 20 ppm on fruit quality of Mandarins (*Citrus reticulata* Blanco). The pre harvest spray of growth regulators significantly improved quality of fruits.

174. Sharma *et al.* (2005) evaluated the performance of GA_3 at 5 and 10 ppm on litchi cv. Dehradun at Jammu. The foliar application of GA_3 10 ppm at flowering significantly increases maximum TSS (18.75 %), total sugar (17.30 %), reducing sugar (8.90 %) and non-reducing sugars (8.21 %) over control. While, maximum ascorbic acid i.e. 37.28 mg/100 g flesh weight was observed in treatment 5 ppm spray of GA_3.

175. Yadav and Chaturvedi (2005) studied the influence of GA_3 and trace elements on fruit quality of ber (*Zizyphus mauritiana* Lamk.) cv. Banarsi Karaka. GA_3 at 30 ppm increased the total soluble solids content and total sugar of fruit.

176. Eman *et al.* (2007) studied the effect of GA_3 sprays for improving the fruit quality of Washington Navel orange trees grown under sandy soil conditions. GA_3 improved the physical and chemical fruit characteristics.

177. Gupta and Kaur (2007) revealed that foliar application of GA_3 @ 25 ppm significantly increased TSS (13.85 %) and decreased acidity (1.10 %) over control in plum cv. Satlaj Purple.

178. Kachave and Bhosale (2007) studied the effect of plant growth regulators and micronutrients on fruiting and yield parameters of Kagzi lime (*Citrus aurantifolia* Swingle) fruits. The results revealed that GA_3 + micronutrient mixture 1% spray was the best treatment observed for increasing fruit quality parameters.

179. Chavan *et al.* (2009) found that spraying of GA_3 @ 150 ppm at initiation of flowering, pea stage and lag phase of fruit development recorded maximum fruit weight (87.23 g), TSS (19.76 ^{0}Brix), total sugar (13.98 %) and minimum acidity (0.22 %) as compared to GA_3 @ 50 ppm and 100 ppm in sapota cv. Kalipatti.

180. Agrawal and Dikshit (2010) recorded that foliar application of 50 ppm GA_3 at flowering increased significantly TSS (19.37 %), ascorbic acid (11.66 mg/100 g of pulp), reducing sugar (8.88 %), non-reducing sugar (6.49 %) and total sugar (15.38 %) and decreased acidity (0.11 %) in sapota cv. Cricket Ball.

181. Bhowmick and Banik (2011) conducted a field trial on mango cv. Himsagar to determine the effect of GA_3 at 20, 40 and 80 ppm for two years. The significantly increased TSS (19.05 ^{0}B), total sugars (15.99 %), reducing sugar (4.11 %), non-reducing sugar (11.28 %) and

ascorbic acid (41.74 mg/100 g pulp) were observed with the spray of GA_3 20 ppm.

182. Singh *et al.* (2011) conducted a field trial to evaluate the effect of GA_3 (40, 50 and 60 ppm) at Kanpur on phalsa. The maximum TSS (20.47 ^{0}B), total sugar (13.98 %) and minimum acidity (1.23 %) were recorded with the application of GA_3 60 ppm.

183. Meena *et al.* (2012) reported that spraying of GA_3 @ 50 ppm during fruit development stage increased fruit firmness (29.66 kg/cm^2), TSS (15.50 ^{0}Brix) and minimum acidity (0.51 %). Whereas, lowest physiological loss in weight (0.95 %) and reducing decay percentage (0.16%) up to third week of storage was observed with the spray of GA_3 @ 20 ppm in grape cv. Thompson Seedless.

184. Bhujbal *et al.* (2013) reported that pre harvest spray of GA_3 @ 150 ppm at 21 day before harvest found maximum total sugar (16.24 %), reducing sugar 10.28 %) and non-reducing sugar (5.96 %) in sapota cv. Kalipatti.

185. Jagtap *et al.* (2013) studied on the effect of foliar application of plant growth regulators and micronutrients on yield and quality of acid lime cv. Kagzi (*Citrus aurantifolia* S.). They observed that foliar application of 50 ppm GA_3 significantly increase TSS (9.58 ^{0}Brix), ascorbic acid content (30.41 mg/100 g), and decrease acidity (7.05 %) as compared to other PGRs GA_3 @ 25 ppm and NAA (200 ppm and 100 ppm).

186. Bisen *et al.* (2014) studied the different level of pre harvest spray of GA_3 (0, 25, 50 and 100 ppm) on guava cv. Allahabad Safeda. They observed that application of GA_3 @ 100 ppm at fruit set, 10 and 20 days before harvesting increase TSS (11.99 ^{O}Brix), total sugar (9.92 %), reducing sugar (5.62 %), non-reducing sugar (4.30 %), ascorbic acid (261.39 mg/100 g pulp) and fruit firmness (7.62 kg/cm^2) as well as decreased acidity (0.39 %) at 6 day after storage.

187. Garhwal (2015) reported that treatment T_8 (GA_3 100 ppm) recorded the highest total soluble solids (19.28 ^{0}Brix), reducing sugar (8.45 %), non-reducing sugar (3.89 %), total sugars (12.34 %) and ascorbic acid (9.81 mg/100 g) and minimum acidity (0.077 %) over control (T10)

188. Sharma and Tiwari (2015) studied the effect of the pre-harvest spray of GA_3 @ 150 ppm on guava cv. Chittidar at full bloom stage and second spray done at one month later. They recorded maximum TSS (12.60 ^{0}Brix), total sugar (10.42 %), reducing sugar (5.82 %) and non-reducing sugar (4.60 %) and ascorbic acid (177.9 mg/100 g pulp) as compared GA_3 @ 100 ppm

189. Khawle (2016) that GA_3 at 125 ppm resulted significantly maximum reducing sugar (10.18 %), non-reducing sugar (5.82%), total sugar (16%), titrable acidity (0.213%) and TSS (19.72%) over all other treatments.

CHAPTER-III

MATERIAL AND METHODS

The present investigation entitled **"Effect of fertilizer levels and growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kalipatti"** was conducted at Department of Horticulture, College of Agriculture, Dapoli (M.S.) during 2017-19. The details of the material used and methods adopted during the course of the investigation are described in this chapter under different headings.

3.1 Experimental site

The experiment was conducted in the sapota orchard of cv. 'Kalipatti' survey No. 7 and 8, Department of Horticulture, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) India, Pin- 415712. The Soil of Experimental plot was red lateritic with uniform depth and good drainage conditions.

3.2 Soil and climate conditions

Dapoli represents more and less tropical climate having average humidity 78% throughout the year. The average minimum and maximum temperature is 18.5°C and 30.8°C respectively with an average precipitation of 3,500 mm. distributed mainly during four months from June to September. The Konkan region lies on west cost of Maharashtra at 17°45' N latitude and 73°12' E longitude. It has an altitude of 240 m from the MSL. Dapoli has lateritic soil with sandy loam texture and acidic pH.

3.3 Experimental details

3.3.1 Effect of fertilizer levels on yield and quality of sapota

Experiment design	:	Randomized block design (RBD)
Total number of treatments	:	4
Number of replications	:	5
Number of plants per treatment	:	2
Total number of plants	:	40
Cultivar	:	Kalipatti
Age of plant	:	40 years
Plant spacing	:	12.5 ×12.5 m
Time of harvesting	:	January to May, at weekly intervals

Treatment details:-

Treatment details with their symbols of different fertilizer levels

Sl. No.	Treatments	Symbol
1.	1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June.	T_1
2.	3 Kg each NPK + 200Kg FYM $Tree^{-1}$ $Year^{-1}$ in June. (Recommended dose - check).	T_2
3.	4.5 Kg each NPK + 300 Kg FYM $Tree^{-1}$ $Year^{-1}$ in two splits i.e. ½ in June and ½ in September.	T_3
4.	6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January.	T_4

Observations recorded

A) Growth observations

1. Plant height(m)
2. Plant spread (m)
3. Canopy volume (m^3)
4. Shoot length (cm) (60 and 120 days after treatment)
5. Number of leaves per shoot (60 and 120 days after treatment)

B) Flowering and fruiting observations

1. Number of flower per shoot
2. Number of fruit set and per cent fruit set
3. Number of fruit retained and per cent fruit retention
4. Period for fruit development

C) Yield observations

1. Number of fruits per plant
2. Fruit yield per plant (Kg)
3. Yield per hectare (T)

D) Physical characteristics of fruit

1. Fruit length (cm)
2. Fruit diameter (cm)
3. Fruit weight (g)
4. Fruit volume (cc)
5. Specific gravity of fruit
6. Number of seeds per fruit
7. Weight of seeds (g)
8. Pulp weight (g)
9. Pulp / seed ratio

E) Chemical characteristics of fruit

1. Total soluble solids (%)
2. Titratable acidity (%)
3. TSS / acid ratio
4. Reducing sugars (%)
5. Non-reducing sugars (%)
6. Total sugars (%)

F) Storage characteristics of fruit

1. Shriveling and spoilage (%)
2. Physiological loss of weight (%)
3. Shelf life of fruits (Days)

G) Chemical properties of soil

1. pH
2. EC (dSm□¹)
3. Organic Carbon (%)
4. Available Nitrogen (Kg/ha)
5. Available Phosphorus (Kg/ha)
6. Available Potassium (Kg/ha)

3.3.2 Effect of growth regulators on yield and quality of sapota

Experiment design	:	Randomized block design (RBD)
Total number of treatments	:	7
Number of replications	:	3
Number of plants per treatment	:	1
Total number of plants	:	21
Cultivar	:	Kalipatti
Age of plant	:	27 years
Plant spacing	:	12.5 ×12.5 m
Recommended dose of fertilizer	:	3 Kg each NPK + 200 Kg FYM/ tree/year
Time of application of treatments	:	1st week of Jan and 1st week of Feb 2018
Time of harvesting	:	March to May, 2018 at weekly intervals

Treatment details:-

Treatment details with their symbols of different growth regulator doses

Sl. No.	Treatments	Symbol
1.	Control (no spray)	**T_1**
2.	GA_3 50 ppm	**T_2**
3.	GA_3 100 ppm	**T_3**
4.	GA_3 150 ppm	**T_4**
5.	NAA 100 ppm	**T_5**
6.	NAA 150 ppm	**T_6**
7.	NAA 200 ppm	**T_7**

Observations recorded

A) Growth observations

1. Plant height(m)
2. Plant spread (m)
3. Canopy volume (m^3)

B) Flowering and fruiting observations

1. Number of flower per shoot
2. Number of fruit set and Per cent fruit set
3. Number of fruit retained and Per cent fruit retention
4. Period for fruit development

C) Yield observations

1. Number of fruits per plant
2. Fruit yield per plant (Kg)
3. Yield per hectare (T)

D) Physical characteristics of fruit

1. Fruit length (cm)
2. Fruit diameter (cm)
3. Fruit weight (g)

4. Fruit volume (cc)
5. Specific gravity of fruit
6. Number of seeds
7. Weight of seeds (g)
8. Pulp weight (g)
9. Pulp to seed ratio

E) Qualitative characteristics of fruit

1. Total soluble solids (%)
2. Titratable acidity (%)
3. TSS / acid ratio
4. Reducing sugars (%)
5. Non-reducing sugars (%)
6. Total sugars (%)

F) Storage characteristics of fruit

1. Shriveling and spoilage (%)
2. Physiological loss of weight (%)
3. Shelf life of fruits (Days)

3.3.3 Method of treatments application

Fertilizers

The inorganic fertilizers (nitrogen, phosphorus and potassium) were applied through urea containing 46 per cent nitrogen, single supper phosphate containing 16 per cent phosphorus and muriate of potash containing 60 per cent potassium, respectively**.** The doses of fertilizer according to treatment were mixed and applied in a ring which covered an area of 150 cm away from main trunk and covering the periphery of the plants. Soil was dug to a depth of 25-30 cm and fertilizers were properly mixed in the soil. Well decomposed farm yard manure is issued from the department is applied according to the treatments.

Growth regulators

The stock solution of PGR's as a solute were prepared by dissolving 10g of PGR's in small quantity of acetone and volume was made up to 1 litre by adding distilled water to obtain concentration of 10000 ppm. It was considered as stock solution. Then by using formula $N_1V_1 = N_2V_2$, required quantity of solution was taken from stock solution for preparing different concentrations of PGR's solutions.

Spraying was done with foot sprayer. Both the upper and lower sides of the leaves were thoroughly sprayed with fine mist. Spraying was done on clear sunny days. The sprayer was washed thoroughly with water after application of every treatment.

3.4 Orchard management

3.4.1 Interculturing

Interculturing was done by 'Kudali' as well as with help of power tiller and then basins rings were prepared.

3.4.2 Weeding

Mechanical weeding followed by hand weeding was done as and when required.

3.4.3 Irrigation

Irrigation was given at alternate days through micro jets at scheduled rate.

3.4.4 Harvesting

The fruits were harvested at full maturity stage, when develop a dull potato colour, the skin of mature fruit turns light yellow colored and mature with a yellowish tinge. A mature fruit when scratched slightly shows a yellowish streak instead of a green streak which is sign of immature condition. As the fruit matures, the milky latex content reduced. The final yield per tree (kg) was obtained by sum of all the pickings.

3.5 Methodology used for observations

3.5.1 Growth observations

3.5.1.1 Tree height (m)

The tree height (m) was recorded twice during experiment i.e. before imposing treatments (January, 2018) and after completion of experiment (January, 2019). The height of plants was measured from ground level to the highest tip of branch with the help of measuring pole demarkated in meter and centimeter. Plant height was reported in meters.

3.5.1.2 Tree spread [North-South and East-West] (m)

The tree spread (m) was recorded in both the sides i.e. North-South and East-West directions twice during experiment i.e. before imposing treatments (January, 2018) and after completion of experiment (January, 2019). North-South and East-West spread was measured in meters with the help of measuring tape.

3.5.1.3 Canopy volume (m^3)

Canopy of sapota trees (m^3) was recorded in both the sides i.e. North-South and East-West directions twice during experiment i.e. before imposing treatments (January, 2018) and after completion of experiment (January, 2019).was recorded in cubic meters before application treatments. It was calculated by using the values of North-South and East-West plant spread (m) and following formula:

Canopy volume (m^3) = 0.5238 × (avg. plant spread) ^{2} ×canopy height

3.5.1.4 Shoot length (cm)

Ten newly emerged uniform size shoots were randomly selected and tagged (in June, 2018, after fertilizer application) in each treatment for recording shoot observations. The initial length of tagged shoot was measured with the help of meter scale at the time of 60 and 120 days after treatment application.

3.5.1.5 Number of leaves per shoot

The numbers of newly emerged leaves of every tagged shoot was counted at 60 and 120 days after treatment application.

3.5.2 Flowering and fruiting observations

3.5.2.1 Number of flower per shoot

Flowers borne in the axile of various leaves of the tagged shoot were recorded. The average number of flower buds per shoot was calculated from the data observed.

3.5.2.2 Number of fruit set and per cent fruit set

The total number of fruits set on each tagged shoot was counted by ten representative shoots of each tree and averaged to obtain effective fruit set. Fruit set percentage was calculated from number of fruits set divided by total number of flowers and multiplied by 100. It can be also presented as under.

$$\text{Fruit set per cent} = \frac{\text{No. of fruits set}}{\text{Total no. of flowers}} \times 100$$

3.5.2.3 Number of fruit retained and per cent fruit retention

The number of fruits available for harvest from tagged shoot was counted and averaged to obtain number of retained fruits and percentage of fruit retention was calculated from number of fruits retained divided by total number of fruits set and multiplied by hundred. It can be also presented as under.

$$\text{Fruit retention (\%)} = \frac{\text{No. of fruits retained}}{\text{Total no. of fruits set}} \times 100$$

3.5.2.4 Period for fruit development

The period for fruit development was computed as the number of days required for harvest from date of flowering.

3.5.3 Yield observations

3.5.3.1 Number of fruits per plant

Total numbers of fruits were recorded from the first to last harvest from various treatments.

3.5.3.2 Fruit yield per plant (Kg)

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

3.5.3.3 Estimated fruit yield per hectare (t)

The fruits yield per hectare was calculated by multiplying the fruit yield per plant with plant per hectare i.e. 64 plants with 12.5 x 12.5 m plant spacing. Total yield was calculated in tonne per hectare.

3.5.4 Physical characteristics of fruit

3.5.4.1 Fruit length (cm)

At the time of harvest length of ten numbers of the fruit from each treatment was recorded longitudinally with the help of vernier callipers in centimetres.

3.5.4.2 Fruit diameter (cm)

Fruit diameter of ten numbers of fruit in each treatment was recorded at equatorial with the help of vernier callipers in centimetre and the average was calculated.

3.5.4.3 Fruit weight (g)

Fruit weight of ten fruits was recorded with the help of electronic balance and average was expressed in gram

3.5.4.4 Fruit volume (cm^3)

The volume of fruit in cm^3 was measured by water displacement method by dipping the fruit in a known volume of water in a graduated glass beaker. Ten representative fruits from each plant used for this purpose and an average were calculated.

3.5.4.5 Specific gravity of fruit

To obtain specific gravity of particular fruit, the weight of fruit was divided by its volume. (Sulladmath and Reddy, 1985)

3.5.4.6 Number of seed per fruit

Ten representative fruits from each plant used for counting the number of seeds per fruit. After removing the seeds from fruit pulp with the help of hand and knife, the seeds were counted and average was calculated.

3.5.4.7 Weight of seed (g)

Seeds were separated from the fruit and weighed on the electronic balance. The average ten fruits seed weight was expressed in grams (g).

3.5.4.8 Pulp weight (g)

The pulp was extracted by hand fruit knife and weight was recorded on electronic balance and presented both as weight of pulp in gram.

3.5.4.9 Pulp to seed ratio

After the separations of seeds and pulp from the individual ripen fruit, weight of the seeds and weight of pulp were recorded and pulp: seed ratio was computed.

3.5.5 Chemical characteristics of fruit

3.5.5.1 Total soluble solids (TSS ^{0}B)

Total soluble solids of the fruit were determined with the help of hand refractometer (Erma Japan, 0 to 32 ^{0}B) where as one drop of fruit juice was put on the prism of the refractometer and the TSS in per cent was recorded directly. The values were corrected at 20 ^{0}C and expressed as degree brix (A.O.A.C., 1990).

3.5.5.2 Titratable acidity (%)

A known quantity of liquid sample pulp was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator. In case of solid sample, a known sample was blended in mortar and pestle with 20-25 ml of distilled water. It was then transferred to 100 ml volumetric flask, made up volume and filtered. A known volume of aliquot (10ml) was titrate against 0.1 N NaOH solution using phenolphthalein as an indicator. The results were expressed as per cent anhydrous citric acid (A.O.A.C., 1990).

3.5.5.6 TSS / Acid ratio

To decide the quality of sapota fruit the TSS / acid ratio was calculated by dividing the value of obtained total soluble solid content by acidity percentage.

3.5.5.3 Reducing sugars (%)

The titrimetric method of Lane and Eynon described by Ranganna (2000) was adopted for the estimation of reducing sugar. Twenty five grams of the homogenized pulp was taken and transferred to a 250 ml volumetric flask and 2 ml of 45 lead acetate solution was added for clarification. After 10 minutes, the solution was deleaded by adding potassium oxalate crystals in excess (5 to 10 g) and volume was made up the distilled water. The contents were then centrifuged for about 10 minutes. The clear supernatant solution was taken in a burette and titrated with boiling Fehling's mixture (5 ml of Fehling's solution A and 5 ml of Fehling's solution B) till the blue colour faded. At the stage 1 ml of 1 % methylene blue indicator was added and the titration was continued till content attained brick red colour. At this stage titration was stopped and the titre value was noted from the burette. Percentage reducing sugars was calculated from the following formula.

$$\text{Reducing sugar (\%)} = \frac{\text{Glucose Equivalent (0.05)} \times \text{Total vol. made up}}{\text{Titre value} \times \text{Weight of pulp}} \times 100$$

3.5.5.5 Non - reducing sugars (%)

Non-reducing sugar was calculated by subtracting the reducing sugar from total sugar.

3.5.5.4 Total sugars (%)

The percentage of total sugar in the fruit was determined by Fehling's solution method was given by Rangana (2000). A known volume of pulp was taken, diluted with distilled water and clarified by saturated lead acetate solution. Later on, the solution was free from lead by adding potassium oxalate crystals and filter through What's men filter paper. An aliquot of 25 ml from the filtrate was taken to which 5 ml of diluted HCL (1:1) was added and the sample was left for inversion for 24 hours at room temperature. Then the solution was neutralized with 40 % NaOH using phenolphthalein as indicator and the final volume was made up on 100 ml and titrated against 5 ml of Fehling's 'A' and 'B' with boiling using ethylene blue as an indicator. The percentage of total sugar was expressed as invert sugar according to the following formula.

$$\text{Total sugar (\%)} = \frac{\text{Total vol. made} \times \text{Glucose Equivalent (0.05)} \times \text{Vol. made up after Inversion}}{\text{Titre value} \times \text{Weight of pulp} \times \text{Aliquot taken for inversion}} \times 100$$

3.5.6 Storage characteristics of fruit

3.5.6.1 Shrivelling and spoilage (%)

The number of visibly shrivelled, diseased, rotten and over ripe fruits were counted at every alternate day up to 10^{th} day of storage period and expressed as percentage over the total number of fruits.

3.5.6.2 Physiological loss of weight (PLW %)

Initial weight of fruits was recorded just before storage. To assess the physiological loss in weight, further weight of fruits were recorded at every alternate day up to 10^{th} day of storage and subtracted from initial weight to calculate loss in weight and expressed in percentage. It was calculated by following formula.

$$PLW\ (\%) = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.5.6.3 Shelf life (Days)

Each fruit among the different treatments were thoroughly scrutinized for any visible symptoms of shrivelling and spoilage and end of shelf life was considered when 12 per cent fruits were shrivelled, over ripened, rotten or any other spoilage symptoms observed.

3.5.7 Soil chemical characteristics

In order to determine soil properties and fertility status of the experimental soil, the soil samples were collected with the help of screw auger up to the depth of 60 cm. The collected soil samples were mixed thoroughly on a clean piece of cloth and the bulk reduced by quarter so that about 500 g of composite sample was obtained. Collected soil samples were taken to the lab and spread on a thick brown paper. Stones, pieces of roots, leaves and other non-decomposed organic residues were removed. It was air dried at 20 to 25 °C and 20 to 60 per cent relative humidity (Jackson, 1973). After air drying soil samples were crushed gently in pastel and mortar and sieved through 2 mm mesh sieve. The grounded soil samples were stored in glass containers. The grounded samples were mixed well before a sample was weighed for analysis. Then soil samples were analysed according to the methods given below.

3.5.7.1 Soil reaction (pH)

The pH of soil was determined using pH meter having combined electrode using 1:2.5 soil : water suspension ratio (Jackson, 1973).

3.5.7.2 Electrical conductivity (dSm^{-1})

Electrical conductivity of soil was determined with help of Systronic Conductivity Meter-306 using 1:2.5 soil : water suspension ratio (Jackson, 1973).

3.5.7.3 Organic carbon (%)

It was determined by following Walkley and Black, wet oxidation method by oxidation of organic matter in soil as described by Black, 1965.

3.5.7.4 Available nitrogen (kg ha^{-1})

Available nitrogen was determined by alkaline permanganate (0.32% $KMnO_4$) method (Subbiah and Asija, 1956).

3.5.7.5 Available phosphorous (kg ha^{-1})

Available phosphorous of the soil was determined by Brays No.1 method for acidic soil. Phosphorus in the extract was determined colourimetrically using Spectrophotometer 660 nm wavelength as outlined by Black, 1965.

12.6.6 Available potassium (kg ha^{-1})

Available potassium was determined by using neutral normal ammonium acetate as an extractant on Flame Photometer as described by Jackson, 1973.

3.7 Statistical analysis

The data obtained was analysed statistically as per the method suggested by Panse and Sukhatme (1985). The standard error of mean (S.E) was worked out and the critical difference (C.D) at 5 per cent was calculated whenever the results were found significant. The important results have been supported through graphs and plates.

CHAPTER IV

RESULTS AND DISCUSSION

The research project entitled **"Effect of fertilizer levels and growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kalipatti"** was conducted at Department of Horticulture, College of Agriculture, Dapoli (M.S.) during 2017-19. The results obtained are presented and discussed as under.

4.1. Effect of fertilizer levels on growth, yield and quality of sapota

4.1.1Growth characteristics

Growth characteristics i.e. tree height, tree spread (North-South and E-W) and canopy volume of sapota trees were measured before imposing treatments (First week of January, 2018) and after completion of experiment (End of January, 2019) whereas length of shoot and number of leaves per shoot were measured after imposing of treatments (June, 2018).

The data on effect of fertilizer levels on the tree growth characteristics are presented in Table 1 and 2 and illustrated with Figure 1 and 2.

4.1.1.1 Tree height

There was non-significant difference among the treatments in tree height observed before and after conduction of experiment (Table 1). The average tree height before starting of experiment was 7.35 m and after completion of experiment was 8.19 m.

4.1.1.2 Tree spread (N-S and E-W)

The data on tree spread at both north-south and east-west direction (Table 1) revealed that there was non-significant difference among the treatments in tree spread at before and after carrying of experiment. The average tree spread on north-south direction before

and after conduction of experiment was 9.68 and 11.22 m respectively. Similarly the average tree spread on east-west direction was measured 9.89 m before starting experiment and 11.14 m after completion of experiment.

4.1.1.3 Canopy volume

The canopy volume of sapota trees showed non-significant difference between different treatments at before and after conduction of experiment (Table 1). The average canopy volume before start of experiment was 333.39 m^3 and after completion 438.60 m^3

The different doses of fertilizers did not significantly influence the growth characters like tree height, tree spread and canopy volume which might be due to age of the trees and as a perennial crop, the effects of the treatments possibly represented after consecutive long term efforts.

The effect of nutrition on growth of trees was reported in sapota by Bhuva (1990), Boora and Singh (2000), Varu, (2012), Meena, (2016) and Cheena *et al.* (2018).

4.1.1.4 Shoot length

All the treatments differed significantly for shoot length of sapota at 60 days after treatment application (Table 2 and Fig. 1). The maximum shoot length of sapota (18.23 cm) was recorded in T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January) which was significantly superior to all other treatments. It was followed by T_3 (16.35 cm), T_2 (14.72 cm) and minimum shoot length (12.84 cm) recorded in T_1 (1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June)

At 120 days after treatment application, there was significant difference in shoot length at different treatments (Table 2 and Fig. 1), the highest shoot length of sapota was 26.48 cm in T_4 and it was followed by T_3 (24.34 cm), T_2 (21.35 cm) and lowest shoot length (20.18 cm) was recorded in T_1

4.1.1.5 Number of leaves per shoot

The perusal data reveals that number of leaves per shoot differed significantly among the treatments at 60 and 120 days after fertilizer application (Table 2 and Fig. 2).

The significantly highest number of leaves per shoot (15.88) was obtained in T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January) at 60 days after treatment application which was followed by T_3 (13.80), T_2 (12.0) and lowest number of leaves per shoot (10.60) recorded in T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June).

At 120 days after treatment application, the similar trend was observed and highest number of leaves per shoot (21.12) was recorded in T_4, followed by T_3 (18.60), T_2 (16.84) and minimum number of leaves per shoot (15.70) recorded in T_1.

The increase in growth characters like shoot length and number of leaves per shoot under high NPK dose in graded form may be due to continuous and sufficient supplementation and availability of nutrients during different vegetative growth stages of the plants. The findings are closely confirmed to the results obtained by Meena (2016) and Maskar *et al.* (2018) in sapota.

4.1.2 Flowering and fruiting parameters

The flowering and fruiting parameters *viz.* number of flowers per shoot, fruit set, fruit retention and period for fruit development were significantly influenced by various graded doses of fertilizer application. The data on these parameters are presented in Table 3 and depicted in Fig. 3 and 4.

4.1.2.1 Number of flowers per shoot

There was significantly maximum number of flowers per shoot (12.52) was recorded in T_4 (Table 3 and Fig. 3) which was followed by T_3 (11.38). The minimum number of flowers per shoot (10.28) was produced in T_1 which was at par with T_2 (10.66).

4.1.2.2 Number of fruit set and fruit set percentage

The perused data (Table 3) showed that the highest number of fruit was set (3.52) in treatment T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January) and it was followed by T_3 (2.84). The lowest fruit set (1.80 fruits) was recorded in T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June) and it was at par with T_2 (1.96).

Fruit set percentage was significantly influenced by the application of fertilizer doses in sapota (Table 3 and Fig. 4). The significantly maximum fruit set percentage (29.69%) was recorded in T_4 which was followed by T_3 (24.91%).The lowest fruit set per cent (17.50%) recorded in T_1 and was at par with T_2 (18.38%).

4.1.2.3 Number of fruit retained and fruit retention percentage

The significantly maximum number of fruit retained per shoot (1.76) in T_4 and it was followed by T_3 (1.26). The minimum number of fruit retained per shoot (0.7) in T_1 which was at par with T_2 (0.8).

It is clear from data (Table 3 and Fig. 4) that different doses of fertilizer treatments had significant influence on fruit retention percentage. The highest fruit retention percentage (47.28%) was recorded in T_4 which was at par with T_3 (44.36%).Whereas lowest fruit retention per cent was registered in T_1 (38.99%) and it was at par with T_2 (40.83%).

Under these treatments of split application of fertilizers along with graded amount of FYM, the prolonged availability of nutrients ensured during the growth period might have enhanced the flowering and increased number of flowers and fruit set percentage to an appreciable extent and increased availability of potash during fruit growth might have influenced in increased fruit retention.

The findings of the present investigation are in close conformity to the findings of Singh *et al.* (2003), Hiwale *et al.,* Bavisker *et al.,* (2011), Varu (2012), Meena (2016), Maskar *et al.* (2018) in sapota and Garhwal *et al.* (2014) in Kinnow mandarin.

4.1.2.4 Period for fruit development

The data given Table 3 reveals that The period for fruit development (214.96 days) was significantly shorter in T_4 which was at par with T_3 (216.32 days) and was followed by T_2 (222.36).The maximum period for fruit development recorded in T_1 (226.12 days).

Earliness in maturity of fruits might be influenced by prolonged availability of nutrients mainly potassium during the fruit development period in plants. This statement also agreed with the findings of Maskar *et al.* (2018).

4.1.3 Yield parameters

The data on effect of fertilizer levels on yield and yield attributes of sapota cv. Kalipatti are presented in Table 4 and illustrated with Figure 5 and 6.

4.1.3.1 Number of fruits per tree

The value in Table 4 shows that the different graded dose of fertilizers significantly influenced number of fruits per tree. The significantly maximum number of fruits per tree (429.46) was recorded in T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January). It was followed by T_3 (379.32), T_2 (282.10) and minimum number of fruits per tree (241.45) recorded T_1 (1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June).

4.1.3.1 Yield per tree

The significantly highest fruit yield per tree (63.85 Kg) was recorded in T_4 (Table 4 and Fig 5) and it was followed by T_3 (48.78 Kg), T_2 (34.16 Kg) and lowest yield per tree (20.61 Kg) was recorded in T_1 (RDF).

4.1.3.1 Yield per hectare

The critical calculated data indicate that application of graded dose of fertilizers significantly enhanced the productivity of trees by increasing the yield per hectare (Table 4 and Fig. 6). The significantly maximum yield/ha (4.09t) was recorded in T_4 which was followed by T_3 (3.12 t), T_2 (2.19 t) and lowest yield (1.32 t/ha) was recorded in T_1.

Table 4. Effect of fertilizers on yield of sapota cv. Kalipatti

Treatments	Number of fruits / tree	Fruit yield / tree (Kg)	Yield / ha (t)
T_1 (1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June**)**	241.45	20.61	1.32
T_2 (3 Kg each NPK +200Kg FYM $Tree^{-1}$ $Year^{-1}$ in June**)**	282.10	34.16	2.19
T_3 (4.5 Kg each NPK+ 300 Kg FYM $Tree^{-1}$ $Year^{-1}$ in two splits i.e., ½ in June and ½ in September**)**	379.32	48.78	3.12
T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January**)**	429.46	63.85	4.09
Range	**241.45 – 429.46**	**20.61 – 63.85**	**1.32 – 4.09**
Mean	**333.08**	**41.85**	**2.68**
SEm ±	**1.18**	**0.17**	**0.01**
CD @ 5%	**3.63**	**0.54**	**0.03**

The significant increase in fruit yield and yield attributing parameters in sapota with application of graded dose of NPK along with organic manure may be due to vigorous shoot growth and higher retention percentage. The beneficial role of graded dose of fertilizers along with organic manure in improving soil physical, chemical and biological properties is well known which intern helps in better nutrient absorption by plant and resulting in higher yield. Similar effects were recorded in sapota by Dalal *et al.* (2004), Hebbara *et al.* (2006), Hiwale *et al.* (2010), Baviskar *et al.* (2011), Varu (2012), Satisha *et al.* (2014), Meena (2016) and Cheena *et al.* (2018). The

related findings were also reported in other fruit crops by Taran *et al.* (1996), Madhavi *et al.*(2005) Ahmed *et al.* (2009) and Dhomane and Kadam (2009) in guava, Patil *et al.* (2005) and Kumar and Kumar (2013) in mango and Musmade *et al.* (2013) in acid lime.

4.1.4 Physical characteristics

Treatments of different graded dose of fertilizers significantly influenced on physical parameters of fruit. The data pertaining to effect of various doses of fertilizer treatments on physical characteristics of fruit are presented in Table 5a and 5b and depicted in Fig. 7, 8, 9 and 10.

4.1.4.1 Fruit length

It is clear that all treatments were significantly varied with fruit length the maximum fruit length (6.20 cm) was recorded in T_4 which was followed by T_3 (6.04 cm), T_2 (5.91cm) and minimum fruit length (5.64 cm) was recorded in T_1 (Table 5a and Fig. 7).

4.1.4.2 Fruit diameter

The various dose of fertilizers influenced the fruit diameter significantly, and maximum fruit diameter (6.08 cm) was in T_4. It was followed by T_3 (5.81 cm) and significantly minimum fruit diameter was recorded in T_1 (5.53 cm) which was at par withT_2 (5.62 cm) (Table 5a and Fig. 7).

4.1.4.3 Fruit weight

The data presented in Table 5a and Fig. 8 revealed that the significantly maximum fruit weight (138.14 g) of sapota was recorded in T_4 and it was followed by T_3 (128.40 g), T_2 (120.42 g) and minimum fruit weight (108.98 g) was recorded in T_1 treatment.

4.1.4.5 Fruit volume

A perusal of the data presented in Table 5a and Fig. 8 revealed that the significantly maximum fruit volume (132.34 cm^3) was recorded in T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January) which was

followed by T_3 (125.10 cm^3), T_2 (123.05 cm^3) and minimum fruit volume (111.76 cm^3) was recorded in T_1 (1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June).

4.1.4.6 Specific gravity

The various dose of fertilizers significantly influenced the specific gravity of fruit. The significantly highest specific gravity (1.04) was recorded in T_4 which was at par with T_3 (1.03). The minimum specific gravity (0.98) was recorded in both T_1 and T_2 (Table 5a).

4.1.4.7 Number of seeds per fruit

The significantly highest number of seeds per fruit of sapota (1.86) was recorded in both T_3 and T_4 treatments (Table 5b and Fig. 9), it was followed by T_2 (1.70) and lowest number of seeds per fruit was recorded in T_1 (1.62).

4.1.4.8 Weight of seeds per fruit

A perusal of the data presented in Table 5b and Fig. 9 revealed that the highest weight of seeds per fruit (1.51g) was recorded in T_4 which was significantly superior to all other treatments. It was followed by T_3 (1.45 g), T_2 (1.37 g) and minimum weight of seeds was observed in T_1 (1.31 g).

4.1.4.4 Pulp weight

The significantly highest pulp weight (130.08 g) was recorded in T_4 which were significantly superior to rest of the treatments. It was followed by T_3 (120.06 g), T_2 (113.08 g) and minimum pulp weight (101.16 g) recorded in T_1 (Table 5b).

4.1.4.9 Pulp/seed ratio

It is clear from Table 5b and Fig. 9 that, all treatments significantly influenced the pulp to seed ratio. The significantly maximum pulp/seed ratio (85.95) in sapota fruits was recorded in T_4

which was at par with T_3 (82.60) and was followed by T_2 (82.44) and minimum pulp/seed ratio (77.29) was recorded in T_1.

The findings clearly indicated that the synergetic influence of graded dose of fertilizers have resulted in enhanced production of growth promoting substances which positively influence physiological activities of tissues which ultimately increase the physical properties of the fruit. The results of the present findings are in the accordance with the findings of Boora *et al.* (2002), Hebbara *et al.* (2006), Patel and Naik (2010), Bavisker *et al.* (2011), Varu (2012) and Meena (2016) in sapota.

4.1.5 Chemical characteristics

The data pertaining to effect of fertilizer levels on chemical properties of fruit in sapota cv. Kalipatti are presented in Table 6 and illustrated with Figure 11, 12, 13 and 14.

4.1.5.1 Total soluble solids (TSS)

A perusal of the data presented in Table 6 and Fig. 11 revealed that the significantly maximum TSS of sapota fruits (24.98^{0}B) was recorded in T_4 and it was followed by T_3 (23.92 ^{0}B), T_2 (22.64 ^{0}B) and lowest TSS (21.58 ^{0}B) was measured in T_1.

4.1.5.2 Titratable acidity

The data on fruit acidity in sapota fruit as influenced by different fertilizer levels indicated the significant difference among the treatments. The significantly minimum titrable acidity (0.13 %) of fruits was recorded in T_4 (Table 6 and Fig 12) and it was followed by T_3 (0.14 %), T_2 (0.15 %) and maximum titrable acidity (0.16 %) was recorded in T_1.

4.1.5.3 TSS/acidity ratio

It is evident from the data shown in Table 6 and Fig. 13 that the significantly highest TSS/acidity ratio (187.01) of fruit was recorded in

T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January) which was followed by T_3 (169.70), T_2 (155.99) and lowest TSS/acidity ratio (138.81) was recorded in T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June).

4.1.5.4 Reducing sugars

A perusal of the data presented in Table 6 and Fig 14 revealed that the significantly maximum reducing sugars (11.06 %) of fruits were recorded in T_4. It was followed by T_3 (10.67 %), T_2 (10.20 %) and lowest reducing sugars (9.85 %) were in T_1.

4.1.5.5 Non reducing sugars

It is evident from the data shown in Table 6 and Fig 14 that the highest non reducing sugars (5.56 %) was recorded in T_4 which was followed by T_3 (5.22 %). The minimum non reducing sugars (4.94 %) were recorded in T_1.

4.1.5.6 Total sugars

On the basis of data shown in Table 6 and Fig 14, the treatment T_4 recorded significantly highest total sugars (16.62 %) and it was followed by T_3 (15.89 %), T_2 (15.33 %) and minimum total sugars (14.79 %) were recorded in T_1.

The incorporation of chemical fertilizers and their graded application along with organic manure influenced the biochemical process such as accumulation of carbohydrates which positively influence chemical properties. The improvement in fruit quality by an increase in total soluble solid content in fruits might have been due to beneficial role of nutrients on the process of photosynthesis which ultimately led to the accumulation of large amount of carbohydrates in sink and there by increased total soluble solid content in fruits. The acidity of sapota fruits significantly decreased with the application of nutrients. This might be due to increase in sugar content with the application of nutrients. The upsurges in chemical properties of sapota fruits due to application nutrient have also been reported by

Singh *et al.* (2003), Patel and Naik (2010), Bavisker *et al.* (2011), Varu (2012) and Meena (2016) and Dutta Ray (2014) in pomegranate.

4.1.6 Storage parameters

The data on effect of fertilizer levels on storage parameters of sapota cv. Kalipatti was presented in Table 7 and illustrated with Figure 15, 16 and 17.

4.1.6.1 Shriveling and spoilage

The data shown in Table 7 and Fig. 15 revealed that different fertilizer doses significantly affected to the shriveling and/or spoilage percentage of sapota fruits. The graded dose with higher nutrition reduced the spoilage.

At second day of storage, there was no shriveling and/or spoilage of sapota fruits observed irrespective of treatment. But at fourth day of storage, shriveling and/or spoilage (0.40 %) of sapota fruits was observed only in treatment T1.

At sixth day of storage, the lowest shriveling and/or spoilage (8.80 %) was observed in T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January) and it was at par with T_3 (9.60 %) and T_2 (11.20 %). The maximum shriveling and/or spoilage (16.00 %) of fruits were observed in T1 (1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June).

At eighth day of storage, significantly minimum shriveling and/or spoilage of fruits were observed in T_4 (12.00 %) which was at par with T_3 (13.60 %).The highest shriveling and/or spoilage (33.60 %) was noticed in T1 treatment and followed by T_2 (27.20 %).

At tenth day of storage, the trend was sustained. The significantly minimum shriveling and/or spoilage (29.60 %) of fruits were observed in T_4 and it was at par with T_3 (33.60 %). The maximum shriveling and/or spoilage (47.20 %) of sapota fruits observed in T1 which was followed byT_2 (40.80 %).

The split application of graded dose of fertilizers might have helped in prolonged availability of nutrients during fruit development and maturity, the increase in availability of nutrient K during maturity of fruits may improve the immune and resistance against pest and disease attack and also improves the durability of fruit firmness thus it reduces the shriveling and spoilage of fruits.

4.1.6.2 Physiological loss in weight (PLW %)

The perusal data presented in Table 7 and Fig. 16 revealed that different fertilizer doses affected significantly to the PLW percentage of sapota fruits.

At second day of storage, significantly minimum PLW (3.18 %) of fruits was observed in T_4. It was at followed by T_3 (3.44 %) and T_2 (4.27 %). The maximum PLW (4.43 %) of fruits was observed in T1.

At fourth day of storage, lowest PLW of fruits was observed in T_4 (6.00 %) and the maximum PLW of fruits was observed in T1 (8.28 %), It was 6.52 % in T_3 and 7.58 %T_2.

At sixth day of storage, similar trend was continued and significantly minimum PLW of sapota fruits was observed in T_4 (9.94 %) and highest PLW in fruits was observed in T1 (12.35 %).

At eighth day of storage, the significantly lowest PLW (11.31) was observed in T_4, followed by T_3 (12.02 %) and T_2 (16.06 %). Whereas, highest PLW (19.72 %) of fruits was again observed in T1

At tenth day of storage, the significantly minimum PLW (27.14 %) was observed in T_4 and it was at par with T_3 (28.62 %). The maximum PLW %of sapota fruits was observed in T1 (39.15 %).

The reduction in fruit weight loss by the different treatment may be due to reduction in rate of respiration and transpiration, which delayed ripening process by supporting the ethylene synthesis during the fruit ripening. The findings of the present investigation are in close conformity to the findings of Mehul Patel *et al.* (2017).

4.1.6.3 Shelf life

The data shown in Table 7 and Fig 17 revealed that different fertilizer dose influenced significantly to the shelf life of sapota fruits.

The significantly maximum shelf life (8.2 days) was recorded in T_4 and it was followed by T_3 (6.8 days) which was at par with T_2 (6.2 days) and minimum shelf life recorded in T_1 (4.40 days).

The graded applications of fertilizers have decreased the shriveling, spoilage and PLW of the fruits which intern improved and increased the shelf life of sapota. The above statements are agreed with the findings of Patel and Naik (2010) and Mehul Patel *et al.* (2017) in sapota.

4.1.7. Soil chemical properties

Initial value of pH (5.68), EC (0.13 dSm^{-1}), OC (15.16 %) and available NPK (219.52, 54.60, 560 Kg/ha respectively) presented in Table 8

The data presented in Table 8 and illustrated with Figure 18 reveals that the different fertilizer treatments has non-significant effect on pH, EC and Organic Carbon of soil and their average values are 5.65, 0.14 dSm^{-1}, 16.12 per cent, respectively after harvest. However the available NPK was significantly influenced due to fertilizer treatments.

The higher available N was estimated in T_3 (229.36 Kg/ha) which is significantly maximum and it was followed by T_4 (227.60 Kg/ha) and T_2 (224.60 Kg/ha) the lowest (215.46 Kg/ha) was in T_1.

The available P was calculated significantly maximum in T_4 (59.27 Kg/ha) and it was followed by T_3 (57.57 Kg/ha) and T_2 (55.10 Kg/ha) the lowest (53.18 Kg/ha) was in T_1.

The estimated value of available K was significantly higher in T_4 (581.36 Kg/ha) and it was followed by T_3 (577.60 Kg/ha) and T_2 (556.64 Kg/ha) the lowest (549.22 Kg/ha) was in T_1.

The application of higher dose of nutrients in graded form improved the fertility status of soil. The results are supported by findings of Shivakumar, *et al.* (2012) in papaya.

4.1.8. Effect of different fertilizer on economics

The data presented in Table 9 revealed that the treatment T_4 resulted maximum net return (Rs. 38605.47/ ha) and B /C ratio (1.23) during experimentation. It was followed by T_3 (net return Rs. 27133.12 / ha and B /C ratio 1.21), T_2 (net return Rs. 17139.71/ha and B /C ratio 1.19) and minimum in T_1 (net return Rs. 9867.48/ha and B /C ratio 1.18). The market sale price of sapota fruit during production season was Rs. 50/kg.

Table 9. Effect of fertilizers on economics of sapota cv. Kalipatti

Treatments	Yield (t/ha)	Expenditure incurred (Rs/ha)	Gross return (Rs/ha)	Net profit (Rs/ha)	B:C ratio
T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June**)**	1.32	56132.52	66000.00	9867.48	1.18
T_2 (3 Kg each NPK +200Kg FYM Tree^{-1} Year^{-1} in June**)**	2.19	92260.29	109400.00	17139.71	1.19
T_3 (4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September**)**	3.12	128866.88	156000.00	27133.12	1.21
T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January**)**	4.09	165894.53	204500.00	38605.47	1.23

4.2. Effect of growth regulators on growth, yield and quality of sapota

4.2.1Growth characteristics

Growth characteristics i.e. tree height, tree spread (N-S and E-W) and canopy volume of sapota trees were measured before imposing treatments (first week of January 2018) and after completion of experiment (end of January 2019). The results obtained for the above parameters are presented and discussed as under.

The data on effect of growth regulators on the tree growth characteristics are presented in Table 10.

4.2.1.1 Tree height

There was non-significant difference among the treatments in tree height observed before and after conduction of experiment (Table 10). The average tree height before starting of experiment was 4.55 m and after completion of experiment was 5.37 m.

4.2.1.2 Tree spread (N-S and E-W)

The data on tree spread at both north-south and east-west direction (Table 10) revealed that there was non-significant difference among the treatments in tree spread at before and after carrying of experiment. The average tree spread on north-south direction at before and after conduction of experiment was 7.68 m and 8.37 m, respectively. Whereas the average tree spread on east-west direction at before and after conduction of experiment was 7.81 m 8.64 m, respectively.

4.2.1.3 Canopy volume

The canopy volume of sapota trees showed non-significant difference between different treatments at before and after conduction of experiment (Table 10). The average canopy volume before start of experiment was 129.76 m^3 and after completion it was176.41m^3.

The different growth regulators with various concentrations did not significantly influence the growth characters like tree height, tree spread and canopy volume which might be due to age of the trees and as a perennial crop, the effects of the treatments may represents after consecutive long term efforts. The growth regulators are growth promoters and irrespective of treatments growth increment was observed.

The maximum growth of trees due to application of growth regulators was earlier reported in sapota by Garhwal (2015). Similar result was recorded by Singh *et al.* (2011) and Kacha (2008) in phalsa

4.2.2 Flowering and fruiting parameters

The flowering and fruiting parameters *viz.* number of flowers per shoot, fruit set, fruit retention and period for fruit development were significantly influenced by application of various doses of growth regulators. The data on above mentioned parameters are presented in Table 11 and depicted in Fig. 19 and 20.

4.2.2.1 Number of flowers per shoot

The data presented in Table 11 and Fig. 19 reveals that there was significantly maximum number of flowers per shoot (16.13) was recorded in treatment T_7 (NAA 200 ppm) which was at par with T_6 (15.60). It was followed by T_5 (15.27), T_3 (14.90) and T_2 (14.50) and were at par among themselves and followed by T_4 (13.67). The minimum number of flowers per shoot (11.87) was recorded in T_1 (control).

4.2.2.2 Number of fruit set per shoot and fruit set percentage

The data on fruit set (Table 11) showed that the significantly highest number of fruit set per shoot (2.37) was in treatment T_7 and it was followed by T_6 (2.07), T_5 (1.83). The treatments T_2 (1.70) andT_3 (1.63) were at par with each other and was followed by T_4 (1.50). The minimum number of fruit set (1.10) was recorded in control (T_1)

Fruit set percentage in sapota was also significantly influenced by the application growth regulators (Table 11 and Fig. 20). The

significantly maximum fruit set percentage (14.68%) recorded in treatment T_7 and it was followed by T_6 (13.25%). The treatments T_5 (12.01%), T_2 (11.40% T_3 (11.27%) and T_4 (10.97%) were at par with each other. The lowest fruit set percent (9.31%) was in T_1 (Control).

4.2.2.3 Number of fruit retained and fruit retention percentage

The highest number of fruit retained per shoot (1.57) was recorded in treatment T_7 and it was followed by T_6 (1.30). The treatmentsT_5 (1.10), T_2 (1.07) and T_3 (0.97) were at par with each other and was followed by T_4 (0.80). The minimum number of fruit set (0.43) recorded in T_1 (Table 11)

It is clear from data (Table 11 and Fig. 20) that different growth regulator treatments had significant influence on fruit retention percentage. The highest fruit retention percentage (66.28%) recorded in NAA 200 ppm treatment (T_7) and it was at par with T_6 (63.03%), T_2 (62.66), T_5 (60.04%) and T_3 (59.19%) and then followed by T_4 (53.79%). The lowest fruit retention percentage (39.34) was observed in T_1 (control).

4.2.2.4 Period for fruit development

The data given in Table 11 revealed that the minimum period for fruit development (216.01 days) was recorded in T_4 (GA_3 150 ppm) which was at par with T_3 (216.65 days) T_2 (216.79 days), T_5 (217.78 days), T_6 (217.94 days) and T_7 (217.96 days). The maximum period for fruit development (224.81 days) recorded in T_1 (Control).

Results from the present investigation revealed that the flowering and fruiting parameters *viz.,* no. of flowers per shoot, fruit set percentage, fruit retention percentage, and fruit development period were increased with increasing levels of NAA and decreased with increasing levels of GA_3. The use of NAA may increase the physiological activity in the plants to build up sufficient food stock for the developing of flowers by creating favorable C/N ratio in terminals which ultimately resulted into increased number of flowers and fruit set per cent. On the other hand, the exogenous applications of NAA

may suppress the vegetative growth which promotes of reproductive growth resulted more number of flowers subsequently increased fruit set per cent (Veinbrant, 1969 and Singh and Chadha, 1992). The increased auxin content reduced the level of abscisic acid in plant and formation of abscission layer of fruit adjacent which reduces the fruit drop and increased fruit retention. The exogenous application of GA_3 promoted endogenous levels of auxin in the plant system and inhibited the formation of spurs as well as flower buds by increasing vegetative growth of the plant. The above findings are in conformity with the results obtained by Delvadia *et al.* (1994),Nambisan *et al.* (2007) and Garhwal *et al.* (2015) in sapota, Brahmachari *et al.* (1996) in guava, Sharma *et al.* (2005) and Singh *et al.* (2005) in litchi, and Singh *et al.* (2011) in phalsa.

4.2.3Yield parameters

The data on effect of growth regulators on yield and yield attributes of sapota cv. Kalipatti are presented in Table 12 and illustrated with Figure 21 and 22.

4.2.3.1 Number of fruits per tree

The data presented in Table 12 revealed that the growth regulators treatments significantly improved the yield and the highest number of fruits per tree (301.00) was harvested in GA_3 150 ppm treatment (T_4) and it was followed by T_7 (290.67), T_3 (285.00), T_6 (279.67) and T_5 (275.67) which were at par with each other. Then it was followed by T_2 (268.00) and lowest number of fruits per tree (243.67) was registered in T_1 (control).

4.2.3.2 Yield per tree

The value in Table 12 and Fig. 21 showed that the different growth regulators significantly influenced the yield per tree. The maximum yield per tree (44.48 Kg) was recorded in T_4 which was

followed by T_7 (40.57Kg), T_3 (37.66Kg), T_6 (35.43Kg), T_5 (33.36Kg), T_2 (31.23Kg).The minimum yield per tree (22.09Kg) was recorded in T_1.

4.2.3.3 Yield per hectare

The significantly enhanced productivity of sapota trees under experiment was observed due to growth regulators treatments (Table 12 and Fig. 22). The significantly maximum yield per hectare (2.85 t) was recorded in T_4 and it was followed by T_7 (2.65 t), T_3 (2.41 t), T_6 (2.27 t), T_5 (2.13 t), T_2 (2.00 t).The minimum yield per hectare (1.42 t) recorded in T_1.

The above stated results show that yield was increased with increasing concentration Gibberellic acid (GA_3). The exogenous application GA_3 may cause the increase in cell size and intercellular spaces coupled with more accumulation of water and nutrients in greater amount thus it should be increases the growth which improve the fruit size and weight which ultimately enhanced yield. The above results were in accordance with the findings of Delavadia *et al.* (1994) and Khawle (2016) in sapota, Kumar *et al.* (1998) in guava, Symal *et al.*(2010) in papaya and Bhowmick and Banick (2011) in mango.

Table 12. Effect of growth regulators on yield of sapota cv. Kalipatti

Treatments	Number of fruits / tree	Fruit yield/ tree (Kg)	Yield / ha (t)
T_1 (Control**)**	243.67	22.09	1.42
T_2 (GA_3 50 ppm**)**	268.00	31.23	2.00
T_3 (GA_3 100 ppm**)**	285.00	37.66	2.41
T_4 (GA_3 150 ppm**)**	301.00	44.48	2.85
T_5 (NAA 100 ppm**)**	275.67	33.36	2.13
T_6 (NAA 150 ppm**)**	279.67	35.43	2.27
T_7 (NAA 200 ppm**)**	290.67	40.57	2.65
Range	**243.67 – 301.00**	**22.09 – 44.48**	**1.42 – 2.85**
Mean	**277.67**	**34.97**	**2.24**
SEm ±	**2.16**	**0.25**	**0.02**
CD @ 5%	**6.67**	**0.77**	**0.05**

4.2.4 Physical characteristics

The treatments of different doses of growth regulators significantly influenced the physical parameters of sapota fruit. The data pertaining to effect of various doses of growth regulator treatments on physical characteristics of fruit are presented in Table 13 and Fig. 23, 24 and 25.

4.2.4.1 Fruit length

It is clear from Table 13 and Fig. 23 that all treatments significantly vary with fruit length, The significantly maximum fruit length (6.16 cm) was recorded in T_4 (GA_3 150 ppm) which was followed by T_7 (6.03 cm), T_3 (5.83 cm) which at par with T_6 (5.82 cm). Then it was followed by T_5 (5.74 cm) and T_2 (5.52 cm).The minimum fruit length (5.22 cm) was in T_1 (Control).

4.2.4.2 Fruit diameter

The various dose of growth regulators influenced significantly the fruit diameter (Table 13 and Fig. 23). The highest fruit diameter (5.81 cm) was recorded in T_4 and it was followed by T_7 (5.72 cm), T_3 (5.46 cm), T_6 (5.40 cm), T_5 (5.31 cm), T_2 (5.24 cm). The minimum fruit diameter (5.09 cm) was measured in T_1.

4.2.4.3 Fruit weight

The data in Table 13 and Fig. 24 revealed that the significantly highest fruit weight (146.17 g) was recorded in T_4 which was followed by T_7 (137.97 g), T_3 (132.13), T_6 (126.30 g), T_5 (121.00 g), T_2 (116.47 g). The lowest fruit weight was recorded in T_1 (89.20 g).

4.2.4.5 Fruit volume

A perusal of the data presented in Table 13 and Fig. 24 revealed that the significantly highest fruit volume (138.77 cc) was in T_4 and it was followed by T_7 (132.67 cc), T_3 (128.72 cc), T_6 (123.02 cc), T_5 (119.81 cc), T_2 (117.76 cc). The minimum fruit volume (92.27 cc) was recorded in T_1.

4.2.4.6 Specific gravity

The various dose of growth regulators significantly influenced the specific gravity of fruit (Table 13), The highest specific gravity (1.05) in sapota was recorded in T_4 which was it was at par with T_7 (1.04) and T_3 and T_6 (1.03) which are same and then it was followed by T_5 (1.01), T_2 (0.99).The lower specific gravity (0.97) was estimated in T_1. The significant variation in fruit weight and volume eventually caused variation in specific gravity of sapota fruits.

4.2.4.7 Number of seeds per fruit

There was non-significant effect of growth regulators on number of seeds per fruit and average number of seeds per fruit was 1.60 (Table 13)

4.2.4.8 Weight of seeds

The data on Table 13 revealed that there was non-significant difference among the treatments for the weight of seeds and the average weight of seeds 1.39 g was recorded.

4.2.4.4 Pulp weight

The significantly maximum pulp weight in sapota was recorded in T_4 (138.00 g) which was followed by T_7 (130.63 g), T_3 (124.43 g), T_6 (118.67 g), T_5 (113.20 g), T_2 (108.74 g).The minimum pulp weight (81.87 g) was in T_1 (Table 13).

4.2.4.9 Pulp/seed ratio

It is clear from Table 13 and Fig. 25 that all treatments significantly influenced the pulp to seed ratio in sapota. The significantly highest pulp/seed ratio (99.28) was recorded in T_4 which followed by T_7 (93.98), T_3 (89.31), T_6 (85.37), T_5 (81.05) and T_2 (78.00), whereas, the lowest ratio (57.29) was in T_1.

Increase in physical characteristics of fruit like fruit length, fruit diameter, fruit weight, pulp weight, fruit volume, specific gravity and pulp to seed ratio of fruit by GA_3 application was probably due to rapid cell division, cell expansion and increased in the volume of

inter cellular spaces mesocarp cells and accumulation of water and nutrients in these intercellular spaces.

Further these fruit characters were also increased by foliar application of NAA which cause excessive cell division in mesocarp and plasticity of cells.

The above findings are in close conformity with the results obtained by Ray *et al.* (1991), Agarwal and Dikshit (2010), Patil *et al.* (2010), Bhujbal *et al.* (2013), Garhwal (2015), Desai (2016) and Khawle (2016). Similar result was also recorded by Kumar *et al.* (1998), Lal *et al.* (2013) in guava, Sharma *et al.* (2005) in litchi, Khachave and Bhosale (2007) Jagtap *et al.* (2013) in lime and Bhowmick and Banik (2011) in mango.

4.2.5 Chemical characteristics

The data pertaining to effect of different growth regulators on chemical properties of fruit in sapota cv. Kalipatti are presented in Table 14 and illustrated with Figure 26, 27, 28 and 29.

4.2.5.1 Total soluble solids (TSS)

A perusal of the data presented in Table 14 and Fig. 26 revealed that the significantly maximum TSS (25.10 ^{0}B) was recorded in T_4 which was followed by T_7 (24.03 ^{0}B). The treatments T_6 (23.40 ^{0}B), T_3 (23.03 ^{0}B), T_2 (22.87 ^{0}B), T_5 (22.80 ^{0}B) was at par with each other. The minimum TSS was observed in T_1 (20.77 ^{0}B).

4.2.5.2 Titratable acidity

The data on Titratable acidity in sapota fruit as influenced by different growth regulators application (Table 14 and Fig. 27). The significantly minimum titrable acidity (0.13 %) was recorded in T_4 which was lowest to all other treatments and it was followed by T_7 (0.14 %), T_6 and T_3 (0.15 %) were recorded same value, then it was followed by T_2 which was equal to T_5 (0.16 %).The maximum acidity (0.17%) was recorded in T_1.

4.2.5.3 TSS/acidity ratio

It is evident from the data shown in Table 14 and Fig. 28 revealed that the significantly highest TSS/acidity ratio (192.60) was observed in T_4 (GA_3 150 ppm) and it was followed by T_7 (171.65), and T_3 (153.60) which was at par with T_6 (153.28). Then it was followed byT_5 (140.74) which was at par with T_2 (139.45).The minimum TSS/acidity ratio (121.68) was in T_1 (Control).

4.2.5.4 Reducing sugars

A perusal of the data presented in Table 14 and Fig. 29 revealed that the significantly maximum reducing sugars (11.58 %) was recorded in T_4 which was followed by T_7 (11.03 %), T_3 (10.76 %), T_6 (10.65 %), T_5 (10.49 %) and T_2 (10.23 %). The minimum reducing sugars was estimated in T_1 (9.89 %).

4.2.5.5 Non reducing sugars

The significantly highest non-reducing sugars (5.65 %) in sapota fruits was in T_4 and it was followed by T_7 (5.39 %) and T_6 (5.26 %) was at par with T_5 (5.23 %), then it was followed by T_3 (5.15 %), T_2 (5.00 %).The minimum non-reducing sugars (4.70 %) was recorded in T_1 (Table 14 and Fig. 29).

4.2.5.6 Total sugars

On the basis of data shown in Table 14 and Fig. 29, the treatment T_4 recorded significantly maximum total sugars (17.23 %) and it was followed by T_7 (16.42 %) and T_6 was recorded same with T_3 (15.91 %), then it was followed by T_5 (15.72 %), T_2 (15.23 %).The minimum total sugars registered in T_1 (14.60 %).

It is observed that the exogenous applications of GA_3 and NAA increased the chemical characters of fruits like TSS and reducing, non-reducing, and total sugars with increasing concentrations which might be due to more accumulation of metabolites and quick conversion of starch into simple sugars during the fruit development. The reduction in titratable acidity probably due to increased cell size

and intercellular spaces coupled with accumulation of water, sugar and other soluble solids in greater amount as a result of translocation of metabolites towards the fruit which decreased the acidity by increased sugar content of fruit. The above findings are in report of Ray *et al.* (1991), Chavan *et al.* (2009) Agarwal and Dikshit (2010), Bhujabal *et al.* (2013), Garhwal (2015) and Khawle (2016). Similar results were also recorded by Sharma *et al.* (2005) in litchi, Singh *et al.* (2011) in phalsa Bhowmick and Banik (2011) in mango, and Kumar *et al.* (2011) Bisen *et al.* (2014) and Sharma and Tiwari (2015) in guava.

4.2.6 Storage parameters

The perusal data on effect of growth regulators on storage parameters of sapota cv. Kalipatti was presented in Table 15 and illustrated with Figure 30, 31 and 32.

4.2.6.1 Shriveling and spoilage

The data shown in Table 15 and Fig. 30 revealed that different growth regulators significantly affected the shriveling and/or spoilage percentage of sapota fruits

At second day of storage there was no shriveling and/or spoilage of fruits was observed. At fourth day of storage shriveling and/or spoilage (5.33 %) was observed in treatment T1 (Control) which is significantly maximum to all other treatments and it is followed by T_5 (1.33 %). However, the shriveling and/or spoilage of sapota fruits were not absolutely observed in rest of the treatments.

At sixth day of storage significantly minimum shriveling and/or spoilage of fruits was noticed in T_4 (5.33 %) which was at par with T_3 and T_7 (9.33 %) which were recorded same value and then it was followed by T_6 (10.67 %) which was at par with T_2 (12.00 %) and T_5 (13.33 %).The maximum shriveling and/or spoilage (22.33 %) was in fruits of control (T_1).

At eighth day of storage, significantly minimum shriveling and/or spoilage (9.33 %) was observed in T_4 (GA_3 150 ppm) which was at par with T_3 (12.00) and T_7 (13.33 %), then it was followed by T_6 (17.33 %) which was at par with T_2 (20.00 %), T_5 (21.33 %).The maximum shriveling and/or spoilage was noticed in T_1 (34.67 %).

At tenth day of storage, significantly minimum shriveling and/or spoilage (18.67 %) was observed in T_4 and it was followed by T_3 (22.67 %) and then T_7 and T_6 (36.00 %) which were recorded same value and was at par withT_2 (37.33 %), then it was followed by T_5 (45.33 %). The maximum shriveling and/or spoilage (54.67 %) recorded in T_1.

4.2.6.2 Physiological loss in weight (PLW %)

The perusal data presented in Table 15 and Fig. 31 revealed that different growth regulators treatments significantly influenced the PLW percentage of sapota fruits.

At second day of storage, significantly lowest PLW (3.11 %) was observed in T_4. It was followed by T_3 (3.31 %) and T_2 (3.48 %) which was at par with T_7 (3.52 %), then it was followed by T_6 (3.76 %), T_5 (4.52 %).The maximum PLW (5.07 %) was recorded in T_1.

At fourth day of storage, similar trend was yet again seen. The minimum PLW (6.29 %) of fruits was in T_4 and it was followed by T_3 (6.91 %), T_2 (7.11 %), T_7 (7.32 %) and T_6 (7.49 %) which were at par with each other and it was followed by T_5 (8.69 %).The highest PLW was in T_1 (9.94 %).

At sixth day of storage, significantly lowest PLW % of sapota fruits was observed in T_4 (9.98 %) and it was followed by T_3 (10.27 %) and then T_2 (10.57 %) which was at par with T_7 (10.60 %), then it was followed by T_6 (10.82 %), T_5 (12.07 %).The highest PLW (14.07 %) was recorded in T_1.

At eighth day of storage, the minimum PLW was again observed in T_4 (11.55 %) and it was followed by T_3 (12.18 %), T_2 (12.95 %), T_7 (13.51 %), T_6 (14.27 %), T_5 (15.03 %).The maximum PLW % was recorded in T_1 (25.45 %).

At tenth day of storage, significantly minimum PLW (28.43 %) was observed in T_4 which was at par with T_3 (29.19 %) and then it was followed by T_2 (31.24 %) which was at par with T_7 (31.31 %) and T_6 (32.85 %), then it was followed byT_5 (34.33 %). The maximum PLW % was observed in T_1 (40.71 %).

4.2.6.3 Shelf life

The data presented in Table 15 and Fig. 32 revealed that different doses of growth regulators significantly influenced the shelf life of sapota fruits.

The significantly highest shelf life of sapota fruits (8.67 days) was recorded in T_4. It was followed by T_3 and T_7 (7.33 days) which were recorded same value and was at par with T_6 (7.00 days) and T_2 (6.67 days) and then it was followed by T_5 (5.33 days). The minimum shelf life (4.00 days) was recorded in control (T_1).

Interpretation of the data also revealed that storage attributes like decreased shriveling and spoilage and PLW percentage and increased shelf life of sapota fruits with increasing levels of GA_3 and NAA might be due to growth regulators minimized physiological loss in weight, spoilage loss, shriveling to the possible extent through the catalytic influence of plant growth regulators on biosynthesis of ascorbic acid from sugar and inhibition of oxidative enzymes. In another way, GA_3 enhances shelf life due to its action as anti-ethylene and ultimately delay ripening process. These above findings are in agreement with the results of Bhanja and Lenka (1994), Garhwal (2015) in sapota, Thapa and Gautham (2002) in mandarin, Kumar *et al.*(2011) in guava and Meena *et al.* (2012) in grape.

4.1.8. Effect of different growth regulators on Economics

The data presented in Table 16 revealed that the treatment T_7 resulted maximum net return (Rs. 53997.15/ ha) and B /C ratio (1.69) during experimentation. It was followed by T_4 (net return Rs. 52425.44 / ha and B /C ratio 1.58), T_6 (net return Rs. 38402.45/ha and B /C ratio 1.51), T_3 (net return Rs. 37711.31/ha and B /C ratio 1.46), T_5 (net return Rs. 33016.09/ha and B /C ratio 1.45), T_2 (net return Rs. 24247.17/ha and B /C ratio 1.32) and minimum in T_1 (net return Rs. 3699.71/ha and B /C ratio 1.05). The market sale price of sapota fruit during production season was Rs. 50/kg.

Table 16. Effect of growth regulators on economics of sapota cv. Kalipatti

Treatments	Yield (t/ha)	Expenditure incurred (Rs/ha)	Gross return (Rs/ha)	Net profit (Rs/ha)	B:C ratio
T_1 (Control)	1.42	67300.29	71000.00	3699.71	1.05
T_2 (GA_3 50 ppm)	2.00	75752.83	100000.00	24247.17	1.32
T_3 (GA_3 100 ppm)	2.41	82788.69	120500.00	37711.31	1.46
T_4 (GA_3 150 ppm)	2.85	90074.56	142500.00	52425.44	1.58
T_5 (NAA 100 ppm)	2.13	73733.91	106750.00	33016.09	1.45
T_6 (NAA 150 ppm)	2.27	75097.75	113500.00	38402.45	1.51
T_7 (NAA 200 ppm)	2.65	78502.85	132500	53997.15	1.69

Table 1. Effect of fertilizers on tree growth characteristics of sapota cv. Kalipatti

Treatments	Tree height (m)		Tree spread (m)				Canopy volume (m^3)	
			North - South		East – West			
	Before expt.	After expt.	Before expt.	After expt.	Before expt.	After expt.	Before expt.	After expt.
T_1 (1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June)	7.28	8.03	9.41	10.67	10.13	11.09	323.31	428.82
T_2 (3 Kg each NPK +200Kg FYM $Tree^{-1}$ $Year^{-1}$ in June)	7.40	8.22	9.80	11.20	9.61	10.81	337.13	429.19
T_3 (4.5 Kg each NPK+ 300 Kg FYM $Tree^{-1}$ $Year^{-1}$ in two splits i.e., ½ in June and ½ in September)	7.38	8.24	9.80	11.42	9.97	11.31	338.24	444.36
T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January)	7.35	8.27	9.73	11.61	9.86	11.35	334.88	452.02
Range	7.28 – 7.40	8.03 – 8.27	9.41 – 9.73	10.67 – 11.61	9.61 – 10.13	11.09 – 11.35	323.31 – 334.88	428.82 – 452.02
Mean	7.35	8.19	9.68	11.22	9.89	11.14	333.39	438.60
SEm ±	0.19	0.15	0.45	0.41	0.51	0.41	31.17	27.67
CD @ 5%	N S	N S	N S	N S	N S	N S	N S	N S

Table 2. Effect of fertilizers on length of shoot and number of leaves per shoot of sapota cv. Kalipatti

Treatments	Length of shoot(cm)		Number of leaves / shoot	
	60 DAT	120 DAT	60 DAT	120 DAT
T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June)	12.84	20.18	10.60	15.70
T_2 (3 Kg each NPK +200Kg FYM Tree^{-1} Year^{-1} in June)	14.72	21.35	12.08	16.84
T_3 (4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September)	16.35	24.34	13.80	18.60
T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January)	18.23	26.48	15.88	21.12
Range	12.84 – 18.23	20.18 – 26.48	10.60 – 15.88	15.70 – 21.12
Mean	15.53	23.09	13.09	18.07
SEm ±	0.20	0.18	0.24	0.20
CD @ 5%	0.61	0.55	0.74	0.60

Table 3. Effect of fertilizers on flowering and fruiting characteristics of sapota cv. Kalipatti

Treatments	No. of flower/ shoot	No. of fruit set/shoot	Fruit set (%)	No. of fruit retained/ shoot	Fruit retention (%)	Fruit development Period (Days)
T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June)	10.28	1.80	17.50	0.7	38.99	226.12
T_2 (3 Kg each NPK +200Kg FYM Tree^{-1} Year^{-1} in June)	10.66	1.96	18.38	0.8	40.83	222.36
T_3 (4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September)	11.38	2.84	24.91	1.26	44.36	216.32
T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January)	12.52	3.52	29.69	1.76	47.28	214.96
Range	10.28 – 12.52	1.80 – 3.52	17.50 – 29.69	0.70 – 1.76	38.99 – 47.28	10.28 – 12.52
Mean	11.21	2.53	22.62	1.13	42.86	219.94
SEm ±	0.12	0.12	0.40	0.04	0.97	0.69
CD @ 5%	0.38	0.37	1.24	0.12	3.00	2.13

Table 5a. Effect of fertilizers on physical characteristics of fruit in sapota cv. Kalipatti

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit volume (cc)	Specific gravity
T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June**)**	5.64	5.53	108.98	111.76	0.98
T_2 (3 Kg each NPK +200Kg FYM Tree^{-1} Year^{-1} in June**)**	5.91	5.62	120.42	123.05	0.98
T_3 (4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September**)**	6.04	5.81	128.40	125.10	1.03
T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January**)**	6.20	6.08	138.14	132.34	1.04
Range	**5.64 – 6.20**	**5.53 – 6.08**	**108.98 – 138.14**	**111.76 – 132.34**	**0.98 – 1.04**
Mean	**5.95**	**5.76**	**123.99**	**123.06**	**1.01**
SEm ±	**0.02**	**0.03**	**0.40**	**0.04**	**0.97**
CD @ 5%	**0.38**	**0.37**	**1.24**	**0.12**	**3.00**

Table 5b. Effect of fertilizers on physical characteristics of fruit in sapota cv. Kalipatti

Treatments	No. of seeds/ fruit	Seeds weight (g))	Pulp weight (g)	Pulp/Seed ratio
T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June**)**	1.62	1.31	101.16	77.29
T_2 (3 Kg each NPK +200Kg FYM Tree^{-1} Year^{-1} in June**)**	1.70	1.37	113.08	82.44
T_3 (4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September**)**	1.86	1.45	120.06	82.60
T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January**)**	1.86	1.51	130.08	85.95
Range	**1.62 – 1.86**	**1.31 – 1.51**	**101.16 – 130.08**	**77.29 – 85.95**
Mean	**1.76**	**1.41**	**116.10**	**82.07**
SEm ±	**0.03**	**0.02**	**0.85**	**1.12**
CD @ 5%	**0.08**	**0.05**	**2.63**	**3.45**

Table 6. Effect of fertilizers on chemical characteristics of fruit in sapota cv. Kalipatti

Treatments	TSS (^{0}B)	Titrable acidity (%)	TSS / acidity ratio	Reducing sugars (%)	Non - reducing sugars (%)	Total sugars (%)
T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June**)**	21.58	0.16	138.81	9.85	4.94	14.79
T_2 (3 Kg each NPK +200Kg FYM Tree^{-1} Year^{-1} in June**)**	22.64	0.15	155.99	10.20	5.13	15.33
T_3 (4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September**)**	23.92	0.14	169.70	10.67	5.22	15.89
T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January**)**	24.98	0.13	187.01	11.06	5.56	16.62
Range	**21.58 – 24.98**	**0.13 – 0.16**	**138.81 – 187.01**	**9.85 – 11.06**	**4.94 – 5.56**	**14.79 – 16.62**
Mean	**23.28**	**0.14**	**162.88**	**10.44**	**5.21**	**15.66**
SEm ±	**0.16**	**0.001**	**2.36**	**0.04**	**0.03**	**0.05**
CD @ 5%	**0.49**	**0.005**	**7.27**	**0.11**	**0.10**	**0.14**

Table 7. Effect of fertilizers on storage characteristics (room temperature 27^{0}C) of sapota cv. Kalipatti

Treatments	Shriveling and spoilage (%)					PLW (%)					Shelf life (days)
	Day 2	Day 4	Day 6	Day 8	Day 10	Day 2	Day 4	Day 6	Day 8	Day 10	
T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June**)**	0	0.40	16.00	33.60	47.20	4.43	8.28	12.35	19.72	39.15	4.40
T_2 (3 Kg each NPK + 200Kg FYM Tree^{-1} Year^{-1} in June**)**	0	0	11.20	27.20	40.80	4.27	7.58	11.56	16.06	33.56	6.20
T_3 (4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September**)**	0	0	9.60	13.60	33.60	3.44	6.52	10.32	12.02	28.62	6.80
T_4 (6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January**)**	0	0	8.80	12.00	29.60	3.18	6.00	9.94	11.31	27.14	8.20
Range	**0**	**0.00 – 0.40**	**8.80 – 16.00**	**12.00 – 33.6**	**29.60 – 47.2**	**3.18 – 4.43**	**6.00 – 8.28**	**9.94 – 12.35**	**11.31 – 19.72**	**27.14 – 39.15**	**4.40 – 8.20**
Mean	**0**	**0.10**	**11.40**	**21.60**	**37.80**	**3.83**	**7.09**	**11.04**	**14.78**	**32.12**	**6.40**
SEm ±	**0**	**0.12**	**0.82**	**1.25**	**1.62**	**0.03**	**0.07**	**0.05**	**0.13**	**0.51**	**0.23**
CD @ 5%	**0**	**N S**	**2.51**	**3.86**	**4.98**	**0.09**	**0.22**	**0.17**	**0.39**	**1.58**	**0.72**

Table 8. Effect of fertilizers on chemical properties of soil before expt. And after harvest in sapota cv. Kalipatti

Treatments	pH	EC (dSm^{-1} at 25° C)	Organic Carbon (%)	Available Nitrogen (Kg/ha)	Available Phosphorous (Kg/ha)	Available Potassium (Kg/ha)
T_1 (1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June**)**	5.65	0.14	16.00	215.46	53.18	549.22
T_2 (3 Kg each NPK + 200Kg FYM $Tree^{-1}$ $Year^{-1}$ in June**)**	5.67	0.15	16.20	224.60	55.10	556.64
T_3 (4.5 Kg each NPK+ 300 Kg FYM $Tree^{-1}$ $Year^{-1}$ in two splits i.e., ½ in June and ½ in September**)**	5.66	0.15	16.12	229.36	57.57	577.60
T_4 (6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January**)**	5.63	0.14	16.30	227.60	59.27	581.36
Range	**5.63 – 5.67**	**0.14 – 0.15**	**16.00 – 16.30**	**215.46 – 229.36**	**53.18 – 59.27**	**549.22 – 581.36**
Mean	**5.65**	**0.14**	**16.16**	**224.25**	**56.28**	**566.21**
SEm ±	**0.01**	**0.003**	**0.07**	**0.42**	**0.47**	**0.49**
CD @ 5%	**NS**	**NS**	**NS**	**1.29**	**1.46**	**1.51**
Before experiment	**5.68**	**0.13**	**15.6**	**219.52**	**54.60**	**560**

Table 10. Effect of growth regulators on tree growth characteristics of sapota cv. Kalipatti

Treatments	Tree height (m)		Tree spread (m)				Canopy volume (m^3)	
			North - South		East – West			
	Before expt.	After expt.	Before expt.	After expt.	Before expt.	After expt.	Before expt.	After expt.
T_1 (Control)	4.44	4.88	8.53	8.92	8.42	9.23	152.04	191.53
T_2 (GA_3 50 ppm)	4.37	5.23	7.92	8.60	8.42	9.17	140.97	194.55
T_3 (GA_3 100 ppm)	4.90	5.65	7.45	8.10	7.70	8.44	133.39	133.22
T_4 (GA_3 150 ppm)	4.86	5.61	7.26	8.03	7.14	8.21	120.81	178.63
T_5 (NAA 100 ppm)	4.50	5.51	7.84	8.51	7.65	8.47	124.65	187.96
T_6 (NAA 150 ppm)	4.20	5.21	7.18	8.14	7.89	8.81	113.69	166.74
T_7 (NAA 200 ppm)	4.59	5.50	7.61	8.25	7.47	8.18	122.80	182.22
Range	**4.20 – 4.90**	**4.88 – 5.65**	**7.18 – 8.53**	**8.03 – 8.92**	**7.14 – 8.42**	**8.18 – 9.23**	**113.69 – 152.04**	**133.22 – 194.55**
Mean	**4.55**	**5.37**	**7.68**	**8.37**	**7.81**	**8.64**	**129.76**	**176.41**
SEm ±	**0.23**	**0.22**	**0.46**	**0.46**	**0.30**	**0.28**	**8.18**	**21.51**
CD @ 5%	**N S**	**N S**	**N S**	**N S**	**N S**	**N S**	**N S**	**N S**

Table 11. Effect of growth regulators on flowering and fruiting characteristics of sapota cv. Kalipatti

Treatments	No. of flower/shoot	No. of fruit set/shoot	Fruit set (%)	No. of fruit retained/shoot	Fruit retention (%)	Fruit development Period (Days)
T_1 (Control**)**	11.87	1.10	9.31	0.43	39.34	224.81
T_2 (GA_3 50 ppm**)**	14.90	1.70	11.40	1.07	62.66	216.79
T_3 (GA_3 100 ppm**)**	14.50	1.63	11.27	0.97	59.19	216.65
T_4 (GA_3 150 ppm**)**	13.67	1.50	10.97	0.80	53.79	216.01
T_5 (NAA 100 ppm**)**	15.27	1.83	12.01	1.10	60.04	217.78
T_6 (NAA 150 ppm**)**	15.60	2.07	13.25	1.30	63.03	217.94
T_7 (NAA 200 ppm**)**	16.13	2.37	14.68	1.57	66.28	217.96
Range	**11.87 – 16.13**	**1.10 – 2.37**	**9.31 – 14.68**	**0.43 – 1.57**	**39.34 – 66.28**	**216.01 – 224.81**
Mean	**14.56**	**1.74**	**11.84**	**1.03**	**57.76**	**218.28**
SEm ±	**0.21**	**0.03**	**0.28**	**0.03**	**1.93**	**0.63**
CD @ 5%	**0.64**	**0.10**	**0.88**	**0.10**	**5.96**	**1.96**

Table 13. Effect of growth regulators on physical characteristics of fruit in sapota cv. Kalipatti

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit volume (cc)	Specific gravity	No. of seeds/ fruit	Seeds weight (g))	Pulp weight (g)	Pulp/ Seed ratio
T_1 (Control**)**	5.22	5.09	89.20	92.27	0.97	1.70	1.40	81.87	57.29
T_2 (GA_3 50 ppm**)**	5.52	5.24	116.47	117.76	0.99	1.63	1.39	108.74	78.00
T_3 (GA_3 100 ppm**)**	5.83	5.46	132.13	128.72	1.03	1.63	1.39	124.43	89.31
T_4 (GA_3 150 ppm**)**	6.16	5.81	146.17	138.77	1.05	1.60	1.39	138.00	99.28
T_5 (NAA 100 ppm**)**	5.74	5.31	121.00	119.81	1.01	1.67	1.40	113.20	81.05
T_6 (NAA 150 ppm**)**	5.82	5.40	126.30	123.02	1.03	1.63	1.39	118.67	85.37
T_7 (NAA 200 ppm**)**	6.03	5.72	137.97	132.67	1.04	1.67	1.39	130.63	93.98
Range	**5.22 – 6.16**	**5.09 – 5.81**	**89.20 – 146.17**	**92.27 – 138.77**	**0.97 – 1.05**	**1.60 – 1.70**	**1.39 – 1.40**	**81.87 – 138.00**	**57.29 – 99.28**
Mean	**5.76**	**5.43**	**124.18**	**121.86**	**1.02**	**1.60**	**1.39**	**116.51**	**83.47**
SEm ±	**0.01**	**0.01**	**0.35**	**0.62**	**0.004**	**0.03**	**0.004**	**0.46**	**0.43**
CD @ 5%	**0.03**	**0.03**	**1.09**	**1.92**	**0.01**	**NS**	**NS**	**1.43**	**1.31**

Table 14. Effect of growth regulators on chemical characteristics of fruit in sapota cv. Kalipatti

Treatments	TSS (° B)	Titrable acidity (%)	TSS / acidity ratio	Reducing sugars (%)	Non - reducing sugars (%)	Total sugars (%)
T_1 (Control)	20.77	0.17	121.68	9.89	4.70	14.60
T_2 (GA_3 50 ppm)	22.87	0.16	139.45	10.23	5.00	15.23
T_3 (GA_3 100 ppm)	23.03	0.15	153.60	10.76	5.15	15.91
T_4 (GA_3 150 ppm)	25.10	0.13	192.60	11.58	5.65	17.23
T_5 (NAA 100 ppm)	22.80	0.16	140.74	10.49	5.23	15.72
T_6 (NAA 150 ppm)	23.40	0.15	153.28	10.65	5.26	15.91
T_7 (NAA 200 ppm)	24.03	0.14	171.65	11.03	5.39	16.42
Range	**20.77 – 25.10**	**0.13 – 0.17**	**121.68 – 192.60**	**9.89 – 11.58**	**4.70 – 5.65**	**14.60 – 17.23**
Mean	**23.14**	**0.15**	**153.28**	**10.66**	**5.20**	**15.86**
SEm ±	**0.18**	**0.002**	**0.96**	**0.03**	**0.02**	**0.03**
CD @ 5%	**0.55**	**0.005**	**2.95**	**0.08**	**0.06**	**0.09**

Table 15. Effect of growth regulators on storage characteristics (room temperature 27^{0}C) of sapota cv. Kalipatti.

Treatments	Shriveling and spoilage (%)					PLW (%)					Shelf life (days)
	Day 2	Day 4	Day 6	Day 8	Day 10	Day 2	Day 4	Day 6	Day 8	Day 10	
T_1 (Control)	0	5.33	22.33	34.67	54.67	5.07	9.94	14.07	25.45	40.71	4.00
T_2 (GA_3 50 ppm)	0	0.00	12.00	20.00	37.33	3.48	7.11	10.57	12.95	31.24	6.67
T_3 (GA_3 100 ppm)	0	0.00	9.33	12.00	26.67	3.31	6.91	10.27	12.18	29.19	7.33
T_4 (GA_3 150 ppm)	0	0.00	5.33	9.33	18.67	3.11	6.29	9.98	11.55	28.43	8.67
T_5 (NAA 100 ppm)	0	1.33	13.33	21.33	45.33	4.52	8.69	12.07	15.03	34.33	5.33
T_6 (NAA 150 ppm)	0	0.00	10.67	17.33	36.00	3.76	7.49	10.82	14.27	32.85	7.00
T_7 (NAA 200 ppm)	0	0.00	9.33	13.33	36.00	3.52	7.32	10.60	13.51	31.31	7.33
Range	**0**	**0.00 – 5.33**	**5.33 – 22.33**	**9.33 – 34.67**	**18.67 – 54.67**	**3.11 – 5.07**	**6.29 – 9.94**	**9.98 – 14.07**	**11.55 – 25.45**	**28.43 – 40.71**	**4.00 – 8.67**
Mean	**0**	**0.95**	**11.76**	**18.29**	**36.38**	**3.82**	**7.68**	**11.20**	**14.99**	**32.58**	**6.62**
SEm ±	**0**	**0.57**	**1.35**	**1.37**	**1.24**	**0.05**	**0.07**	**0.05**	**0.28**	**0.59**	**0.22**
CD @ 5%	**0**	**1.77**	**4.15**	**4.22**	**3.84**	**0**	**0.22**	**0.17**	**0.39**	**1.58**	**0.68**

CHAPTER V
SUMMARY AND CONCLUSION

SUMMARY:

The present investigation entitled "**Effect of fertilizer levels and growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kalipatti**" was conducted at Department of Horticulture, College of Agriculture, Dapoli (M.S.) during 2017-19 with following objectives.

190. To study the effect of graded doses of fertilizers on yield and yield attributes of sapota.
191. To study the effect of graded doses of fertilizers on physico – chemical properties of sapota.
192. To study the effect of NAA and GA_3 on yield and yield attributes of sapota.
193. To study the effect of NAA and GA_3 on physico – chemical properties of sapota.

The data obtained during the present investigation was statistically analysed as per the methods prescribed by Panse and Sukhatme (1985). The salient findings of the investigation are summarized here under.

5.1 Effect of fertilizer levels on growth, yield and quality of sapota

5.1.1 Growth observations

There was non-significant variation among treatments for tree height, tree spread and canopy volume before and after experiment was observed. The average tree height before and after experiment i.e. 7.35 m and 8.19 m, the average tree spread in N-S direction i.e. 9.68 m and 11.14 m and in E-W direction i.e. 9.89 m and 11.14 m at before and after conducting the experiment respectively, while the

average canopy volume before starting experiment i.e. 333.39 m^3 and after completion of experiment i.e. 438.60 m^3 were recorded.

The application of treatment T_4 i.e. 6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January resulted in significantly maximum shoot length and number of leaves per shoot at 60 & 120 days after treatment (18.23 cm, 26.48 cm and 15.88, 21.12 respectively).

While, the application of treatment T_1 i.e. 1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June recorded significantly minimum shoot length and number of leaves per shoot at 60 & 120 days after treatment in treatment (12.84 cm, 20.18 cm and 10.60, 15.70 respectively).

5.1.2 Flowering and fruiting observations

The significantly maximum number of flowers per shoot (12.52), number of fruit set (3.52), fruit set % (29.69%), number of retained fruits (1.76), fruit retention % (47.28%) and minimum period for fruit development (214.96 days) were observed with application of treatment T_4 i.e. 6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January.

Whereas, the application of treatment T_1 i.e. 1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June resulted significantly minimum number of flowers per shoot (10.28), number of fruit set (1.08), fruit set (17.50%), number of retained fruits (0.7), fruit retention % (38.99%) and maximum period for fruit development (226.12 days).

5.1.3 Yield observations

The application of treatment T_4 i.e. 6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January resulted in significantly maximum number of fruits per tree (429.46), fruit yield per tree (63.85 Kg) and yield per hectare (4.09 ton).

While, the application of treatment T_1 i.e. 1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June recorded significantly minimum number of fruits per tree (268.30), fruit yield per tree (29.63 Kg) and yield per tree (1.89 ton),

5.1.4 Physical characteristics of fruit

The significantly maximum fruit length (6.20 cm), fruit diameter (6.08 cm), fruit weight (138.14 g), pulp weight (130.08 g), volume of fruit (132.34 cm^3), specific gravity of fruit (1.04), number of seeds per fruit (1.86), seed weight per fruit (1.51 g) and pulp/seed ratio (85.95) resulted in application of treatment T_4 i.e. 6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January

While, the application of treatment T_1 i.e. 1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June recorded significantly minimum fruit length (5.64 cm), fruit diameter (5.53 cm), fruit weight (108.98 g), pulp weight (101.16 g), volume of fruit (111.76 cm^3), specific gravity fruit (0.98), minimum number of seeds per fruit (1.62), seed weight per fruit (1.31g) and pulp/seed ratio (77.29).

5.1.5 Chemical characteristics of fruit

The application of treatment T_4 i.e. 6 Kg each NPK + 400 Kg FYM $Tree^{-1}$ $Year^{-1}$ in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January resulted in significantly maximum TSS (24.98 ^{0}B), TSS/acidity ratio (187.01), reducing sugars (11.06%), non-reducing sugars (5.56%), total sugars (16.62%) and minimum Titratable acidity (0.13%),

While, the application of treatment T_1 i.e. 1.5 Kg Each NPK + 100Kg FYM $Tree^{-1}$ $Year^{-1}$ in June recorded significantly minimum TSS (21.58 ^{0}B), TSS/acidity ratio (138.81), reducing sugars (9.85%), non-reducing sugars (4.94%), total sugars (14.79%) and highest Titratable acidity of fruit (0.16%).

5.1.6 Storage characteristics of fruit

The trees treated with treatment T_4 i.e. 6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January, resulted in significantly minimum PLW % on 2nd, 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 3.18%, 6%, 9.94%, 11.31% and 27.14% respectively), shrivelling and/or spoilage % on 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 0%, 11.40%, 21.60% and 37.80% respectively) and significantly maximum shelf life (8.2 days).

While, the significantly highest PLW % on 2nd, 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 4.43%, 8.28%, 12.35%, 19.72% and 39.15% respectively), shrivelling and/or spoilage % on 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 0.40%, 16%, 33.60% and 47.20% respectively) and significantly minimum shelf life (4.4 days) were recorded with application of treatment T_1 i.e. 1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June recorded

5.1.6 Chemical properties of soil

The soil chemical properties like pH, EC and organic carbon percentage are shown non-significant variation among treatments with different fertilizer doses after completion of experiment. The soil analysis resulted in the average values of pH, EC, organic carbon as 5.65, 0.14 dSm^{-1} and 16.16 % respectively.

Whereas there was significant difference between treatments recorded for available NPK after the completion of experiment. The significantly highest available N (229.36 Kg/ha) analysed in treatment T_3 i.e. 4.5 Kg each NPK+ 300 Kg FYM Tree^{-1} Year^{-1} in two splits i.e., ½ in June and ½ in September, and maximum available P and K (59.27 and 581.36 Kg/ha respectively.) were recorded with treatment T_4 i.e. 6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓in June, ⅓ in September and ⅓ in January.

While, the significantly minimum amount of available NPK (215.46, 53.18, 549.22 Kg/ha respectively) recorded with treatment T_1 i.e. 1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June.

5.1.7 Economics feasibility of different fertilizer treatments

The trees treated T_4 i.e. 6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January, resulted in maximum net return (Rs. 38605.47/ ha) and B /C ratio (1.23) during experimentation and minimum net return (Rs. 9867.48/ha) and B /C ratio (1.18) in treatment T_1 (1.5 Kg Each NPK + 100Kg FYM Tree^{-1} Year^{-1} in June.)

5.2 Effect of growth regulators on growth, yield and quality of sapota

5.2.1 Growth observations

There was non-significant variation among treatments for tree height, tree spread and canopy volume before and after experiment was observed. The average tree height before and after experiment i.e. 4.55 m and 5.37 m, the average tree spread in N-S direction i.e. 7.68 m and 8.37 m and in E-W direction i.e. 7.81 m and 8.64 m before and after conducting the experiment respectively were recorded. The average canopy volume before starting experiment i.e. 129.76 m^3 and after completion of experiment i.e. 176.41 m^3 were recorded.

5.2.2 Flowering and fruiting observations

The application of treatment T_7 i.e. NAA 200 ppm resulted in significantly maximum number of flowers per shoot (16.13), number of fruit set (2.37) fruit set percentage (14.68%), number of retained fruits (1.57) and fruit retention percentage (66.28%). While, the minimum period for fruit development (216.01 days) recorded with application of GA_3 150 ppm (T_4).

While, the treatments T_1 i.e. control recorded significantly minimum in number of flowers per shoot (11.87), number of fruit set (1.10) fruit set percentage (9.31 %), number of fruits retained (0.43), fruit retention percentage (39.34 %) and The maximum period for fruit development (224.81 days).

15.2.3 Yield observations

The application of treatment T_4 i.e. GA_3 150 ppm resulted in significantly maximum number of fruits per tree (301.00), fruit yield per tree (44.48 Kg) and yield per hectare (2.85 ton).

While, the treatments T_1 i.e. control recorded significantly minimum in number of fruits per tree (243.67), minimum fruit yield per tree (22.09 Kg) and yield per tree (1.42 ton).

5.2.4 Physical characteristics of fruit

The application of treatment T_4 i.e. GA_3 150 ppm resulted in significantly maximum fruit length (6.16 cm), fruit diameter (5.81 cm), fruit weight (146.17 g), volume of fruit (138.77 cm^3), specific gravity of fruit (1.05), pulp weight (138.00 g), pulp/seed ratio (99.28).

While, the treatments T_1 i.e. control recorded significantly minimum in fruit length (5.22 cm), fruit diameter (5.09 cm), fruit weight (89.20 g), volume of fruit (92.27 cm^3), specific gravity of fruit (0.97), pulp weight (81.87 g), pulp/seed ratio (57.29), and maximum seed weight (1.42 g).

There was non-significant difference found in number of seeds per fruit with average value of 1.60 seeds per fruit and also for and seed weight per fruit which recorded average value of 1.39 g.

5.2.5 Chemical characteristics of fruit

The application of treatment T_4 i.e. GA_3 150 ppm resulted in significantly maximum fruit TSS (25.10 ^0B), TSS/acidity ratio (192.60), reducing sugars (11.58%), non-reducing sugars (5.65%), total sugars (17.23%) and minimum Titratable acidity of fruit (0.13%).

While, the treatments T_1 i.e. control recorded significantly minimum in fruit TSS (20.77 ^{0}B), TSS/acidity ratio (121.68), reducing sugars (9.89%), non-reducing sugars (4.70%), total sugars (14.60%) and highest Titratable acidity of fruit (0.17%).

5.2.6 Storage characteristics of fruit

The application of treatment T_4 i.e. GA_3 150 ppm resulted in significantly minimum PLW % on 2nd, 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 3.11%, 6.29%, 9.98%, 11.55% and 28.43% respectively), shrivelling and/or spoilage % on 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 0%, 5.33%, 9.33% and 18.67% respectively) and maximum shelf life (8.67 days).

While, the treatments T_1 i.e. control recorded significantly maximum PLW % on 2nd, 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 5.07%, 9.94%, 14.07%, 25.45% and 40.71% respectively), shrivelling and spoilage % on 4th, 6th, 8th, and 10th day of storage of fruits (i.e. 5.33%, 22.33%, 34.67% and 54.67% respectively) and minimum shelf life (4.00 days).

5.1.7 Economics feasibility of different fertilizer treatments

The trees applied with treatment T_7 i.e. NAA 200 ppm resulted in maximum net return (Rs. 53997.15/ ha) and B /C ratio (1.69) during experimentation and minimum net return (Rs. 3699.71/ha and B /C ratio (1.05) in control (T_1).

CONCLUSION:

On the basis of results obtained in the present investigation entitled "**Effect of fertilizer levels and growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kalipatti**" it may be concluded that the application of fertilizer dose of 6 Kg each NPK + 400 Kg FYM Tree^{-1} Year^{-1} in three splits i.e., ⅓ in June, ⅓ in September and ⅓ in January (T_4) has enhanced the new vegetative growth, flowering, fruiting and yield characteristics i.e. number of leaves per shoot, length of shoot, number of flowers per

shoot, fruit set, fruit retention and minimum number of days required for maturity as well as maximum number of fruits per plant, yield per plant and per hectare. This treatment also improved nutritional qualities of fruits viz. total soluble solids, sugar content (reducing, non-reducing and total sugars), TSS/ acid ratio, and reduction in fruit acidity, and it also resulted in increased physical characteristics of fruit like fruit and pulp weight, fruit volume, specific gravity and pulp to seed ratio. The storage parameters like PLW per cent and shrivelling and spoilage of fruits were decreased with above mentioned treatment and thus it increased the shelf life of fruits. Highest Benefit:Cost ratio is calculated in this treatment

On the other hand the spraying of growth regulator NAA at 200 ppm (T_7) have increased the flowering and fruiting characteristics i.e. number of flowers per shoot, fruit set, fruit retention. While the trees treated with GA_3 at 150 ppm (T_4) have increased yield and yield attributing characters like number of fruits per plant, yield per plant and per hectare and also improved physical characters of fruit like fruit and pulp weight, fruit volume, specific gravity and pulp to seed ratio, and same treatment also improved quality characters of fruits viz. total soluble solids, sugar content (reducing, non-reducing and total sugar), TSS/ acid ratio, and reduction in fruit acidity and also reduced PLW per cent and shrivelling and spoilage of fruits and thus it increased the shelf life of fruits. As the cost of NAA is less compared to GA_3, the highest Benefit:Cost ratio is calculated in treatment T_7 (NAA at 200 ppm).

As the sapota is perennial fruit crop, for confirmation of results the experiment may be conducted for consecutive years.

LITERATURE CITED

A.O.A.C. 1990. *Official Methods of Analysis*. Association of Official Agricultural Chemists.Benjamin Franklin Station, Washington, DC., USA.

Agrawal, S. and Dikshit, S.N. 2010. Studies on the effect of plant growth regulators on qualitative characters of sapota cv. Cricket Ball. *Ind. J. Hort.* **67** (4): 117-180.

Ahmad, M.B.M., Salik, M.R. and Awan, M.Z. 2009. Manure and fertilizers effect on yield and fruit quality of guava (*Psidium guajava* L.). *Journal of Agricultural Resources*, 3: 247-251.

Ahmed T., Burhanuddin M., Haque M.A., Hossain M.A. 2011. Preparation of Jam from Sapota (*Achras zapota*). *A Scientific Journal of Krishi Foundation,* **9**(1&2): 1-7.

Anonymous, 2017. Indian Horticulture Database. National Horticulture Board, Gurgaon, Haryana, 04 p.

Baviskar, M.N., Bharad, S.G., Dod V.N. and Varsha G. Barne. 2011. Effect of integrated nutrient management on yield and quality of sapota. *Plant Archives* **11** (2): 661-663.

Bhanja, P.K. and Lenka, P.C. 1994. Effect of pre and postharvest treatments on storage life of sapota fruits cv. Oval. *Orissa J. Hort*. **22** (1/2): 54-57.

Bhat, A., Kher, R. and Gupta, S.P. 2000. Effect of growth regulators and nutrients on fruit cracking and quality in lemon. *Haryana J. Hort. Sci.* **30** (3&4): 207.

Bhati, B.S. and Yadav, P.K. 2003. Effect of foliar application of urea and NAA on quality of ber (*Zizyphus mauritiana* L.) cultivar Gola. *Haryana J. Hort. Sci.* **32** (1&2): 32-33.

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

Bhujbal, D.S., Naik, D.M. And Kale, S.A. 2013. Studies on effect of growth regulators on flowering, fruiting and quality of sapota. *International J. Agricultural Sciences.* **9** (1): 289-292

Bhuva H.P., Kartodia J.S. and Patel R. G. 1990. Effect of different levels of moisture regieme and nutrient on growth, yield and economics of sapota (*Achras zapota* L.) cv. Kalipatti. *Haryana J. Hort. Sci.* **19** (1-2): 71-78

Bisen, S., Thakur, R.S. and Tembhare, D. (2014). Effect of calcium nitrate and gibberellic acid application on growth, fruit quality and post-harvest behavior of guava fruit cv. Allahabad Safeda. International Quarterly j. Enviro. Sci. **5** : 55-62.

Biswas, B., Sen, S.K. and Maity, S.C. 1989. Effect of different levels of nitrogen and potassium in growth, yield and quality of papaya var. 'Ranchi'. *Haryana Journal of Horticultural Science*, **18**: 197-203.

Black C.A. 1965. "Methods of Soil Analysis: Part I Physical and mineralogical properties". Agronomy No.9. American Society of Agronomy, Madison, WI.

Boora R.S. and Devi singh. 2000. Effect of NPK on growth, yield and quality of sapota (*Manilkara achraz* (Mill.) Forseberg) cv. Cricket ball. *Haryana J. Hort. Sci.* **29** (3/4):188-189.

Borah, S.C., Barbora, A.C. and Bhattacharya, D. 2001. Effect of organic and inorganic manuring on growth, yield and quality of 'Khasi Mandarin' (*Citrus reticulata* Blanco). *South Indian Horticulture*, **49**: 115-118.

Bose, T.K. and Mitra, 1990. Fruits: Tropical and Subtropical. Naya Prakash, Calcutta, pp. 565-591.

Brahmachari, V.S., Mandal, A.K., Kumar, R. and Rani, R. 1996. Effect of growth substances on flowering and fruiting characters of 'Sardar' guava. (*Psidium guajava* L.) *Hort. J.,* **9** (1): 1-7.

Chadha, K.L. 1992. Strategy for optimization of productivity and utilization of sapota (*Manilkara achras* (Mill.) Fosberg). *Indian J. Hort.* **49** (1): 1-17.

Chakrawar, V.R. and Singh, R. 1978. Studies on citrus granulation, IV. Effect of some growth regulators on granulation and quality of citrus fruits. *Haryana J. Hort. Sci.,* **7** (3-4): 130-135.

Chattopadhyay, P.K. and Jana, A.K. 1988. Effect of growth substances on fruit growth and development of Giant Governor Cavendish banana. *Prog. Hort.,* **20** (1-2): 136-139.

Chavan, S.R., Patil, M.B., Phad, G.N. and Suryawanshi, A.B. (2009). Effect of growth regulators on yield attributes and quality of sapota [*Manilkara Achras* (Mill.) Forsberg] cv. Kalipatti. *Asian j. Horti.* **4** (1): 176-177.

Cheema, G.S., Bhat, S.S. and Naik, K.C. 1954. Commercial fruits of India. Macmillan and Co. Madras, India.

Cheena, J., Soujanya, B. and Dr. Vijaya, M., 2018. Studies on the effect of integrated nutrient management on growth and yield of sapota (*Achras sapota* L.) cv. Kalipatti. *Int. J. Chemical Studies,* **6**(4): 352-355

Chundawat, B.S and Bhuva, H.P. 1982. Performance of some cultivars of sapota (*Acharas sapota* L.) in Gujarat. *Haryana Journal of Horticultural Science,* **11**: 154-159.

Dalal, S.R., Gonge, V.S., Jogdande, N.D. and Moharia, Anjali. 2004. Response of different levels of nutrients and PSB on fruit yield and economics of sapota. *PKV Research Journal*, **28**: 126-128.

Daulta, B.S. 1982. Effect of GA, pinching and ringing on the improvement of bunch, berry size and quality of grape. *Prog. Hort.,* **14** (2-3) : 141-143.

Delvadia, D.V., Chakarwar, V.R. and Manke, V.G. 1994. Effects of growth regulators on flowering and yield of chiku during rainy season. *Journal of Maharashtra agric. univ.* **19** (3): 346-348.

Desai Veljibhai N. 2015 "Influence of pre harvest spraying treatments of chemicals and plant growth regulators on quality parameters and shelf life of sapota [*Manilkara achras* (mill.) Forsberg] fruits cv. Kalipatti" *a thesis submitted to the Anand agricultural university.*

Dhomane, P.A. and Kadam, A.S. 2013. Influence of different sources of nitrogen on yield and benefit cost ratio of guava (*P. guajava* L.) cv. Sardar. *Scholarly Journal of Agricultural Science*. **3**(7): 261-263.

Dudi, O.P., Kumar, S., Singh, S. and Singh, D. 2004. Effect of urea and FYM on fruit size and yield of 'Kinnow Mandarin. *Haryana Journal of Horticultural Science,* **33**(3/4): 178-180.

Dutta Ray, S.K., Takawake, P.V., Chatterjee, R. and Hnamte, V. 2014. Yield and quality of pomegranate as influenced by organic and inorganic nutrients. *The Bioscan*, **9**(2): 617-620.

Dutton, D.R. 1976. The propagation of tropical fruit tree. In: Commonwealth Agricultural Bureaux, Farnham. Royal, Slough, England.

Eman, A.A., El-Migeed, M.A. and Omayma, M.I. 2007. GA_3 and Zinc sprays for improving yield and fruit quality of Washington navel orange trees grown under sandy soil conditions. *Res. J. Agri. and Biol. Sci.*, **3**(5): 498-503.

Ganeshamurthy, A.N., Satisha, G.C. and Patil, P. 2011. Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes. *Karnataka Journal of Agricultural Science*, **24**: 29-38.

Ganjyal, G.M., Hanna, M.A. and Devadattam, D.S., 2005. Processing of sapota (sapodilla): powdering. *Journal of Food Technology,* **3**(3): 326-330.

Garhwal, P.C. 2015. Effect of SADH, NAA and GA_3 on growth, yield and quality of sapota [*Manilkara achras* (Mill.) Forsberg] cv.

Kalipatti. *A thesis submitted to department of horticulture, college of agriculture, Junagadh agricultural university.*

Garhwal, P.C., Yadav, P.K., Sharma, B.D., Singh, R.S. and Ramniw, A.S. 2014. Effect of organic manure and nitrogen on growth yield and quality of kinnow mandarin in sandy soils of hot arid region. *African Journal of Agricultural Research,* **9**(34): 2638-2647.

Gautam, U.S., Singh, R., Tiwari, N., Gurjar, P.S. and Kumar, A. 2012. Effect of integrated nutrient management in mango cv. Sunderja. *Indian Journal of Horticulture*, **69**: 151-155.

Gawande, S.S., Jitonde, D.J., Turkhede, A.B. and Darange, S.O. 1998. Effect of organic and inorganic fertilizers on yield and quality of sapota. *Journal of Soils and Crops*, 8(1): 58-60.

Gupta, M. and Kaur, H. 2007. Effect of growth regulators on pre harvest fruit drop in plum (*Prunus salicina* L.) cv. Satluj Purple. *Ind. J. Hort.* **64** (3): 278-281.

Hebbara, M., Ganiger, V.M., Reddy, B.G.M. and Joshi, V.R.2006. Integrated nutrient management in sapota (*Manilkara zapota*) using vermicompost to increase yield and quality. *Indian Journal of Agricultural Science,* **76**: 587-590.

Hiwale, S.S., Apparao, V.V., Dandhar, D.G. and Bagle, B.G. 2010. Effect of nutrient replenishment through organic fertilizers in sapota cv. Kalipatti. *Indian Journal of Horticulture,* **67**(2): 274-276.

Hiwarale, J.S., Patil, M.N. and Laharia G.S. 2004. Effect of organic and inorganic fertilizer on growth, yield and quality of lime. *Annals of Plant Physiology*, **18**(1): 28-30.

Jagtap, V.M., Patel, H.C., Nehete, D.S. and Godage, S.S., (2013). Effect of foliar application of plant growth regulators and micronutrients on yield and quality of acid lime cv. Kagzi lime (*Citrus aurantifolia* S,). *The Asian J. Hort.* **8** (1): 57-59.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 103p.

Kacha, H.L. 2008. Effect of NAA, GA_3 and ethrel on yield and quality of phalsa (*Grewia asiatica* L.) under South Sourashtra conditions. M.Sc. (Ag.) *thesis submitted to Junagadh Agricultural University, Junagadh.* pp: 34-51.

Kachave, P.M. and Bhosale, S.S. 2007. Effect of plant growth regulators and micronutrients on fruiting and yield parameters of kagzi lime (*Citrus aurantifolia* Swingle). *J. Maharashtra Agri. Uni.* **32** (2): 85-87.

Kaur, N., Monga, P.K., Thind, S.K., Vij, V.K. and Thatai, S.K. 1997. Physiological fruit drop and its control in Kinnow mandarin. *Ind. J. Hort.* **54** (2): 132-134.

Kavyashree, N., Naik, B.H. and Tippesh, D., 2018. Effect of plant growth regulators on yield and quality of sapota (*Achras zapota* L) through crop regulation under hill zone of Karnataka. *Int. J. Minor Fruits, Medicinal and Aromatic Crops,* **4**(2): 13-17.

Kher, R., Bhat, S. and Wali, V.K. 2005. Effect of foliar application of GA3, NAA and CCC on physico-chemical characteristics of guava cv. 'Sardar'. *Haryana J. Hort. Sci.* **34** (1/2): 31-32.

Khawle G.B. Effect of growth regulators on yield and quality of sapota (*Manilkara achras* (Mill.) Forsberg) cv. Kaiipatti. A thesis submitted Submitted to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Kumar, J., Rana, S.S., Verma, H.S. and Jindal, K.K. 1996. Effect of various growth, yield and fruit quality of strawberry cv. Tioga. *Haryana J. Hort.* Sci. **25** (4): 168-171.

Kumar, P. and Kumar, G. 1994. Effect of growth regulators sprays on yield and quality of litchi fruits (*Litchi chinensis* Sonn) cv. rose scented. *Ind. J. Hort.* **51** (1): 71-76.

Kumar, M. and Kumar, R. 2013. Response of organic manures on growth and yield of mango (Mangifera indica L.) cv. Dashehari.*HortFlora Research Spectrum*, **2**(1): 64-67

Kumar, D., Panday, V. and Anjaneyulu, K. 2008. Effect of planting density and nutrient management on growth, yield and quality of micro-propagated banana Rasthali (AAB – Pathkapoora). *Indian Journal of Horticulture*, **65**: 272-276.

Kumar, P. and Singh, S. 1993. Effect of GA3 and Ethral on ripening and quality of mango. cv. Amrapali. *Hort. J.,* **6** (1) 19-23.

Kumar, S.P., Singh, C. and Jain, B.P. 1998. Effect of foliar feeding of K, N, Zn and gibberellic acid on chemical composition of guava fruit (*Psidium guajava* L.). *J. Res. Birsa Agricultural University*, **10** (2): 173-176.

Kumar, V., Singh, M.K., Singh, M., Dev, P. and Mohan, B. 2012. Influence of integrated nutrient management on yield and quality of lemon cv. Pant lemon-1 under western U.P. conditions. *Annals of Horticulture,* **5**: 137-139.

Lal, G. and Sen, N.L. 2001. Effect of N, Zn and Mn fertilization on fruits quality of guava (*Psidium guajava* L.) cv. 'Allahabad Safeda'. *Haryana Journal of Horticultural Science,* **30**: 209-210.

Lal, N., Das, R.P. and Verma, L.R. (2013). Effect of plant growth regulators on flowering and fruit growth of guava (*Psidium guajava* L.) cv. Allahabad Safeda. *The Asian J. Hort.* **8**(1): 54-56.

Madhavi, A., Maheswara Prasad, V. and Girwani, A. 2008. Integrated nutrient management in mango. *The Orissa Journal of Horticulture,* **36**(1): 64-68.

Madhavi, A., Prasad, M., Prabhakar Reddy, I. and Girwani, A. 2005. Integrated nutrient management for increased productivity and quality in guava. *1st International Guava Symposium*, 5-8, Dec. CISH, Lucknow, 83 p.

Mahalle, P.H., Jadhav, B.J., Panchbhai, D.M. and Athawale, R.B. 2001. Effect of N, P and K on growth, fruit set, yield and quality of custard apple. *The Orissa Journal of Horticulture*, **29**: 54-57.

Maskar, S.L., Manjare, P.B. and Tonde, M.G. 2017. Effect of Bio-fertilizers and Inorganic Fertilizers on Growth and Yield of Sapota [*Manilkara achras* (Mill.) Forseberg] cv. Kalipatti. *Int. J. Curr. Microbial. App. Sci* (2018) Special Issue-**6**: 2606-2613

Meena H.R. 2016 Integrated Nutrient Management in Sapota cv. 'Kalipatti'. A thesis submitted to Maharana Pratap University of Agriculture and Technology, Udaipur.

Meena, V.S., Nambi, V.E., Kashyap, P., and K.K. Meena. 2013. NAA and ferrous sulphate induced changes in physico-chemical composition and shelf life of ber. *Indian Journal of Horticulture*, **70**(1):37-42.

Meena, V.S., Nambi, V.E., Vishawakarma, R.K., Gupta, R.K. and Nangare, D.D. 2012. Effect of gibberellic acid on fruit quality and storability of grape in semi-arid region of Punjab. *Agricul. Sci. Dig.* **32**: 4 pp. 344

Mehul Patel, N.J. Vihol, A.D. Patel and H.C. Patel. 2017. Effect of integrated nutrient management on quality parameters of sapota [*Manilkara achras* (Mill.) Forseberg] Cv. Kalipatti. *International Journal of Chemical Studies*, **5**(6): 889-891.

Mitra, S.K. and Bose, T.K. 1985. Guava In: Fruits Tropical and Subtropical (Edtd. T. K. Bose and S. K. Mitra) Naya Prakash Calcutta, pp 278-303.

Mitra, S.K., Gurung, M.R. and Pathak, P.K. 2010. Integrated nutrient management in high density guava orchards. *Acta Horticulture*, **849**: 349-355.

Musmade, A.M., Jagtap, D.D., Pujari, C.V. and Hiray, S.A. 2010. Integrated nutrient management of acid lime. *The Asian Journal of Horticulture,* **4**(2): 305-308.

Mustafa, M., Pandey, S.K., Katare, S., Pandey, D. and Singh, A. 2013.Response of integrated nutrient management in aonla (*Emblica officinalis* Gaertn) under medium black soil. *Progressive Horticulture.* **45** (2): 385-387.

Nagargoje, B.S., Kachave, D.B., Shinde, S.B., Jadhav, K.M. 2007. Effect of NAA on flower drop, fruit set, fruit drop and fruit retention in sapota variety Kalipatti. *Journal of Soils and Crops*. **17** (1): 173-175.

Nambisan, J.V., Desai, U.T., Kshirsagar, D.B. and Kammble, A.B. 2007. Effect of plant growth regulators on yield of sapota cv. Kalipatti. *J. of Maharashtra Agric. Univ*. **32** (2): 280-281.

Pandey, I.C., Tripathi, B.M. and Upadhyay, N.P. 1980. Effect of plant growth regulators on fruit ripening and quality of mango. *Punjab Hort. J.*, **21** (12) 24-27.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural workers. ICAR, New Delhi,: 145-155.

Parihar, M. C., Singh, R. and Gupta, S. C. 1999. Effect of NAA on vegetative growth of phalsa (*Grewia asiatica* L.). *Haryana J. Hort. Sci.* **28** (3-4) : 200.

Patel, D.R., and Naik, A.G. 2010. Effect of pre-harvest treatment of organic manures and inorganic fertilizers on post-harvest shelf life of sapota cv. Kalipatti. *Indian Journal of Horticulture*, **67**: 381-386.

Patil, M.B., Munde, G.R., Nainwad, R.V. and Mane, S.S. 2011. Studies on effect of plant growth regulator on physical characters of sapota. *The Asian J. Hort.*, **6** (1): 98-100.

Patil, D.R., Patil, H.B., Prashanth, J.M. and Patil, S.N. 2005. Studies on integrated nutrient management strategies for higher productivity in mango cv. Alphanso. *Karnataka Journal of Agricultural Science*, **18** (3): 862-864.

Pawar, C.D., Patil, A. A., Joshi, G. D., 2011. Physico-chemical parameters of sapota fruits at different maturity stages. *Karnataka J. Agric. Sci.,* **24** (3): 420-421.

Pereira, L.S. and Mitra, S.K. 1999. Studies of organic along with inorganic nutrition in guava. *Indian Agriculture*, **43**: 155-160.

Pramanik, D.K. and Bose, T.K. 1974. Studies on the effect of growth regulator on fruit set and fruit drop in some minor fruits. *South Indian Hort.*, **22** (3-4): 117-23.

Ram, R.A., Rajput, M.S. and Bhriguvanshi, S.R. 1999. Effect of controlled release fertilizers on growth, yield and fruit quality of guava cv. 'Sardar' in Ustochrepts. *Indian Journal of Horticulture*, **56**: 104-111.

Rangana, S. 2000. Hand book of analysis and quality control for fruit and vegetable production. Tata McGraw Hill Publishing Company Limited, New Delhi.

Rathore, A.C. and Dhyani, S.K. 2005. Comparative performance of organic supplements and inorganic fertilization on growth, yield and quality of guava (*Psidium guajava* L.) under rainfed condition in Doon Valley. *1st International Guava Symposium,* 5-8, Dec., CISH, Lucknow, 62 p.

Ray, D.P., Samanta, 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 agric.* **36** (1): 09-18.

Reddy, M.G. 1959. Physico-chemical investigations on sapota and its products. M.Sc. (Food Tech.) Thesis, CFTRI, Mysore, Karnataka.

Rema, J. and Sharma, V.P. 1991. Effect of plant growth regulators on yield and quality of phalsa (*Grewia subinaequalis* L.). *South Indian Hort.*, **39** (6): 327-331.

Richards, L.A. 1968. Diagnosis and improvement of saline and alkaline soils. Hand Book No. 60, Oxford and IBH publishing Co., New Delhi. pp.47-52.

Sandhu, A.S.; Singh, K.; Singh, M.L. and Brar, W.S. 1985. Effects of GA3 and NAA on berry thining and quality of 'Perlette' grapes. *Haryana J. Hort. Sci.*, **14** (3-4): 211-214.

Saraswathi, T., Rangasamy, P. and Azahakiamanavalan, R.S. 2003. Effect of preharvest spray of growth regulators on fruit retentation and quality of mandarins (*Citrus reticulata* Blanco). *South Indian Hort.*, **51**(1-6): 110-112.

Satisha, G. C. Prakash Patil, Shirol, A. M. and Ganeshamurthy, A. N., 2014. Integrating fertilizer N rates with organics on soil-available nutrients and yield of sapota under semi-arid conditions of Karnataka. *J. Hortl. Sci.,* Vol. **9**(2):172-178.

Sawant, V.S. 1989. Studies on post harvest handling and preservation of Sapota (Manilkaraachrus(Mill.) Forsberg)fruit cv. Kalipatti, M.Sc. (Agri.) *Thesis. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra.*

Sen, N.L. and Chauhan, K.S. 1983. Effect of differential NPK fertilization on physico-chemical characters of pomegranate. *Punjab Horticultural Journal,* **23**:59-63.

Sharma, P., Singh, A.K. and Sharma, R.M. 2005. Effect of plant bio regulators and micro nutrients on fruit set and quality of litchi cv. *Dehradun. Ind. J. Hort.* **62**(1): 24-26.

Sharma, S., Bal, J.S. and Gill, K.S. 2002. Effect of pre harvest application of plant growth regulators on quality and shelf life of winter guava cv. Sardar. *Haryana J. Hort Sci.* **31**(1&2):29-31.

Shrama, R. and Tiwari, R. (2015). Effect of growth regulators sprays on growth, yield and quality of guava under Malwa plateau conditions. *Annuals of Plant & Soil Res.* **17**(3): 287-291.

Shivakumar, B.S., Dharmatti, P.R. and Channal, H.T. 2012. Effect of organic cultivation of papaya on yield, economics and soil nutrient status. *Karnataka Journal of Agricultural Science*, **25** (4): 488-492.

Singh, D., Ahlawat, V.P., Verma, S.L. and Singh, B. 2003. Effect of nitrogen, phosphorus and potassium fertilization in sapota cv. Cricket Ball. *Indian Journal of Agricultural Science*, **73** (8): 419-421.

Singh, A.K. and Rajput, C.B.S. 1986. Effect of GA_3, BA and Calcium on flowering, fruiting and fruit quality of mango (*Mangifera indica* L.) cv. Langra. *Punjab Hort. J.,* **24** (4): 45-52.

Singh, A.K., Sharma, P., Sharma, R.M. and Tiku, A.K. 2005. Effect of plant bio regulators and micro nutrients on tree productivity, fruit cracking and aril proportion of litchi (*Litchi chinensis* Sonn.) cv. Dehradun. *Haryana J. Hort. Sci.* **34** (3-4): 220-221.

Singh, A.K., Singh, S., Raoappa, V.V., Hiwale, S.S. and Joshi, H.K. 2014. Long term effect of INM on aonla (Emblicaofficinalis) and soil quality under rainfed hot semi-arid environment. *Indian Journal of Agricultural Science,* **84** (5): 585-588.

Singh, A.R. 1977. Effect of foliar spray of nitrogen and growth regulators on flowering and fruiting of mango. *Punjab Hort. J.,* **17** (2-3): 34-40.

Singh, S., Kumar, P., Brahmachari, V.S. and Singh, D. N. 1995. Effect of pre-harvest spray of GA3 and Ethrel on storage life of mango cv. Amrapali. *Orissa J. Horti.,* **23** (1-2): 112-118.

Singh, G. and Reddy, Y.T.N. 1997. Regulation of cropping in guava. *Ind. J. Hort.* 54 (1): 44-49.

Singh, U.R. and Singh, A.P. 1976. Control of fruit drop in mango. Proceeding of Fruit Research Workshop, Hyderbad. PP: 24-28.

Singh, J.P., Kumar, S., Katiyar, P.N. and Dwivedi, A.K. 2011. Effect of calcium nitrate, GA_3 and ethrel on fruiting, ripening and chemical traits of phalsa. (*Grewia subinaequalis* D.C.). *Annals of Hort.* **4** (1): 72-76.

Srivastava, A.K., Huchche, A.D., Das, A.K. and Kumar, D. 2008. INM method sustained productivity of citrus. Annual Report, NRCC Nagpur, pp. 36-42.

Subbaiah, B.V and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soil. *Current Sci.,* **25**: 255-260.

Sulladmath, U.V. and Reddy, M.A.N. 1985. Sapota, In: *Fruits of India-Tropical and Sub-Tropical,* Ed. T.K. Bose, Nayaprakash, Culcutta, India, pp.-439-464.

Sundarrajan, P., Singh, V. R. and Tiwari, R. 1988. A note on the effect of gibberelic acid on fruit set, size and quality of fruits on certain varieties of guava (*Psidium guajava* L.). *South Ind. Hort.*, **17**: 41-42.

Sutaria, R.N. 1966. A text book of systematic botany. Khadayata Book Dept., *Ahemdabad, India Edn.*, pp. 298-303.

Symal, M.M., Bedanga, B. and Pakkiyanathan, 2010. Influence of growth substances on vegetative growth, flowering and fruit quality of papaya. *Indian J. Hort.,* **67** (2): 173-176.

Tarai, R. and Ghosh, S.N. 2006. Integrated nutrient management in sweet orange cv. 'Mosambi' (Citrus sinensisOsbeck) grown under rain fed laterite soil. *The Orissa Journal of Horticulture*, **34**: 72-75.

Teran, L., Melendez, I., Garcia-Aguilar, L., Acuna, J.G. and Urdaneta, M. 1996. Effect of nitrogen and potassium application of yield in guava (*Psidium guajava*) cultivation. *Revista-de-la-Facultad-de-Agronomia,Universidad-del-Zulia*, **13**: 363-370.

Tiwari, R.B., Tiwari, J.P. and Lal, S. 1992. Effect of shoot pruning, NAA and Urea on cropping pattern of guava. *Ind. J. Hort.* **49** (4): 305-308.

Tsadik, K.W. and Zelleke, A. 1993. Effect of CCC and GA sprays on fruits of 'Kai Dube' variety of grapes (Vitis vinifera L.). *Haryana J. Hort. Sci.* **22** (3): 183-187.

Varu, D. 2012. Effect of organic and inorganic nitrogen on growth, yield and quality of sapota cv. Kalipatti. *Journal of Fruit and Ornamental Plant Research,* **20**(1): 55-64.

Veinbrant, S.N. 1969. The use of growth regulators daminozide and ethephon for promoting flower bud differentiation in young vigorous apple trees. Abstracts. No. 1469. *Deppt. Agric. Fruitt Crops branch, Ferntree Gully*, Austrelia.

Yadav, D.N. and Chaturvedi, O.P. 2005. Influence of GA3 and trace elements on fruit drop, growth and quality of Ber (*Zizyphus mauritiana* L.) cv. Banarasi Karaka. *Farm Sci. J.*, **14**(1): 27-28.

Yadav, S., Bhatia, S. K., Godara, R. K. and Rana, G. 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.

INTRODUCTION

ABSTRACT

MATERIAL AND METHODS

REVIEW OF LITERATURE

RESULTS AND DISCUSSION

SUMMARY AND CONCLUSION

APPENDICES

LITERATURE CITED