Effect of NAA and Micronutrients on Flowering, Fruit Setting, Yield and Quality of Litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur.

Thesis

Submitted to the
Central Agricultural University, Imphal
in partial fulfilment of the requirements for the award of the degree of

Master of Science (Horticulture)

In

Fruit Science

by

SANABAM INDIRA DEVI
B.Sc. Horticulture
U-19-AR-01-005-M-H-010

DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE AND FORESTRY
Pasighat, Pin: 791102, Arunachal Pradesh, India

September 2021

Affectionately Dedicated To

My

Beloved Mother and My Family Members

COLLEGE OF HORTICULTURE AND FORESTRY
CENTRAL AGRICULTURAL UNIVERSITY
Pasighat, Pin-791102, Arunachal Pradesh, India

CERTIFICATE - I

Certified that **Ms. Sanabam Indira Devi [Registration No. U-19-AR-01-005-M-H-010]** has satisfactorily prosecuted her course of research for a period of not less than two semesters and that the thesis entitled **"Effect of NAA and Micronutrients on Flowering, Fruit Setting, Yield and Quality of Litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur"** submitted by her to the Central Agricultural University, Imphal -795004 (Manipur) in partial fulfilment of the requirements for the award of the degree of **Master of Science (Horticulture)** in the subject of **Fruit Science** is the result of original research work conducted by her under my supervision and is sufficiently of high standard to warrant its presentation to the examination.

I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any University.

Date...22/9/2021.....

22/9/2021

(S. Romen Singh)

Name and Signature of the Chairperson
Student's Advisory Committee

Tel:0368-2224887,Te Fax: 0368-2225066
E-mail:pa_deanchf@hotmail.com/ripondam@gmail.com

COLLEGE OF HORTICULTURE AND FORESTRY

CENTRAL AGRICULTURAL UNIVERSITY

Pasighat, Pin-791102, Arunachal Pradesh, India

CERTIFICATE – II

This is to certify that the thesis entitled **"Effect of NAA and Micronutrients on Flowering, Fruit Setting, Yield and Quality of Litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur"** submitted by **Ms. Sanabam Indira Devi [Registration No. U-19-AR-01-005-M-H-010]** submitted to the Central Agricultural University, Imphal-795004 (Manipur) in partial fulfilment of the requirements for the award of the degree of **Master of Science (Horticulture)** in the subject of **Fruit Science** has been approved by the Student's Advisory Committee after oral examination jointly with Dean's Nominee.

22/09/2021
(Pranabjyoti Sarma)
Dean's Nominee

22/9/2021
Head of Department

22/09/2021
Dean

22/9/2021
(S. Romen Singh)
Chairperson,
Student's Advisory Committee

22/09/2021
(B.N. Hazarika)
Member,
Student's Advisory Committee

22/9/21
(L. Wangchu)
Member,
Student's Advisory Committee

22.09.21
(Chandra Deo)
Member,
Student's Advisory Committee

22/09/2021
(L. Shantikumar)
Member,
Student's Advisory Committee

DECLARATION

I hereby declare that the thesis entitled **"Effect of NAA and Micronutrients on Flowering, Fruit Setting, Yield and Quality of Litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur"** is an authentic record of the work done by me and that no part thereof has been presented for the award of any other degree, diploma, associateship, fellowship or any other similar title.

S. Indira Devi

Date: 22/09/2021 **(Sanabam Indira Devi)**

Place: Pasighat

ACKNOWLEDGEMENTS

First and foremost, I would like to thank the Almighty in heaven for His showers of blessings throughout my research work to complete the research successfully.

It is my proud privilege to express my deepest sense of gratitude and genuine obligation to the honourable and beloved chairman of my Advisory Committee, Dr. S. Romen Singh, Assistant Professor, Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, for his affectionate guidance, needful help and unending benevolence during the entire course of the present investigation and finalization of this manuscript. His close view, selfless mentoring and encouragement made the work complete with perfection. I am too much beholder to him for which I would be thankful forever.

I would like to express my sincere thanks to all the members of my advisory committee, Dr. L. Wangchu, Associate Professor and Head, Department of Fruit Science, who was ever ready to extend a helping hand in all the ways he could, Dr. B.N. Hazarika, Professor, Department of Fruit Science, Dr. Chandra Deo, Associate Professor and Head, Department of Vegetable Science and Mr. L. Shantikumar, Assistant Professor, Department of Basic Science and Humanities for their valuable suggestions and insightful remarks during the course of my research.

I owe my deepest gratitude to Dr. B.N. Hazarika, Dean, College of Horticulture and Forestry, Pasighat for providing indispensable advice, information and all the necessary facilities for undergoing the research.

I would like to grasp this opportunity to express my profound gratitude to Dr. Siddhartha Singh, Assistant Professor, Department of Basic Science and Humanities, Mr. N. Devachandra Singh, Assistant Professor, Dr. Barun Singh, Assistant Professor and Dr. PK Nimbolkar, Assistant Professor Department of Fruit Science for their professional guidance and constructive suggestions from time to time.

I would also like to thank Santosh Bhaiya, Department of Basic Science and Humanities, Manosh Bhaiya, Department of Natural Resources Management and Sir Arun kumar,

Lab Assistant , Department of Plant Protection for all the help and tireless effort rendered on me in all the laboratory works.

I would also like to thank all the non teaching staffs and workers of Fruit Science Department for extending their cooperation and valuable assistance as and when required.

I express my sincere thanks to my seniors Da Anush, Da William, Che Gaitri, Sis. Jome and Che Reena for their ever ready helping hand and guidance throughout my research programme.

This journey would not have been possible without the support of my dear friends, Bidya, Mashine, Subhas, Robert , Monika, Sunayna, Geying and Khaling. Your being with me throughout the research and all the helps you rendered, I can't afford to forget. No words can thank you enough.

Finally, I express my profound gratitude to my beloved parents, younger sister Sushilla and my two brothers for their unfailing support, love and encouragement throughout the process of my research and writing this thesis.

To those, whose names I may have missed out, let it be known that your aid, solicitude with dedication and love is priceless, highly appreciated and will always be remembered.

S. Indira Devi

Date : 22/09/2021

(Sanabam Indira Devi)

Place : Pasighat

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LIST OF SYMBOLS/ABBREVIATIONS

%	per cent
°B	°Brix
cm	centimeter
mm	millimeter
N	Nitrogen
P	Phosphorus
K	Potassium
mg	milligram
g	gram
kg	kilogram
ml	milliliter
@	at the rate
RDF	Recommended Dose of Fertilizer
RBD	Randomized Block Design
NS	non significant
N-S	North-South
E-W	East-West
viz.	namely

i.e.	that is
NAA	Naphthalene acetic acid
ppm	Parts per million
M	Male
F	Female

Name: Sanabam Indira Devi **Registration No.:** U-19-AR-01-005-M-H-010

Chairperson: Dr. S. Romen Singh **Degree**: M.Sc. (Horticulture)
Major: Fruit Science

Thesis title: Effect of NAA and Micronutrients on Flowering, Fruit Setting, Yield and Quality of Litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur.

ABSTRACT

The present investigation was conducted to evaluate the effect of foliar application of NAA and micronutrients on litchi cv. Muzaffarpur. It was carried out on 10 years old trees of uniform size at the Fruit Research Farm (Litchi Block), Department of Fruit Science, College of Horticulture and Forestry, Pasighat, Arunachal Pradesh during the year 2020-21. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments and 4 replications. The treatments applied were: T_1 (NAA @ 10 ppm), T_2 (NAA @ 15 ppm), T_3 (NAA @ 20 ppm), T_4 (NAA @ 25 ppm), T_5 (NAA @ 10 ppm + 0.5% Borax + 0.5% Zinc sulphate), T_6 (NAA @ 15 ppm + 0.5% Borax + 0.5% Zinc sulphate), T_7 (NAA @ 20 ppm + 0.5% Borax + 0.5% Zinc sulphate), T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate), T_9 (0.5% Borax + 0.5% Zinc sulphate) and T_{10} (Control).

Experimental results revealed that the imposition of different treatments had a significant effect on increasing flowering, fruit setting and improving the yield and quality of the fruits. Maximum increase in plant height (36.50 cm), canopy height (34.95 cm), volume of the canopy (68.70 m^3), highest number of female flower/panicle (75.00), fruit setting %/panicle (26.25%), number of fruits at harvest stage/panicle (15.00), maximum yield/plant (24.00 kg), maximum TSS (18.75ºBrix), ascorbic acid (25.70 mg/100 g), total sugar (15.70%), reducing sugar (10.05%) with minimum titratable acidity (0.24%) were recorded in treatment T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate) whereas, date of 50% flowering (1st March) i.e. early flowering, early fruit maturity (25th May), maximum fruit diameter (2.54 cm), fruit volume (18.40 cm^3), fruit weight (20.60 g), aril weight (13.24 g), juice content (9.20 ml) with minimum fruit cracking%/plant (3.61%) were obtained in treatment T_7 (NAA @ 20 ppm + 0.5% Borax + 0.5% Zinc sulphate). However, non-significant effect was found in stem girth, fruit length and shelf life of the fruits.

Therefore, application of recommended dose of fertilizers (1200:500:600 g NPK/plant/year) along with foliar spray of NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate thrice (first application after emergence of new flushes during November followed by second application at one month interval during December and third application after fruit setting during April) can be recommended to the litchi growers under foothills condition of Arunachal Pradesh to increase the yield and productivity.

Key words: NAA, Borax, Zinc sulphate, Litchi, yield, quality.

(S. Romen Singh)
Chairperson

(Sanabam Indira Devi)
Authoress

Chapter- 1
Introduction

Litchi (*Litchi chinensis* Sonn.) considered as “Queen of fruit”, is one of the most important sub-tropical fruits which belongs to the family Sapindaceae, a family with some other important fruit crops. The Sapindaceae is a large family consist of about 150 genera and 2000 species, scattered mostly in tropical and sub-tropical regions. The other most widely cultivated edible fruit tree other than litchi of this family includes Longan (*Euphoria longana* Lam.), Rambutan (*Nephelium lappaceum* L.) and Pulasan (*Nephelium mutabile* Blume) (Mishra *et al.*, 2017a). Litchi have nut type fruit botanically and edible part is translucent aril/pulp with single seed which is known for its excellent quality, juicy, sweet-acid taste, characteristic pleasant flavour, attractive colour and nutritional value. Fresh pulp has a musky flavour and when dried, it is acidic and very sweet. The fruit is a rich source of sugars, vitamins and minerals like Magnesium, Calcium, Iron, Copper, Phosphorous and Potassium. It can be processed into juice, wine, pickles, jam, jelly, ice cream and yoghurt (Singh and Kaur, 2016). It comes to the market in the month of May-June when the market is full of other fresh fruits. Even though the availability of different types of fruit in the market is increase, the demand for fresh litchi is always very high due to its unique taste, flavour and colour.

Litchi is native to south eastern China where it has been cultivated for over 4000 years and from where it was introduced into eastern India through Myanmar by the end of 17th century (Kaur, 2017). About 95% of the world litchi production lies in south-east Asia with China, India, Vietnam, Thailand, Bangladesh and Nepal are the important leading producing countries. In the southern hemisphere the major players are Australia, South Africa and Madagascar. Countries with small scale production include Philippines, Indonesia, Israel, USA, Brazil, Mexico, Canary Islands, Mauritius, Zimbabwe and Mozambique. India ranked second in the world next to China in Litchi production.

Litchi is highly sensitive to climatic requirement and is adapted to area of the world characterized by warm subtropics and elevated tropics having cooled dry winters and warm wet summers (Kaur, 2017). As it is highly specific to climatic requirements its cultivation is restricted to few states in our country. In India the cultivation of litchi was done in an area of 96 thousand ha in 2018-19 and 2019-20. But in terms of production it has increased from 721 thousand MT in 2018-19 to 728

thousand MT in 2019-20 (Anon., 2020). The total production of litchi is concentrated mainly in the states of Bihar, West Bengal, Uttar Pradesh, Jharkhand and Assam. It is also grown to a smaller extend in Tripura, Orissa, Punjab, Himachal Pradesh and Nilgiri hills in the south (Kaur, 2017). Besides, nowadays it is also started cultivation in the subtropical regions of Tripura, Assam, Meghalaya and Arunachal Pradesh of North East India.

The litchi fruit consists of about 60% juice, 8% rag, 19% seed and 13% skin which varies depending upon variety and climatic conditions under which it is grown. Litchi fruits are considerably rich in sugar and the total sugar content varies from 6.46 to 18% with an average of 11.85% (Singh and Singh, 1954). The range of acidity in the fruit varies from 0.20 to 0.64% in which malic acid is the predominant acid followed by citric, succinic, levulinic, phosphoric, glutaric, malonic, and lactic acids. The litchi fruit also contains vitamin C (ascorbic acid) ranging from 40.2 to 90 mg/100 g, protein 0.8 to 0.9%, fat (0.3%), pectin (0.424%) and minerals about 0.7% comprising mainly calcium, phosphorus and iron (Singh and Singh, 1954).

Muzaffarpur is one of the most popular cultivar of Uttar Pradesh, North Bihar, Jharkhand and Uttaranchal. It is known as “Shahi” in Uttaranchal and Muzaffarpur in Uttar Pradesh. It is an early season maturing cultivar ripens during fortnight of May to first week of June at different locations. Trees are very vigorous, high yielder but mature fruits are prone to cracking. Fruits are medium to large in size, medium in weight, globules-heart or obtuse in shape with red tubercles at ripening. Aril is greyish-white in colour, moderately juicy and sweet. Seeds are small, smooth, shining round-ovate in shape and blackish-chocolate in colour. The fruits are known for excellent aroma and quality aril (Anon., 2011).

The inflorescence in litchi is an abundantly branched panicle usually emerging terminally from the previous season growth. Litchi produces many inflorescences with three different flowering types *viz.* male, female and pseudohermaphrodite. Male flower have six to ten stamens and the pistil in male flower is pinkish white or grayish and abortive. Female flower have a functional bicarpellate pistil with six to ten staminodes which never develop and dehisce as in males. In pseudohermaphrodite, the anthers are as in males but the ovary is neither so ill-developed as in male nor so well-developed as in female. All the flowers are not open in one time, male flower open in first phase which is followed by female and pseudohermaphrodite. Under normal conditions, each inflorescence bears about 100 to 250 female flowers. But only a small percentage of these develop into mature fruit after huge flower and fruitlet dropping. Most of the flowers and fruitlets drop during the 1st

month after pollination due to lack of pollination or improper fertilization which is responsible for low productivity of litchi (Anon., 2011).

The difficulty behind the low economic potential of litchi cultivation in various litchi growing regions includes poor fruit set, heavy fruit drop, fruit cracking and inferior fruit quality. As there were huge scope and potential of plant growth regulators in litchi to increase the production by enhancing the female flower in the panicle and reducing the fruit drop, therefore, they have been used for many years to change the fruit plant behaviour for the economic benefits such as to control the vegetative growth, increase in flowering and fruit setting, enhancing of fruit maturity and ripening and improving fruit quality. Through many research it is found that the synthetic auxin *viz*. NAA check fruit drop and increases the fruit retention percentage, the fruit weight and TSS of the fruits (Sultana *et al.*, 2016).

Besides, micronutrients play a vital role in improving the growth, flowering, yield and quality of litchi even though these elements are needed in small quantities. The foliar application of micronutrients has evolved into an important practice in recent years in the production of fruits while application of fertilizer to the soil remains the basic method of feeding the majority of the fruit plants. Foliar feeding of micronutrients is comparatively more effective for rapid recovery of plants, as under high soil pH conditions most of macro and micronutrients are unavailable to the plants. In foliar feeding as nutrients are applied directly to the site of their metabolism and they are not subjected to losses as in case of soil application, they are found effective in improving the vegetative growth, yield and quality of fruits. Zinc (Zn) plays an important role in the metabolic activities of plants. The principal function of Zinc in plants is as a metal activator of enzymes like dehydrogenase, glucose-6 phosphodiesterase, carbonic anhydrase, etc. Also, it is involved in the synthesis of tryptophan, a precursor of IAA and associated with water uptake and water retention in plant bodies (Noggle and Fritz, 1989). Boron, on the other hand, is considered to be important for hormone metabolism, photosynthetic activities, cellular differentiation and water absorption. It is also involved in reproduction, pollen tube germination and fertilization. Boron deficiency results in the production of less number of flowers and is mostly sterile, also fruits are deformed and return themselves commercially useless (Yawalkar *et al.,* 1992).

In North Eastern Region of India cultivation of litchi is limited to small pockets. However, it is gaining momentum in some states like Tripura, Assam and Meghalaya. In Arunachal Pradesh, the commercial cultivation of litchi is in rudimentary stage. The major reasons for slow spread of litchi cultivation in North Eastern Region includes lack of scientific practices of cultivation like lack of integrated nutrient

management including plant growth regulators and micronutrients which are essential for improving yield and fruit quality, resulting in low yield and quality fruit production, serious pest and diseases incidence, lack of processing industry, marketing and transportation facilities etc. Further, the moisture stress condition during litchi fruit developmental stage is prone to fruit cracking disorder which hamper the quality and shelf-life of the fruit. In contrary, the demand of the fresh fruits in the local as well as in outside market is very high during the season (May-June). Keeping in view this high market demand of litchi, it is necessary to encourage the farmers for litchi cultivation which will give good returns to them.

Soils of North Eastern Region are acidic in nature which limits the availability of micronutrients to the plants from the soil. But there has been no approach so far for the standardization of micronutrients requirements of Litchi. Thus the present study is planned to see the effect of NAA at different concentrations on flowering and fruit retention and standardization of micronutrients requirement of Litchi for quality fruit production in North East region. In view of these, the following objectives have been laid out:

1) To study the effect of NAA and micronutrients on flowering and fruit retention of litchi cv. Muzaffarpur.
2) To study the effect of NAA and micronutrients on yield and quality of litchi cv. Muzaffarpur.
3) To evaluate the effect of NAA and micronutrients on shelf life of litchi cv. Muzaffarpur.

Chapter - 2
Review of Literature

Litchi (*Litchi chinensis* Sonn.) is an important sub-tropical evergreen fruit crop of India with high demand in market due to its unique taste, flavour and colour. As a result, its good quality fruit production with higher yield is quite important to meet its demand and supply chain system. The present experiment was planned to determine the effect of combination of NAA and micronutrients to increase flowering and fruit retention and also to correlate yield and quality parameters. In this chapter, efforts have been made to review the existing literature pertaining to the above mentioned topic, *viz.,* practices which can increase flowering and fruit retention in litchi and improvement in yield and quality of fruits. However, not much systematic research work has been done on flowering, fruit retention and use of NAA and micronutrients in litchi in India. Hence, the review also includes other crops related to the above investigation and presented in the following headings of this chapter.

2.1 To study the effect of NAA and micronutrients on flowering and fruit retention of Litchi

Arunadevi *et al.* (2019) carried out an investigation to study the effect of plant growth regulators on growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle.) var. PKM 1. The treatment consisted of soil drenching of Paclobutrazol (PP_{333}) (0.5, 1.0 and 1.5 g a.i/m^2) and foliar application of Cycocel (CCC) (500 and 1000 ppm) and Naphthalene acetic acid (NAA) (100 and 200ppm). The result revealed that highest fruit set percentage (71.18%), fruit retention percentage (57.09%), number of fruits per tree (885), yield per tree (52.05 kg) , juice volume (35.62 ml per fruit), acidity (8.82%) and ascorbic acid (39.97 mg/100g) were recorded in the treatment combination of PP_{333} 1.5g a.i/m^2 + NAA 200ppm (T_{10}). Minimum values of these characters were recorded in control treatment (T_0).

Lenka *et al.* (2019) assessed the effect of micronutrients and bio-regulators on growth, flowering, fruiting and yield of Guava (*Psidium guajava*) cv. Allahabad Safeda. Maximum number of flowers per shoot (7.74), fruit set (79.27%) and yield per plant (24.43 kg/tree) were recorded under the treatments SA @ 100ppm (T_{12}) and minimum days required for fruit set to maturity (130.00 and 131.00) were observed under the treatment $ZnSO_4$ @ 0.6% (T_3) during rainy and winter seasons, respectively. The fruit retention was found maximum (73.27% and 67.54%) in NAA @ 100ppm (T_9),

which was at par with SA @ 100 ppm (T_{12}), while minimum (36.32% and 34.94%) fruit retention was recorded in control for both rainy and winter season respectively. Application of NAA @ 100 ppm was also found to be equally good for fruit set and fruit retention during both the seasons of investigation.

Rathod *et al.* (2019) studied the effect of foliar application of micronutrients and growth regulator on yield of aonla (*Emblica officinalis* Gaertn.) *cv*. Gujarat Aonla-1 during 2017-18 and 2018-19 and pooled analysis was carried out. Foliar application of Borax @ 0.5% (M_5) and NAA @ 20 ppm (G_3) significantly reduced fruit drop 9.11% and 28.43% as compare to control 45.47% and 32.15% respectively. Also, Borax @ 0.5% (M_5) and NAA @ 20 ppm (G_3) increased fruit set 68.75% and 70.91% as compare to control 62.80% and 58.39% respectively. The said combinations of micronutrients and growth regulator (M_5G_3) were also associated with higher fruit retention (36.25%), average fruit weight(48.06 g), fruit diameter(4.76 cm) and higher fruit yield (120.20 kg/tree).

Chaudhary *et al.* (2018) conducted an experiment to assess the effect of plant growth regulators and micro-nutrients on growth, fruiting behaviour and yield of aonla during two consecutive years (Y1=2015-16 & Y2=2016-17) and pooled analysis was also carried out. The investigation revealed that maximum fruit set (75.82%), fruit retention (30.70%), fruit length (3.99 cm), fruit width(3.91 cm), fruit yield (67.45 kg/tree) were recorded in treatment T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} in pooled analysis for both the years. However minimum fruit drop (69.31%) was also recorded in treatment T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} in pooled analysis for both the years.

Patel *et al.* (2018a) evaluated the response of pre harvest chemicals spray on fruit retention and yield of mango cv. Kesar. The chemicals consisted of CPPU (5ppm, 10ppm), GA_3 (25ppm, 50ppm), NAA (30ppm, 60ppm), $CaCl_2$ (1.0%, 2.0%), $ZnSO_4$ (0.5%, 1.0%). The result revealed that maximum fruit retention (6.75%) and yield (74.80 kg/tree) was recorded with the foliar application of NAA 60ppm (T_5). The highest average weight of fruit (284.00g) was obtained with the foliar application of NAA 30ppm (T_4).

Patel *et al.* (2018b) studied the effect of foliar spray of micro nutrients on yield and quality of Aonla (*Emblica officinallis* Gaertn. L.) cv. NA-6. The result revealed that the foliar application of $CuSO_4$ (0.4%) +$ZnSO_4$ (0.5%) was found to be most effective in reducing the intensity of fruit drop (74.07%), high fruit retention (25.93%), improving the fruit size and fruit weight, pulp: stone ratio (22.57), increase Vitamin-C

content (575.50 mg/100g) and highest fruit yield (74.59 kg/plant) as compared to other treatments.

Singh *et al.* (2018) carried out an investigation to assess the effect of different combinations of PGR's and micronutrients on growth and flowering of papaya (*Carica papaya* L.) cv. Pusa Nanha during 2013-14 and 2014-15 and pooled analysis was carried out. The results shows that foliar application of Copper sulphate 0.25% + Manganese sulphate 0.25% + NAA 30 ppm + GA_3 60 ppm (T_{15}) attained maximum pooled value in terms of plant height (cm) (139.99 cm), stem girth (cm) (42.69 cm), number of leaves (29.52) where as minimum days taken for initiation of first flower (103.83 days) was recorded with the spray of Copper sulphate 0.25%+ Manganese sulphate 0.25% (T_5).

Mahmoud *et al.* (2017) studied the impact of the interaction between Amino acids (AA), Naphthalene acetic acid (NAA) and Naphthalene acetamide on plum cv.Santa Rosa on fruit abscission, yield and quality. The results indicated that combine application of AA 0.25 ml/L+NAA 10 ppm + NAD at 10 ppm recorded the highest significant fruit set percentage, lowest significant fruit drop percentage, maximum yield (62- 64 kg/ tree), increased fruit weight, length, diameter, firmness, pulp/stone ratio and total soluble solids content, but decreased titratable acidity in plum cv. Santa Rosa.

Mishra *et al.* (2017a) conducted an experiment on the effect of plant bio-regulators on quality and yield of litchi (*Litchi Chinensis* Sonn.) cv. Rose Scented and the result revealed that fruit retention at the time of harvesting showed maximum in treatment T_8 (61.95%) when GA_3 50ppm was sprayed closely followed by T_5 (61.20%) when NAA 50 ppm was sprayed which were statistically at par with each other. The fruit retention under control (33.09) was significantly minimum when compare with all other treatments.

Mishra *et al.* (2017b) carried out an investigation on effect of foliar feeding of micro-nutrients on yield of aonla (*Emblica officinalis* Gaertn) cv. NA-7 under high density planting. The minimum fruit drop (75.03%) and maximum fruit retention (24.80%) was recorded in combination spray of $CuSO_4$ (0.4%) + $ZnSO_4$ (0.25%) + Borax (0.25%) (T_6). The maximum TSS (12.35%), reducing (3.05%), non-reducing (2.58%) and total sugars (5.63%), Vitamin 'C' (560.5 mg/100g of fruit pulp) and fruit yield (99.04 kg/tree) were recorded with treatment of $CuSO_4$ (0.4%) + $ZnSO_4$ (0.25%) + Borax (0.25%) whereas minimum acidity (1.37%) and stone weight (1.86 g) were also recorded in T_6. They concluded that foliar feeding of $CuSO_4$ (0.4%) + $ZnSO_4$ (0.25%) +

Borax (0.25%) gave best result for the production of maximum fruit yield and better quality of aonla fruits.

Merwad *et al.* (2016) determined the beneficial effect of NAA, Zn, Ca and B on fruiting, yield and fruit quality of Alphonso mango trees grown under drip irrigation system. The obtained results show that treatment No. 16 (NAA + Zn + Ca + B) recorded higher fruit set (11% and 10.76%), fruit retention (3.16% and 2.92%) and reduce in fruit drop(71.30% and 72.90%) and malformed panicles(3.10% and 2.40%) in the first and second season respectively. In case of fruit quality both physical and chemical properties, the results show that spaying Zn, Ca, B and NAA gave a high quality comparing with the control.

Sultana *et al.* (2016) conducted an experiment to evaluate the effect of various plant growth regulators in flower and fruit setting of Litchi during 2014-2015 at different locations in Malda district of West Bengal. Highest percentage of inflorescence retention (74.66), maximum fruit weight (23.26 g), highest yield (121.67 quintal/ha) and increase in the inflorescence of litchi plant was recorded with the application of NAA @ 20ppm (T_3). Control (T_4) shows minimum percentage of inflorescence retention (45.66), fruit weight (17.56 g) and yield (80 quintal/ha).

Chandra and Singh (2015) sprayed zinc sulphate, magnesium sulphate and copper sulphate to see their effect on yield and quality of 8 years old Aonla (*Emblica officinallis* Gaertn L.) cv. NA-7 under Garhwal Himalaya during the year 2013-2014. They found that the combined foliar application of $ZnSO_4$ (0.5%) + $MgSO_4$ (0.5%) + $CuSO_4$ (0.5%) (T_8) was found to be most effective in reducing the intensity of fruit drop, high fruit retention, improving the fruit size and fruit weight, pulp: stone ratio, increase of Vitamin C content and highest fruit yield as compared to other treatments.

Meena *et al.* (2014) conducted an experiment to find out the effect of nutrients spray on growth, yield and quality of six year old Aonla cv. NA-7 at Mandsaur. Combined sprayed of 0.6% calcium nitrate + 0.4% borax + 0.8% zinc sulphate (T_{10}) recorded minimum fruit drop (32.6%) and maximum fruit retention (67.4%) and the maximum fruit drop (79.2%) and minimum fruit retention (20.8%) were recorded under control.

Jagtap *et al.* (2013) conducted an experiment to determine the effect of foliar application of plant growth regulators and micronutrients on yield and quality of acid lime cv. Kagzi (*Citrus aurantifolia* Swingle.) of the year 2011. The result revealed that maximum no. of fruits per tree (1020.33) was recorded in T_6 (NAA 200 mg/L) with less fruit drop and increase the fruit retention.T_4 (GA_3 50 mg/L) show significantly

increase in yield attributing characters like fruit volume (47.90 cc), fruit diameter (4.54 cm), fruit weight (47.40 g) and fruit yield per tree (46.38 kg).

2.2 To study the effect of NAA and micronutrients on yield and quality of Litchi

Kavinprashanth *et al.* (2021) estimated the effect of micronutrients and plant growth regulators on yield and quality of acid lime (*Citrus aurantifolia* Swingle.). The treatment consists of foliar application of growth regulators *viz.,* NAA, GA_3 and 2,4-D and micronutrients such as boric acid, $FeSO_4$ and $ZnSO_4$. The study reported that yield, number of fruits per plant, fruit weight, fruit diameter, fruit circumference, fruit volume, juice content and ascorbic acid were found to be increased by application of NAA 30ppm + Boric acid (0.2%) and the number of seeds were found to be reduced by application of 2,4-D when compared to control.

Vani *et al.* (2021) conducted an experiment to study the effects of plant growth regulators (SA @ 100ppm, GA_3 @ 100ppm, NAA @ 200ppm) and micronutrients ($ZnSO_4$, Boric acid, $CuSO_4$, $MgSO_4$, $ZnSO_4$ each at 0.4%) on yield and economics in fifteen year old guava cv. L-49.The result revealed that in interaction effects of NAA @ 200ppm and ZnSO4 @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @ 0.4% + $MgSO_4$ @ 0.4% has recorded significantly maximum fruit yield per tree (116.92 kg/tree), yield per hectare (46.77 t/ha), fruit weight (187.07 g). Maximum B:C ratio (5.07) was recorded in NAA @ 200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $MgSO_4$ @ 0.4%. They concluded that combination application of NAA @ 200ppm and ZnSO4 @ 0.4% + Boric acid @ 0.4% + CuSO4 @ 0.4% + MgSO4 @ 0.4% was superior in improving the yield and economics of guava cv. L-49.

Dhakad *et al.* (2020) investigated the effect of NAA and zinc sulphate application on fruit drop, yield and quality attributes of mulberry (*Morus alba* L.). Maximum fruit set (74.07%), fruit retention (47.26%) and fruit yield (27.35 kg/tree) was recorded from the trees treated with zinc sulphate @ 0.4 per cent and NAA @ 60 ppm. Highest TSS (27.20%), ascorbic acid (19.44 mg/100ml of juice), TSS: acid ratio (226.67) and minimum acidity (0.12%) was observed in the fruits harvested from the trees treated with zinc sulphate @ 0.4 per cent and NAA @ 40 ppm.

Devaraja *et al.* (2019) studied the effect of micronutrients and plant growth regulators on yield and fruit quality of litchi (*Litchi chinensis* Sonn.*)* cv. Muzaffarpur under foothills of Arunachal Pradesh in the year 2016.The result revealed that highest TSS (18.09°Brix), total sugar (26.13%), reducing sugar (14.49%) and ascorbic acid (38.06 mg/100g) was observed with 0.4% $ZnSO_4$ sprayed (T_1) while

minimum TSS (15.27°Brix), total sugar (17.47%), reducing sugar (11%) and ascorbic acid (35.70%) was recorded in the plants under control (T_9).

Helal *et al.* (2019) evaluated the effect of some growth regulators and boron on fruiting and quality of Orange. Highest fruit set (72.34 and 70.34%) and fruit retention (3.42 and 3.42%), number of fruits/tree (629.8 and 629.9) and yield / tree (124.64 kg and 119.35 kg) in both the seasons were recorded from orange tree spraying with NAA @ 25 ppm+ B @ 500 ppm. Spraying orange trees with B @ 500 ppm recorded the highest values of fruit weight (217.78 g and 217.07 g), pulp weight (179.47 g and 174.80 g) and pulp/ fruit ratio (0.82 and 0.82) in both seasons.

Tsomu and Patel (2019) determined the effect of growth regulators (NAA and GA_3) and micronutrients ($ZnSO_4$ and borax) on yield and quality parameters of mango cv. Mallika. It was observed that combined effect of NAA 20 mg/l + Borax 0.2% significantly increased the number of fruits per plant (213.33), fruit yield (79.97 kg/tree) and various biochemical properties such as titratable acidity (%), TSS (%), reducing sugar (%), non reducing sugar (%), total sugar and ascorbic acid (mg/100g).

Devi *et al.* (2018) conducted an experiment to determine the effect of foliar nutrition and growth regulators on nutrient status and fruit quality of Eureka lemon (*Citrus limon*). The experiment comprised twelve foliar applications consisting of 6%, 8% and 10% K_2SO_4; 0.5%, 0.75% and 1.0% $CaCl_2$; 20 ppm, 30 ppm and 40 ppm 2,4-D and 20 ppm, 30 ppm and 40 ppm NAA. They reported that two time application of 40 ppm NAA resulted in the most effective treatment for minimizing fruit cracking and improving the fruit quality as compared to the other treatments in Eureka lemon.

Sahay *et al.* (2018) carried out an experiment to examine the response of pre-harvest foliar application of micronutrients and growth regulators on yield attributes of litchi (*Litchi chinensis* Sonn.) cv. Purbi. The results indicate that the micronutrients and plant growth regulators had beneficial effect on flowering, fruiting, fruit retention and fruit yield. The maximum fruit set (48.64%), fruit retention (25.36%) and number of fruits per tree (4982), a minimum fruit drop (74.64%) and fruit cracking (7.96%) were recorded with application of NAA @ 20ppm (T_5). The highest fruit yield per tree (102.98 kg), maximum fruit length (4.29 cm), width (3.7 cm), volume (18.86 cc) and weight (20.67 g) was recorded with application of NAA @ 20ppm (T_5) followed by 2,4-D @ 10ppm (T_7).

Priyadarshi *et al.* (2018) studied the effect of growth regulators and micronutrients spray on chemical parameters of litchi (*Litchi chinensis* Sonn.) cv. Calcuttia on 12 years old tree. The result revealed that the plants treated with $ZnSO_4$

@ 0.75% (T_9) recorded highest total soluble solids (20.40°B) and highest non-reducing sugars (2.98%). Application of Boric acid @ 0.75% (T_{12}) recorded maximum reducing sugars (11.14%). Foliar spray of boric acid (0.5%) + $ZnSO_4$ (0.5%) (T_{17}) significantly increases the total sugar content (13.79%) and decreased the titratable acidity (0.32%) of fruits.

Bhatt *et al.* (2017) determined the influence of foliar application of bio-regulators and nutrients on the fruit quality of lemon (*Citrus limon* Burma.) cv. Pant Lemon-1. The result revealed that maximum fruit weight (110.01 g), fruit volume (108.11 g), acidity (6.68 %) were recorded with NAA @ 50 ppm while the values for fruit length, fruit juice, total soluble solids, total sugars, shelf-life of fruits have been obtained maximum with GA_3 @ 20 ppm.

Kaur (2017) conducted an experiment to find out the effect of micronutrients and plant growth regulators on fruit set, fruit retention, yield and quality attributes in litchi cultivar Dehradun. Different doses of zinc sulphate ($ZnSO_4$) @ 0.4%, 0.6%, and 0.8%; Borax @ 0.2%, 0.4% and 0.6% along with control were sprayed on new growth flushes before initiation of inflorescence, whereas 2, 4-D @ 10 ppm, 20 ppm and 30 ppm; GA_3 @ 25 ppm, 50 ppm and 75 ppm were sprayed after fruit setting . The results shows that maximum fruit set (78.15%), fruit retention (60.17%), fruit length (5.6 cm), breadth (5.0 cm), fruit weight (25.90 g), fruit yield (158.73 kg/tree), pulp weight (22.19 g), pulp stone ratio (9.44), TSS (22.96°Brix) and sugars (18.52%) with minimum fruit cracking (2%), stone weight (2.35 g), peel weight (1.36 g) and acidity (0.4%) were recorded with 0.4% borax application followed by 50 ppm GA_3.

Majumder *et al.* (2017) studied the response of growth regulators and micronutrients on yield and physico-chemical quality of Ber (*Zizyphus mauritiana* Lamk) cv. BAU Kul-1. The treatment consisted of two different levels of NAA, GA_3, 2,4-D, $ZnSO_4$ and H_3BO_3 along with a control (water spray). Maximum fruit retention (42.83%) and total no. of fruits/tree (514) were obtained with the application of NAA @ 20 mg/l. Highest TSS (11.7°Brix), total sugar (8.33%), reducing sugar (5.21%) and TSS: Acid (107.36) ratio with lowest fruit acidity (0.10%) were recorded with the application of H_3BO_3 at 0.4% whereas highest vitamin-C content of fruit was recorded with GA_3 @ 20 mg/l (64.68 mg / 100 g) followed by NAA @ 20 mg/l.

Kumar *et al.* (2016) studied the effect of micronutrients and plant growth regulators on yield and quality of litchi (*Litchi chinensis* Sonn.) cv. Purbi at Sabour on 30 years old trees. Maximum number of fruits per tree (5422), average weight of individual fruit (20.91 g) and fruit yield per tree (111.05 kg) was recorded with the

application of borax (0.4%). Interaction treatment i.e., Borax 0.4% × GA_3 20 ppm produced highest fruit yield per plant of 123.10 kg. GA_3 (20 ppm) and $ZnSO_4$ (0.4%) were found most effective treatments to increase the content of reducing sugar and total sugar.

Singh and Kaur (2016) studied the influence of foliar application of zinc and boron on the fruit quality of litchi cv. Dehradun in the year 2015. Zinc sulphate and boron both was applied @ 0.3%, 0.6% and 0.9% as foliar spray at pea stage .The results of the study indicated that the application of boron 0.9% resulted in maximum fruit volume (23.59 cc),specific gravity (1.02 g/cc), TSS (19.47%), TSS/acid ratio (57.39), reducing sugars(11.33%), total sugars (17.41%), maximum ascorbic acid (33.18 mg/100g) while minimum acidity (0.33%) was observed in the plants under control.

Lal *et al.* (2015) evaluated the effect of pre-harvest application of Gibberellic acid, NAA, and Calcium nitrate on fruit drop, maturity and storage quality of Kinnow mandarin. Minimum fruit drop (14.28%) was reported at foliar application of NAA @ 20 ppm. The delayed in fruit maturity was recorded in treatment with GA3 @ 100 ppm (296.95 days). It was also recorded that calcium nitrate at 2.0 and 1.5 per cent and NAA 20 ppm prove more effective in minimizing the loss of fruit spoilage, fruit weight, fruit juice, ascorbic acid, TSS and total sugars.

Sharma and Tiwari (2015) conducted an experiment to determine the effect of growth regulator sprays on growth, yield and quality of guava cv. Allahabad Safeda under Malwa Plateau conditions. The result shows that maximum increase in plant height (0.63 m), canopy spread E-W (0.81 m) and N-S (0.85 m), canopy height (0.57 m), maximum fruit volume (174.6 ml), fruit length (6.54 cm) and diameter (5.74 cm) at harvest, number of fruit/plant (251.1), average fruit weight (223.37 g), yield/tree (56.10 kg), ascorbic acid (180.1 mg/100 g) and pectin (1.61%) content were recorded with the foliar spray of NAA 100 ppm.

Meena *et al.* (2014) conducted an experiment to study the effect of nutrients spray on growth, yield and quality of aonla on six year old aonla tree cv. NA-7. They obtained that the highest increment in plant height (0.95 m), Canopy spread E-W and N-S (0.89 m and 0.86 m) and canopy height (0.93 m) were observed with the combined spray of 0.6% calcium nitrate + 0.4% borax + 0.8% zinc sulphate. Further, the result shows that the maximum fruit volume (44.10 ml), fruit length (4.20 cm), fruit diameter (4.46 cm), pulp thickness (1.41 cm) and highest reducing sugar (3.56%), non reducing sugar (2.99%), juice (78.22%), fruit weight (45.20 g), yield per tree (42.70 kg)

were recorded with the combined spray of 0.6% calcium nitrate + 0.4% borax + 0.8% zinc sulphate. Minimum values of these characters were recorded with water spray (control).

Bhowmick and Banik (2011) assessed the effect of growth regulators (NAA and GA_3) and micronutrients ($ZnSO_4$ and Borax) on fruit retention and fruit physico-chemical properties in mango cv. Himsagar. Maximum fruit retention percentage (7.25%) as well as maximum number of fruits at harvest (790.17/tree) was recorded with NAA at 40 ppm and maximum yield (217.24 kg/tree) was obtained with GA_3 at 40 ppm. Maximum length (9.28 cm), breadth (7.31 cm) and weight (283.38 g) were recorded with GA_3 at 40 ppm, whereas highest TSS, total sugars and non-reducing sugar content were recorded with $ZnSO_4$ at 1.5 per cent.

Dutta *et al.* (2011) studied the effect of plant growth regulators on fruit quality and leaf mineral composition of litchi (*Litchi chinensis* Sonn.) cv. Bombai grown in New Alluvial Zone of West Bengal on 20 years old tree. Treatment with NAA at 50 mg/L (T_4) resulted in maximum fruit weight (24.22 g), size (3.8/3.4 cm) and edible ratio (2.25) followed by NAA at 25 mg/L (T_3) while GA_3 at 100 mg/L (T_2) recorded maximum TSS (19.8°Brix), total sugar (14.30%), sugar : acid ratio (23.8) and ascorbic acid (32.25 mg/100 g pulp) content of fruit followed by GA_3 at 50 mg/L (T_1). Leaf mineral (N, P and K) contents were influenced by PGR treatments. Both NAA at 50 mg/L (T_4) and GA_3 at 100 mg/L (T_2) are equally effective in improving the fruit quality and leaf mineral composition of litchi.

Pandey *et al.* (2011) investigated the influence of NAA, GA_3 and Zinc Sulphate on fruit drop, growth, yield and quality of ber cv. Banarsi Karaka. The result shows that the application of NAA 20 ppm + GA_3 40 ppm + $ZnSO_4$ 0.4% proved to be the most effective treatment for increasing fruit length (3.98 cm), width (2.99 cm), weight (20.13 g), yield (118.25 kg) and weight of fruit pulp (19.02 g), TSS (14.20ºBrix), total sugars (10.71%), acidity (0.17%) and ascorbic acid (78.35 mg/100g) content and reduction in fruit drop (78.20%) and increase in fruit retention (21.81%) in ber cv. Banarsi Karaka.

Ghosh *et al.* (2009) evaluated the effect of nutrients and plant growth regulators on fruit retention, yield and physicochemical characteristics in aonla cv. NA-10. The result revealed that maximum fruit retention (22.3%) and yield per tree (54.9 kg) was recorded with spray of NAA at 10 ppm, followed by NAA 20 ppm. Fruit weight (31.3 g) was maximum with 0.5% $ZnSO_4$ spray, followed by NAA 10 ppm. Highest TSS (9.5º Brix) was recorded with spray of NAA at 10 ppm, followed by NAA 20 ppm.

Kumar *et al.* (2009) assessed the effect of NAA (10, 15 and 20 ppm), GA3 (50, 75 and 100 ppm) and boric acid (0.1, 0.2 and 0.3%) on vegetative growth, yield and quality of strawberry Cv. Chandler. The result revealed that plants treated with NAA at 20 ppm produced berries with maximum TSS (7.68°Brix), total sugars (5.97%) and titratable acidity (0.92%) contents, whereas the ascorbic acid content was maximum (56.66 mg) in the berries of plants treated with GA3 at 100 ppm.

2.3 To study the effect of NAA and micronutrients on shelf life of Litchi

Kumar *et al.* (2021) studied the effect of plant nutrients on quality and shelf life of papaya (*Carica papaya* L.) Cv. Taiwan Red Lady. Results revealed that the combined foliar application of plant nutrients significantly increased the TSS (12.26ºBrix), total sugars (7.91%), reducing sugars (6.07%), non-reducing sugars (1.84%) and ascorbic acid (23.56 mg/100g) and reduced physiological loss in weight PLW% (15.62%), titrable acidity (0.011%) and shelf life (6.83 days) was obtained with the treatment T_4: KNO3 (1.5%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) + $ZnSO_4$ (0.5%) per tree.

Ravikiran *et al.* (2018) conducted a field experiment to know the effect of integrated nutrient management and micronutrients on post harvest quality parameters and shelf life of mango (*Mangifera indica* L.) cv. Banganapalli under high density planting. The result revealed that maximum TSS (17.76°Brix), total sugar (13.43%), reducing sugar (5.23%), non reducing sugar (8.20%), ascorbic acid (32.36 mg/100g pulp) and shelf life (12.90 days) and minimum acidity (0.304%) was recorded from the application of F_2M_2 - 50% RDF + 50% VC + 250 g *Azotobacter* + (0.8%) $ZnSO_4$ + (0.5%) H_3BO_3 + (0.5%) $FeSO_4$ / tree (T_5) when compare with other treatments.

Sudha *et al. (*2018) performed an experiment to determine the effect of micronutrients on quality and shelf-life of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler during the year 2015-2016. They found that maximum fruit yield per plot (1010.50 g), maximum TSS (10.18°B), (9.56°B) and (9.12°B) on 3rd day, 5th day and 7th day respectively, minimum acidity (0.44%), (0.43%) and (0.35%) on 3rd day, 5th day and 7th day respectively, maximum vitamin C (51.63 g), (51.26 g) and (50.23 g) on 3rd day, 5th day and 7th day respectively and maximum shelf-life (at the room temperature) (2.51 days) from the application of 0.4% ($ZnSO_4$+ Boron+ $FeSO_4$) (T_{11}) while minimum shelf-life (at the room temperature) (1.63 days) was obtained under control (T_0).

Patel *et al.* (2017) investigated on the influence of plant growth regulators and boron on nutritional quality and shelf life of Aonla fruit. They reported that the shelf life of aonla fruits was extended up to 16 days at room temperature when

the treatment was given in combination of plant growth regulators and boron (40 ppm NAA + 50 ppm GA_3 + 0.5% Boron) at pin head and pea stage.

Thirupathaiah *et al.* (2017) studied the effect of micronutrients on post harvest quality and shelf life of Sapota cv. Kalipatti. They found out that foliar spray of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.3% B (T_{10}) shows the maximum number of days (5.00 days) to ripe the fruit after harvest with the maximum shelf life (12 days) while the minimum number of days to ripe (3.00) was noticed in T_1 (control) and in T_2 (water sprayed) with the minimum shelf life (8 days) in T_1 (control).

Meena *et al.* (2013) evaluated the effect of naphthalene acetic acid (NAA) and ferrous sulphate on physico-chemical characteristics and shelf life of ber cv. Gola. The results revealed that 100 ppm NAA and 0.4% $FeSO_4$ was found most effective in significantly increasing the fruit weight (18.35 & 22.95%), fruit length (23.11 & 27.95%) and fruit width (20.15 & 17.9%) respectively over the control. The application of 75 ppm NAA and 0.3% $FeSO_4$ helped in maintaining the marketability and also reduced the fruit weight loss (2.19 and 2.41%) and fruit decay loss (10.37 and 9.81%), respectively over the control. They concluded that application of 100 ppm NAA and 0.4% $FeSO_4$ was found most economical than the other treatments.

Chapter - 3
Materials and Methods

The required details of materials used and methods employed while conducting the present investigation are described below.

3.1 Experimental site

The present investigation was carried out during the year 2020-21 at Fruit Research Farm (Litchi Block), Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. It is geographically located at 28^0 04' 43" N latitude and 95^0 19' 26" E longitude with an altitude of 153 m above mean sea level. The topography of the land is medium high in situation endowed with good drainage facility.

3.2 Climate and weather

Pasighat falls under the humid sub-tropical climate. The average annual temperature and rainfall of this region are 26.93^0C and 398.36 mm respectively. Monsoon commences from June and often continues till September with peak precipitation during July. October is the warmest while February is the coldest month of the experimental period with average temperature of 30.34^0C and 24.00^0C respectively. The summary of meteorological details during the year 2020-21 has been presented in Appendix-I.

3.3 Experimental materials

3.3.1 Description of the crop

The research was carried out on ten years old Litchi trees cv. Muzaffarpur planted at a spacing of 8 m × 8 m. It is a tall evergreen tree with dense, round- topped canopy and a short stocky trunk. The new flushes are a distinctive red-brown when immature and light to dark green as they mature. Inflorescences are many branched panicles with tiny petalless, greenish-white to yellowish flowers borne in terminal clusters of 30-75 cm long previous season shoot. Litchi produce male, female and pseudohermaphrodite flowers open in three different phases respectively. Fruits are round, oval or heart-shaped with a thin, leathery, rough or minutely warty skin which can be peeled easily when fresh. The aril or flesh is generally translucent white, juicy or firm, and sweet and aromatic with musky flavour.

3.3.2 Plant growth regulator

Synthetic auxin *viz*. Naphthalene acetic acid (NAA) @ 10 ppm, 15 ppm, 20 ppm and 25 ppm were applied as foliar spray to the treated plants. Since it is insoluble in water, it is initially dissolved in a small amount of 1 N sodium hydroxide (NaOH) solution and then brought to the required volume with water for preparation of spray solutions.

3.3.3 Micronutrients

Two micronutrients, *viz*., Borax @ 0.5% and Zinc sulphate @ 0.5% were applied as foliar spray to the plants. Since they are soluble in water, the spray solution was prepared by dissolving the required amount of micronutrients in water.

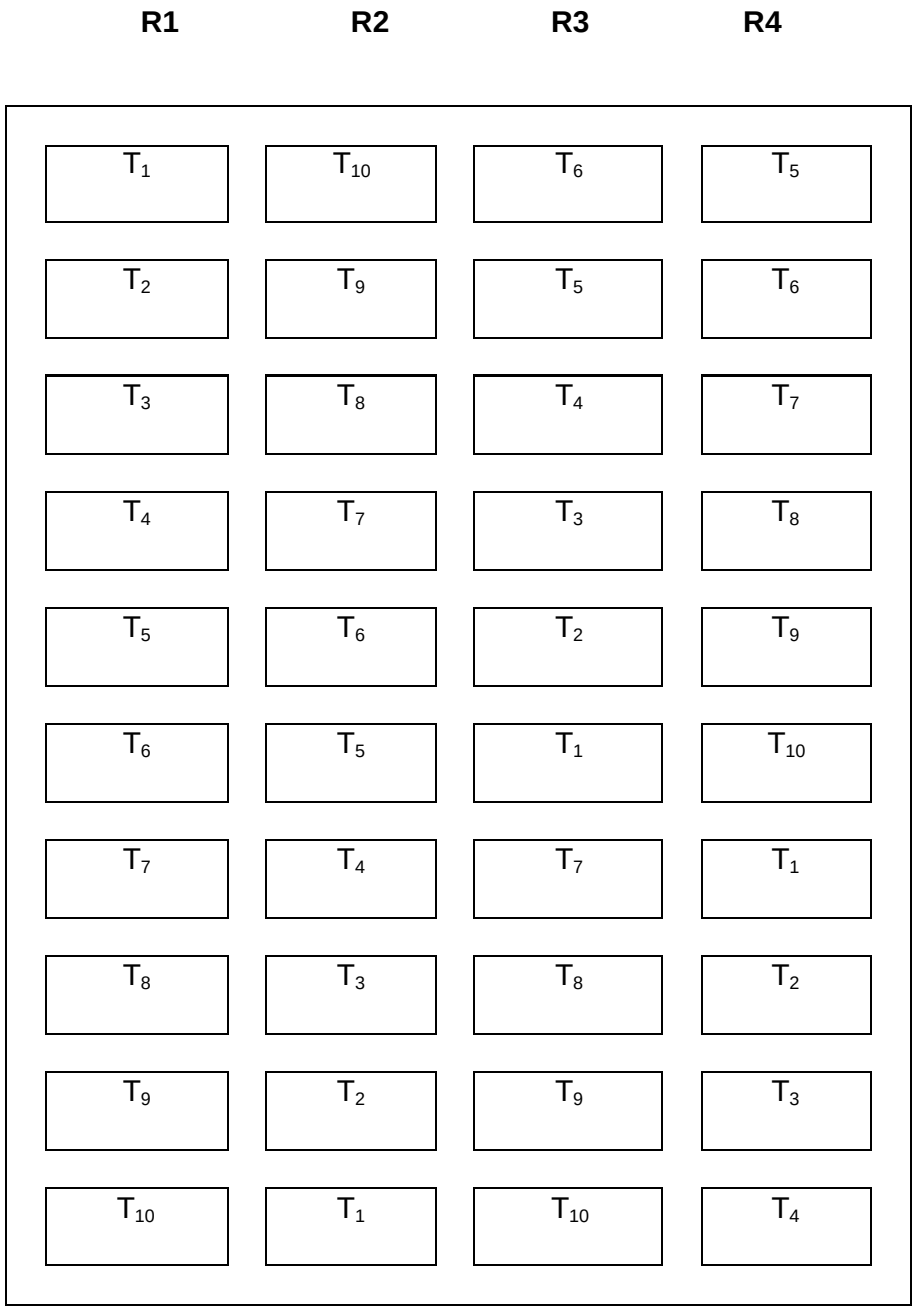
3.3.4 Treatments

Treatments	Details
T_1	NAA @ 10 ppm
T_2	NAA @ 15 ppm
T_3	NAA @ 20 ppm
T_4	NAA @ 25 ppm
T_5	NAA @ 10 ppm + 0.5% Borax + 0.5% Zinc sulphate
T_6	NAA @ 15 ppm + 0.5% Borax + 0.5% Zinc sulphate
T_7	NAA @ 20 ppm + 0.5% Borax + 0.5% Zinc sulphate
T_8	NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate
T_9	0.5% Borax + 0.5% Zinc sulphate
T_{10}	Control

3.4 Experimental methods

3.4.1 Layout and experimental design

The experiment was laid out in a Randomized Block Design (RBD) consisting of 10 (ten) treatments and 4 (four) replications with one plant in each treatment. A layout of the experiment is given in Fig. 3.1



Design= RBD Spacing= 8m × 8m

No. of replications= 4 No. of treatment plant per replication= 1

No. of treatments= 10 Total plant population= 40

Fig. 3.1 Layout of experimental plot

3.4.2 Fertilizer application

The recommended dose of fertilizer (RDF) for 10 years and above old litchi tree is 1200:500:600 g NPK/plant/year (Anon., 2009.). Half dose of RDF was applied to all the plants under study before flowering during October and the remaining half dose was applied after fruit setting during April.

3.4.3 Treatment application

First foliar spray of PGR (NAA @ 10 ppm, 15 ppm, 20 ppm and 25 ppm) and micronutrients (0.5 % Borax and 0.5 % Zinc sulphate) was applied after emergence of new flushes during November, the second spray was applied after one month interval during December and the third spray was applied after fruit setting during April. Micronutrients were applied one week ahead of PGR.

3.4.4 Branch Tagging

Tagging of branches was done before the initiation of panicle formation i.e. prior to flowering. For observation, 4 branches/plant was tagged randomly on four directions (North, South, East and West) of the selected treated plant.

3.4.5 Flower counting

Number of male, functionally female and functionally male flower per panicle was counted on the tagged branches of each plant starting from 1st week of March and continues till fruit setting happens.

3.4.6 Fruit counting

Percentage of fruit setting per panicle was found out just after fruit set by counting the number of fruits retained on the panicle and thereafter the number of fruits per panicle retained at harvesting stage was counted. During harvesting stage of the fruit, fruit cracking percentage per plant was found out.

3.4.7 Irrigation

Irrigation was provided to the plants just after fertilizer application and as per requirement during dry periods.

3.4.8 Weeding

The experimental plot was kept clean by removing any unwanted weeds either manually or mechanically at regular interval. Dried twigs were also removed whenever required.

3.4.9 Plant protection

Various plant protection measures were taken up during the investigation to prevent pests and diseases. It included the application of Cypermethrin @ 1ml/litre after emergence of new flushes for controlling leaf eating caterpillar. Shoot borer infested tree branches were pruned off manually and closed the entrance of the tunnel (hole) by plugging with cotton wool soaked in insecticide solution (Cypermethrin @ 1ml/litre of water) and paste washing soap.

3.4.10 Harvesting

The fruits were harvested when they were fully matured, start to develop attractive red colour on the peel and flatness of tubercles and smoothness of epicarp.

3.5 Observations recorded

3.5.1 Plant growth parameters

3.5.1.1 Plant height (cm)

Plant height was measured by using a measuring tape from the ground level to the terminal shoot apex and was expressed in centimetre (cm). The initial measurement was taken right after the application of treatment and the final measurement was taken after harvesting of fruits. Increase in plant height was then recorded by subtracting the initial value from the final value.

3.5.1.2 Stem girth (cm)

Stem girth was measured by using a measuring tape at 50 cm from the ground level of the tree trunk in all the plants and was expressed in centimetre (cm). The initial measurement was taken right after the application of treatment and the final measurement was taken after harvesting of fruits. Increase in stem girth was then recorded by subtracting the initial value from the final value.

3.5.1.3 Canopy height (cm)

Canopy height was calculated by subtracting the height of the lowermost branch from plant height which was measured by using a measuring tape right after the application of treatment and the final measurement was taken after harvesting of fruits. Increase in canopy height was then recorded by subtracting the initial value from the final value.

3.5.1.4 Volume of the canopy (m^3)

Volume of the canopy was found out by using the formula $\pi r^2 h$ where r is the radius of the canopy and h is the height of the canopy which was measured by using a measuring tape right after the application of treatment and the final measurement was taken after harvesting of fruits. Difference in volume of the canopy was then recorded by subtracting the initial value from the final value and expressed in cubic metre (m^3).

3.5.1.5 Canopy spread (North-South and East-West) (cm)

The initial spread of the plant from North-South and East-West was measured by using a measuring tape right after the application of treatment and the final value was measured after harvesting. The difference in canopy spread was calculated by subtracting the initial value from the final value and expressed in centimetre (cm).

3.5.2 Flower and fruit setting parameters

3.5.2.1 Date of 50% flowering

Number of days was counted from date of panicle initiation till the emergence of flower for each treatment plant and date of synchronised flowering of two plants out of four plants in each treatment was recorded for all the treatments during flowering period.

3.5.2.2 Number of male, functionally female panicle and functionally male flower per

In litchi there are three types of flowers *viz*, male, hermaphrodite functioning as female and pseudo hermaphrodite functioning as male. The first flower to open is male followed by hermaphrodite and pseudo hermaphrodite. During flowering period total number of male, functionally female and functionally male flowers per panicle of the tagged branches on four directions (North, South, East and West) was counted.

3.5.2.3 Fruit setting percentage per panicle

Total number of fruits set per panicle of the tagged branches on four directions (North, South, East and West) of each plant was counted during fruit setting period. The fruit setting (%) was calculated by dividing total number of fruit set per panicle by the total number of flowers per panicle and then multiplied by 100.

$$\text{Fruit set (\%)} = \frac{\text{Total number of fruit set per panicle}}{\text{Total number of flowers per panicle}} \times 100$$

3.5.2.4 Number of fruits at harvest stage per panicle

Total number of fruits retained on per panicle of the tagged branches of each plant was counted during harvesting of the fruit.

3.5.2.5 Fruit cracking percentage per plant

Total number of cracked fruits on each plant from fully matured stage till harvesting of the fruit was counted. Fruit cracking percentage was calculated as follows:

$$\text{Fruit cracking \%} = \frac{\text{No.of cracked fruits}}{\text{Total no.of fruits on the plant}} \times 100$$

3.5.3 Yield Parameter

3.5.3.1 Yield per plant (kg)

Fruits from each plant were harvested separately for all the treatments and the yield/plant was calculated by weighing the fruit in weighing balance in terms of kilogram (Kg).

3.5.4 Fruit Parameters

3.5.4.1 Fruit length (cm)

Ten fruits were selected in random from each plant after harvest and the fruit length was measured from blossom end to stem end by using a digital Vernier caliper. The average fruit length was then expressed in centimetre (cm).

3.5.4.2 Fruit diameter (cm)

Diameter of the fruit was measured at the middle portion of ten representative fruit samples from each plant by using a digital Vernier caliper. The average fruit diameter was then expressed in centimetre (cm).

3.5.4.3 Fruit volume (cm^3)

Fruit volume was determined by water displacement method. Volumes of ten randomly selected fruits were measured individually by submerging them in a container with water and measured the volume of the displaced water. The average fruit volume was then expressed in cubic centimetre.

3.5.4.4 Fruit weight (g)

Ten fruits were randomly selected and the fresh weight was recorded by using a precision weighing balance. The average fruit weight was expressed in grams (g).

3.5.4.5 Peel weight (g)

Ten randomly selected fruits were peeled and the peel weight was measured by using a precision weighing balance. The average peel weight for each fruit were determined and expressed in grams (g).

3.5.4.6 Aril weight (g)

Ten fruits were randomly selected from each plant and then the peel and seed were removed. The aril of the fruits were then weighed on a precision weighing balance and the average aril weight for each fruit were determined and expressed in grams (g).

3.5.4.7 Juice content (ml)

The aril was taken from ten randomly selected fruits from each treatment. The aril was smashed and squeezed manually with the help of muslin cloth. Juice was collected and measured in a measuring cylinder. The average juice content of the fruits were determined and then expressed in millimetre (ml).

3.5.4.8 Seed length (cm)

Seeds of ten fruits which were randomly selected from each plant after harvest were removed and the seed length was measured from blossom end to stem end by using a digital Vernier caliper. The average seed length was then expressed in centimetre (cm).

3.5.4.9 Seed diameter (cm)

Ten fruits were randomly selected from each plant after harvest and the seeds were removed. The diameter of the seed was measured at the middle portion of ten representative seed samples from each plant by using a digital Vernier caliper. The average seed diameter was then expressed in centimetre (cm).

3.5.4.10 Seed weight (g)

Ten fruits were randomly selected from each plant after harvest and the seed was removed. The seed weight was measured on a precision weighing balance and the average seed weight was expressed in grams (g).

3.5.5 Quality parameters

3.5.5.1 TSS (°Brix)

TSS of the fruit was determined by hand held Refractometer (0-32 B). A small drop of fruit juice from the randomly selected fruit sample was placed over the prism surface and the reading was observed through the eyepiece.

3.5.5.2 Titratable acidity (%)

Titratable acidity of the fruit was determined by adopting the standard method formulated through A.O.A.C (Association of Official Analytical Chemists) (1975) by titrating the fruit juice against 0.1 N NaOH solution using phenolphthalein as an indicator (light pink end point) and expressed as percentage in terms of malic acid equivalent from random representative samples.

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value x Normality of alkali x Equivalent weight of acid x 100}}{\text{Volume of sample taken}}$$

3.5.5.3 Ascorbic acid (mg/100g)

Ascorbic acid content of fruits was determined by the method described by Ranganna (1986) using 2, 6-dichlorophenol Indophenol dye. The samples extracted in metaphosphoric acid solution were titrated with dye to pink end point. The ascorbic acid content was calculated and expressed as mg per 100 g of fruit weight sample.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Volume of sample}}$$

3.5.5.4 Total sugar (%)

Total sugar content was estimated by Anthrone method as described by Hodge and Hofreiter (1962). In this method, a known sample weight of the fruit was taken and hydrolysed by dilute hydrochloric acid by keeping it in a boiling water bath for three hours. It was cooled, neutralized with solid sodium carbonate until effervescence ceased and centrifuged. The supernatant was then mixed with Anthrone reagent (as indicator). The absorbance of the green colour product was read at 630 nm in spectrophotometer. A standard graph was plotted with the concentration of the standards on the X-axis against the absorbance on the Y-axis. From the graph, the total sugar content was calculated by using the formula:

$$\text{Amount of sugar present in 100 mg of the sample} = \frac{\text{mg of glucose}}{\text{Volume of the sample taken}} \times 100$$

3.5.5.5 Reducing sugar (%)

Reducing sugar content was estimated by Spectrophotometric method as described by Somogyi (1952). 100 mg of the fruit sample was weighed and macerated with 10ml of hot 80% ethanol to extract the sugar. The supernatant was evaporated completely in hot plate at 80 °C. The residue was dissolved in 10 ml distilled water to make extract in different volume. The absorbance was recorded at 620 nm in spectrophotometer. A standard graph was plotted with the concentration of the standards on the X-axis against the absorbance on the Y-axis. From the graph, the total sugar content was calculated by using the formula:

Absorbance responds to 0.1 ml of test = x mg of glucose

10ml contains = $\frac{x}{0.1}$ x 10 ml of glucose

= % of reducing sugar

3.5.5.6 Non-reducing sugar (%)

The non-reducing sugar content was obtained by the subtraction of the reducing sugar content from the total sugar content.

Non reducing sugars content = (total sugar - reducing sugar) x 0.95

3.5.5.7 Date of fruit maturity for each treatment

When the fruits change their skin colour from green to deep red, flattening of tubercles and smoothening of epicarp, it indicates that the fruits are mature. Number of days was counted from date of flowering till the fruits get mature for each treatment plant and date was recorded.

3.5.5.8 Shelf life under room temperature (number of days)

The shelf life of the fruit was determined by visual observation under room temperature and this was continuing till the fruits started to shrivel, peel starts dull brown colour formation and no longer marketable.

3.5.6 Soil parameter (Before and after experiment)

3.5.6.1 pH

The pH of the soil sample before and after experiment was determined by potentiometric method using a digital pH meter. A soil-water suspension in the ratio of 1:2.5 was prepared in which the electrodes of the instrument were immersed to give the reading. The pH value ranges from 0-14. It has no unit.

3.5.6.2 Available Nitrogen (kg/ha)

Available nitrogen in the soil before and after experiment was determined by using Alkaline $KMnO_4$ method (Subbiah and Asija, 1956). The Nitrogen Analyser was used for the estimation. For its determination, 5 g of soil sample was taken in digestion tube and the tube was fitted into the distillation unit. 0.32% $KMnO_4$, 2.5% NaOH solution and distilled water was added automatically by the machine into the fitted digestion tube. The distilled ammonia gas from the tube was collected in the receiver solution containing 2.5% Boric Acid and Mixed Indicator. The distillate was titrated against 0.01 N HCl solution. The end-point is a light pink colour. The nitrogen in the plant sample was determined by using following formula and expressed in kg/ha**.**

$$\text{Available N (kg/ha)} = \frac{\text{Titre value} \times \text{Normality of Acid} \times \text{Atomic weight of N}}{\text{Weight of Sample} \times 1000}$$

3.5.6.3 Available Phosphorus (kg/ha)

The available phosphorus in the soil before and after experiment was determined according to Bray's Method for Acid Soil (Bray and Kurtz, 1945). The phosphates in the soil solution was extracted with Bray No.1 Extractant and filtered through a filter paper. To the filtrate, Dickmann and Bray's Reagent and Stannous Chloride were added. The intensity of the blue colour was measured using a Colorimeter at 630nm wavelength. The concentration of the sample was determined from the standard curve and the available Phosphorus content was calculated using the following formula and expressed in kg/ha.

$$\text{Available P (kg/ha)} = \text{Conc. from graph} \times \frac{\text{volume of extractant used}}{\text{weight of sample}} \times \frac{\text{made up volume of filtrate}}{\text{volume of filtrate used}} \times 2.24$$

3.5.6.4 Available Potassium (kg/ha)

The available potassium in the soil before and after experiment was determined by using Ammonium Acetate method (Hanway and Heidal, 1952). In this, 5 g of soil sample was taken in 100 ml of conical flask and 25 ml of neutral 1 N ammonium acetate solution. The solution was shaken for 5 minutes and then filtrated through Whatmann No.1 filter paper and K concentration was measured using Flame Photometer. The available potassium was calculated by using following formula and expressed in kg/ha.

$$\text{Available K (kg/ha)} = \text{Conc. from graph} \times \frac{\text{volume of extractant used}}{\text{weight of sample}} \times 2.24$$

3.6 Statistical analysis

Observations recorded during field experiment and data obtained from laboratory analysis were subjected to the statistical analysis of variance for RBD. Significance and non-significance of the variance due to different treatments were determined by calculating the respective 'F' values according to the method described by Gomez and Gomez (2010). Standard error (SEm±) was calculated by using the following formula:

$$SEm\pm = \sqrt{\frac{MSE}{r}}$$

where, MSE= Mean sum of squares of error

r = Number of replication

If the treatment regarding a parameter was found significant, Critical Difference (CD) value was calculated by using the below formulae (Chandel, 1993)

$$CD = \sqrt{\frac{2MSE}{r}} \times t.05$$

where, $t_{.05}$= t value at 5% level of significance for error degree of freedom

Fig. 3.2 Experimental Plot

Fig. 3.3 Field data collection

Fig. 3.4 Tagging of branches

Fig. 3.5 Application of Fertilizers

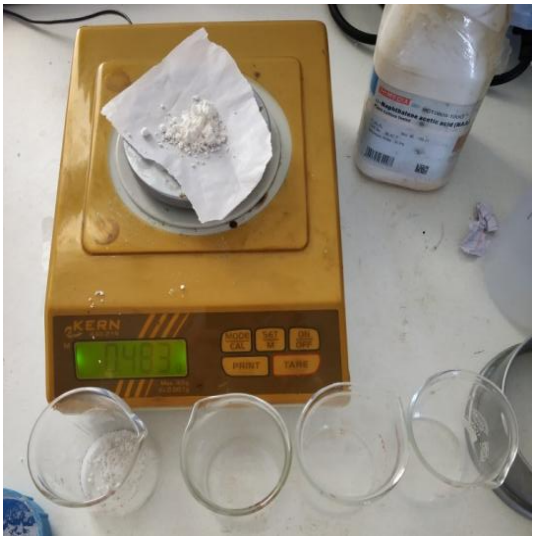


Fig. 3.6 Application of Treatments

Fig. 3.7 Panicle formation

Fig. 3.8 Inflorescence

(a) **(b)** **(c)**

Fig. 3.9 (a) Male flower (b) Functionally female flower (c) Functionally male flower

Chapter - 4
Results

The present work of investigation entitled “Effect of NAA and micronutrients on flowering, fruit setting, yield and quality of litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur.” was conducted during the year 2020-2021 at Fruit Research Farm (Litchi Block), Department of Fruit Science, College of Horticulture and Forestry. In this very chapter, the experimental data obtained from the experimental results have been statistically presented under the following heads.

4.1 Plant growth parameters

4.2 Flower and fruit setting parameters

4.3 Yield parameter

4.4 Fruit parameters

4.5 Quality parameters

4.6 Soil parameter (Before and after experiment)

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Data given in Table 4.1 and Fig. 4.1 with respect to plant height was found to be significantly influenced by the application of NAA and micronutrients and their combination. The maximum mean increase in plant height was observed in T_8 (36.25 cm) which is at par with T_7 (33.75 cm), T_6 (28.75 cm), T_4 (26.25 cm) and T_5 (24.5 cm) and the minimum was observed in T_{10} (8 cm).

4.1.2 Stem girth (cm)

The data obtained from the impact of NAA and micronutrients and their combination on the growth of stem girth (Table 4.1 and Fig 4.1) was found to be non-significant. However, the maximum mean increase in stem girth was noticed in T_5 (1.5 cm) and minimum was noticed in T_{10} (0.85 cm).

4.1.3 Canopy height (cm)

The effect of different treatments on canopy height was found to be significant (Table 4.1 and Fig 4.2). The highest mean increase in canopy height was recorded in T_8 (34.95 cm) which is at par with T_7 (34.27 cm) and T_9 (31.9 cm) and the lowest was observed in T_{10} (6.3 cm).

4.1.4 Volume of the canopy (m^3)

The data on the effect of different treatments on volume of the canopy of the tree is presented in Table 4.1 and Fig 4.3. From the data, it is evident that volume of the canopy of the tree was highly significant due to the effect of application of NAA and micronutrients. The maximum mean increase in volume of the canopy was observed in T_8 (68.7 m^3) which is at par with T_9 (60.26 cm), T_7 (55.21 cm) and T_5 (48.09 cm) and the minimum mean increase was recorded in T_{10} (29.27 m^3).

4.1.5 Canopy spread [East- West and North- South] (cm)

The different treatments were found to have a significant effect on canopy spread in the East- West direction (Table 4.1 and Fig 4.4) wherein, the highest mean increase in canopy spread (E-W) was noticed in T_4 (32.5 cm) which is statistically at par with T_2 (26.75 cm), T_9 (26.25 cm) and T_5 (25 cm) and the lowest was found in T_{10} (13.5 cm).

The treatments were also found to have a significant influence on canopy spread in North- South direction (Table 4.1 and Fig 4.4). The highest mean increase in canopy spread (N-S) was recorded in T_3 (29.75 cm) which is at par with T_7 (28.75 cm), T8 (27.5 cm), T_4 (23.75 cm) and T_6 (23.5 cm) and the lowest was observed in T_2 (17.5 cm).

Table 4.1 Effect of NAA and micronutrients on growth parameters of litchi

Treatments	Increase in plant height (cm)	Increase in stem girth (cm)	Increase in canopy height (cm)	Increase in canopy spread (North-South) (cm)	Increase in canopy spread (East-West) (cm)	Increase in volume of the canopy (m^3)
T_1	12.50	1.32	10.42	25.00	18.75	37.86
T_2	18.50	1.15	22.27	17.50	26.75	40.15
T_3	20.00	1.40	17.82	29.75	20.00	42.92
T_4	26.25	1.17	13.40	23.75	32.50	47.89
T_5	24.50	1.50	16.20	22.50	25.00	48.09
T_6	28.75	0.87	23.75	23.50	23.00	47.63
T_7	33.75	1.22	34.27	28.75	23.75	55.21
T_8	36.25	1.12	34.95	27.50	17.50	68.70
T_9	15.50	1.20	31.90	21.25	26.25	60.26
T_{10}	8.00	0.85	6.30	20.00	13.50	29.27
SEm±	4.65	0.27	3.69	2.48	3.06	7.39
CD (5%)	13.56	NS	10.76	7.23	8.92	21.55

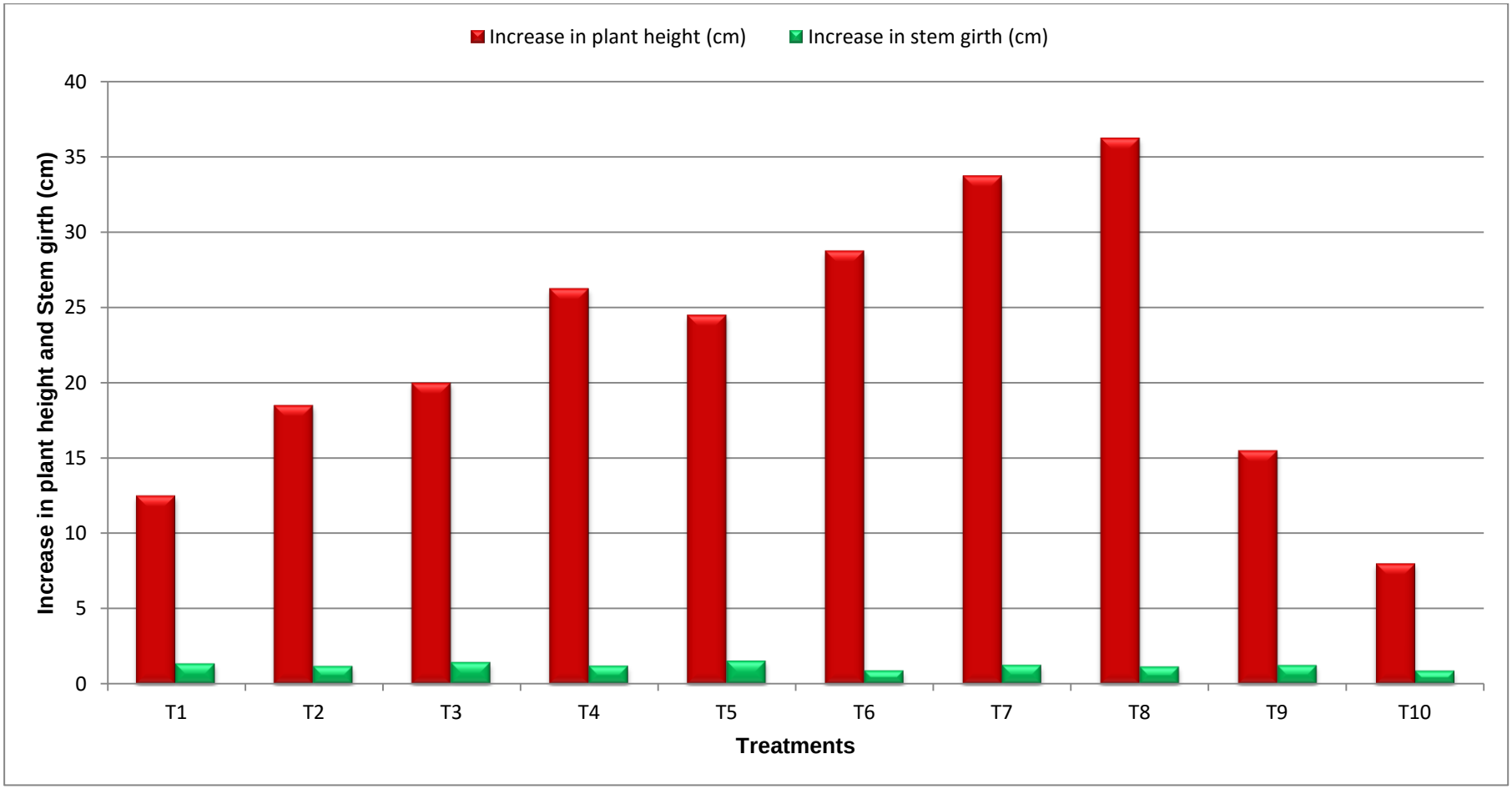


Fig. 4.1 Effect of NAA and micronutrients on plant height and stem girth

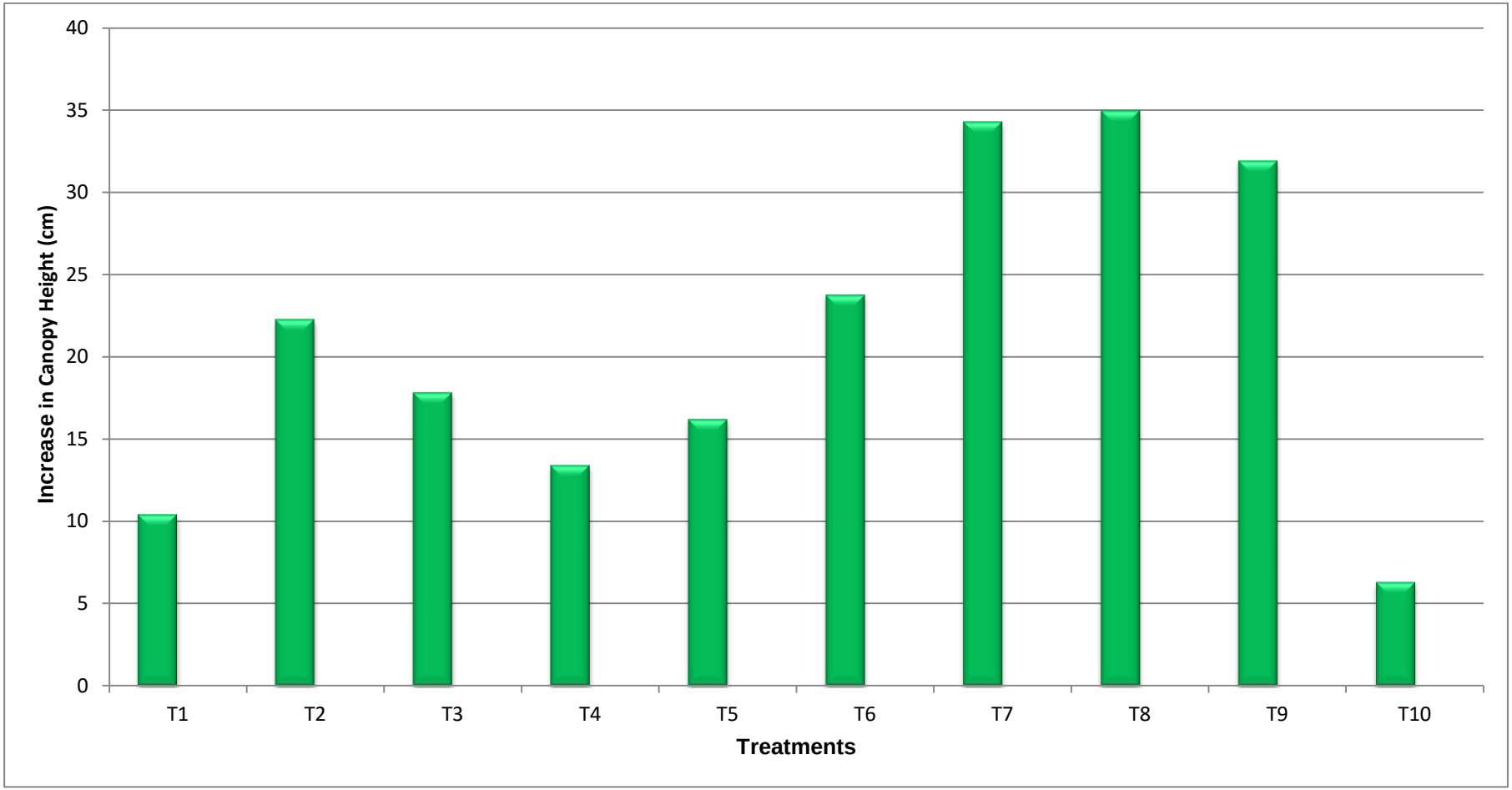


Fig. 4.2 Effect of NAA and micronutrients on canopy height

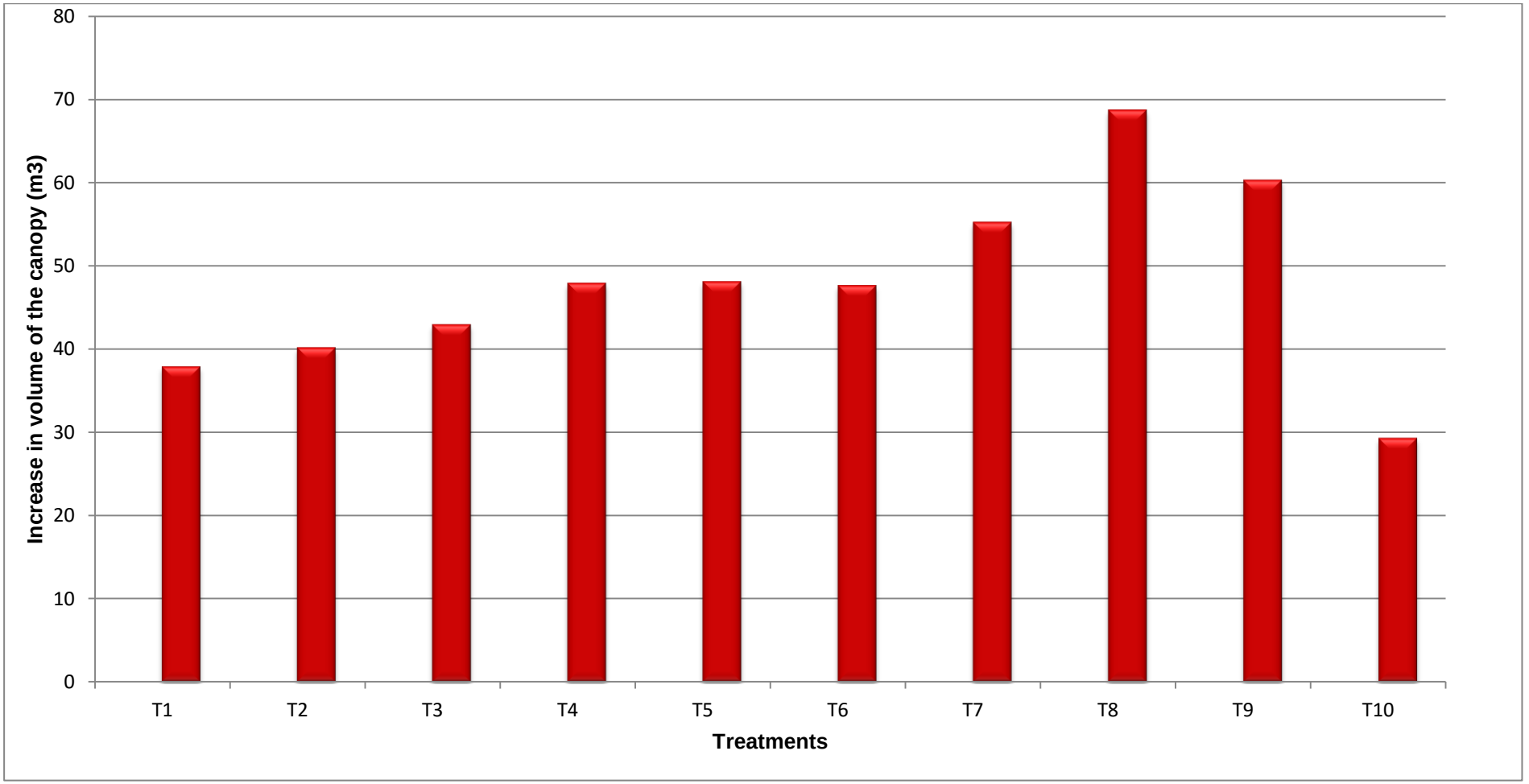


Fig. 4.3 Effect of NAA and micronutrients on volume of the canopy

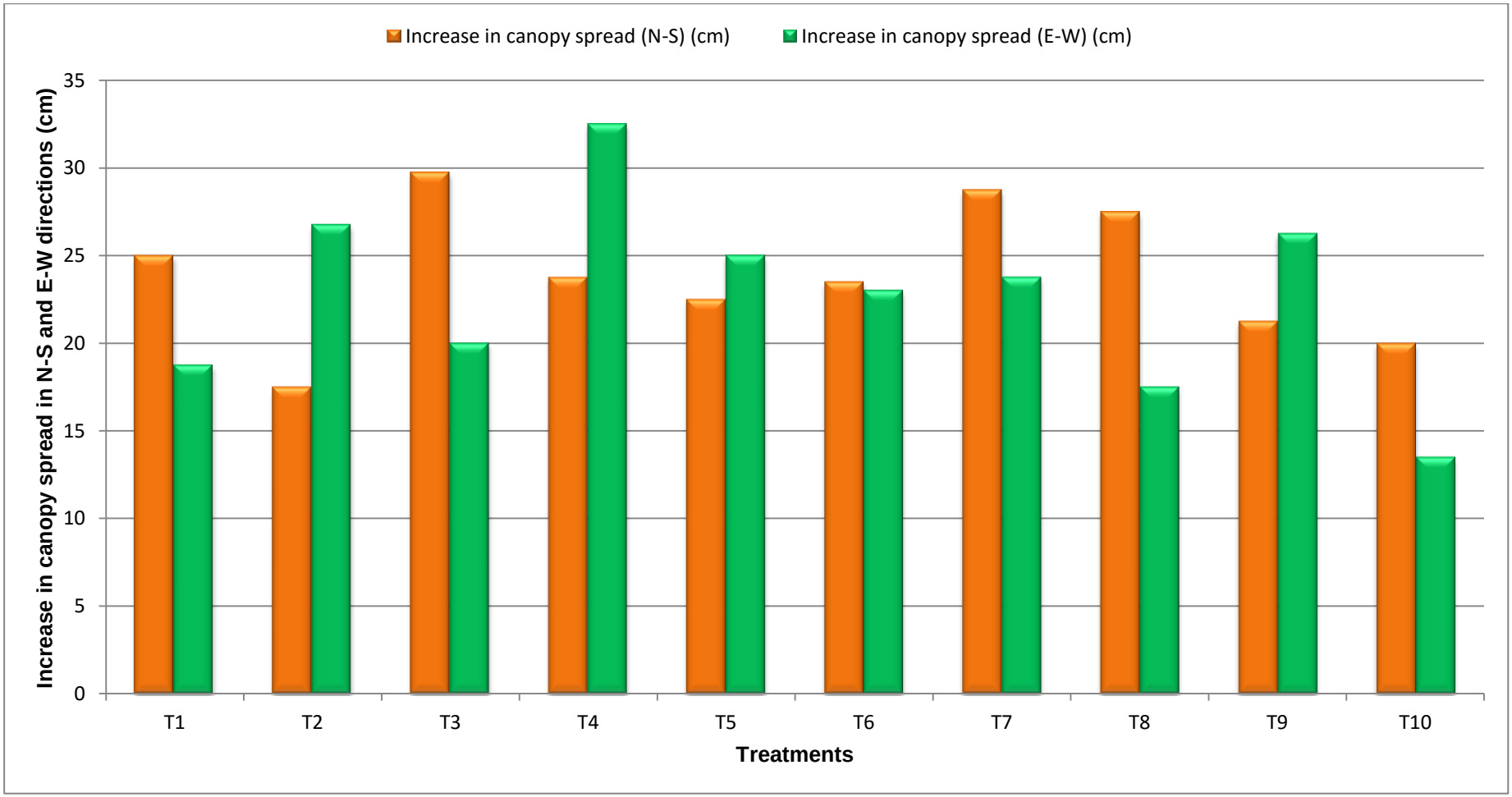


Fig. 4.4 Effect of NAA and micronutrients on canopy spread (N-S and E-W direction)

4.2 Flower and Fruit setting parameters

4.2.1 Date of 50 % flowering

Date of 50% flowering of each treatment was significantly influence by the application of NAA and micronutrients as shown in Table 4.2. Treatment T_7 exhibited the early flower emergence (1st March) with less number of days taken from date of panicle initiation to flower emergence i.e. 14 days which is statistically at par with T_6 (3rd March) and T_8 (4th March) with 14.75 and 15 days respectively taken from panicle initiation to flower emergence and the late flower emergence was observed in treatment T_{10} (15th March) with more number of days taken from date of panicle initiation to flower emergence i.e. 17.5 days.

4.2.2 Number of male, functionally female and functionally male flowers per panicle

The data given in Table 4.2 and Fig 4.5 showed that the number of male, functionally female and functionally male flowers per panicle was highly significant due to the application of NAA and micronutrients and their combination. From the data, it is evident that the maximum number of male flowers per panicle was recorded in T_{10} (72) and the lowest number was observed in T_3 (51).

Likewise, the highest number of functionally female flowers per panicle was recorded in T_8 (75) and the lowest number was observed in T_{10} (37). Similarly, the highest number of functionally male flowers per panicle was found in T_{10} (60) which is at par with T_9 (54) and the minimum number of functionally male flowers per panicle was observed in T_1 (43).

Table 4.2 Effect of NAA and micronutrients on date of 50% flowering, number of male, functionally female and functionally male flowers per panicle

Treatments	Date of 50% flowering		Number of male flowers per panicle (M_1)	Number of functionally female flowers per panicle (F)	Number of functionally male flowers per panicle (M_2)	Sex ratio $\frac{(M1 + M2)}{F}$	Length of the Panicle (cm)	Width of the Panicle (cm)
	Number of days from panicle initiation to flowering	Date of flower emergence						
T_1	16.5	13th March	60	46	43	2.26	15.40	16.00
T_2	16.25	12th March	57	52	46	1.99	17.00	15.80
T_3	15.50	9th March	51	53	47	1.93	15.70	16.20
T_4	15.75	8th March	53	52	48	1.95	16.00	16.00
T_5	15.25	6th March	53	52	46	2.10	15.80	15.70
T_6	14.75	3rd March	52	60	48	1.70	17.30	15.00
T_7	14.00	1st March	64	61	44	1.81	18.70	16.50
T_8	15.00	4th March	61	75	49	1.47	21.50	16.30
T_9	16.00	14th March	70	45	54	2.85	19.00	15.40
T_{10}	17.50	15th March	72	37	60	3.56	18.50	15.50
SEm±	0.35		3.92	4.65	2.11	0.19	0.33	0.21
CD (5%)	1.02		11.43	13.57	6.15	0.56	0.96	0.61

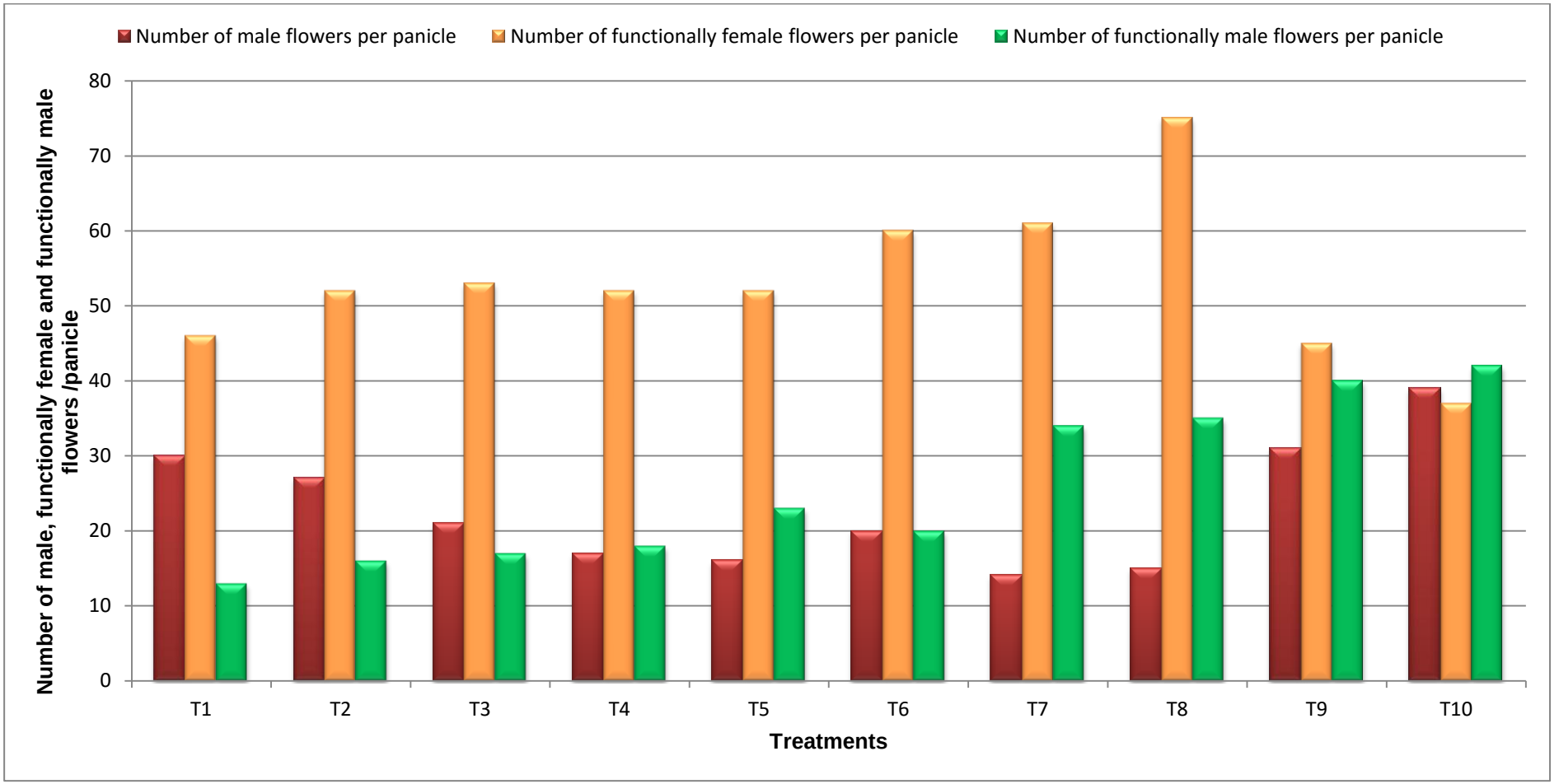


Fig. 4.5 Effect of NAA and micronutrients on number of male, functionally female and functionally male flowers per panicle

4.2.3 Fruit setting % per panicle

The effect of different treatments on fruit setting % per panicle is furnished in Table 4.3 and Fig 4.6. Fruit setting % per panicle was significantly influence by the application of NAA and micronutrients and their combination. The highest fruit setting % per panicle was recorded in treatment T_8 (26.25%) which is statistically at par with T_7 (26.04%) and the lowest fruit setting % per panicle was observed in treatment T_{10} (13.29%).

4.2.4 Number of fruits at harvest stage per panicle

The effect of different treatments on the number of fruits at harvest stage per panicle was found to be significant among the treatments as shown in Table 4.3 and Fig 4.7. The maximum number of fruits at harvest stage per panicle was recorded in treatment T_8 (15) and the lowest number of fruits at harvest stage per panicle was observed in T_{10} (7).

4.2.5 Fruit cracking % per plant

The data on the effect of different treatments on fruit cracking percentage per plant is given in Table 4.3 and Fig 4.8. The data expressed that the fruit cracking percentage was significantly varied due to the application of NAA and micronutrients and their combination. The lowest fruit cracking percentage was recorded in treatment T_7 (3.61%) which is at par with T_8 (3.7%) and T_5 (3.84%) and the highest fruit cracking percentage was observed in T_{10} (13.24%).

4.3 Yield parameter

4.3.1 Yield/plant (kg)

The data recorded on yield per plant showed that it was significantly influenced by the different treatments (Table 4.4 and Fig. 4.9). The highest yield was recorded in treatment T_8 (24 kg) while the lowest was observed in treatment T_{10} (10 kg).

Table 4.3 Effect of NAA and micronutrients on fruit setting % per panicle, number of fruits at harvest stage per panicle and fruit cracking % per plant.

Treatments	Fruit setting % per panicle	Number of fruits at harvest stage/panicle	Fruit cracking % per plant
T_1	18.59 (4.37)*	9	13.16 (3.70)
T_2	19.19 (4.44)	10	10.69 (3.34)
T_3	20.36 (4.57)	11	6.10 (2.57)
T_4	20.48 (4.58)	10	5.03 (2.35)
T_5	24.16 (5.00)	11	3.84 (2.08)
T_6	25.64 (5.11)	12	4.08 (2.14)
T_7	26.04 (5.15)	13	3.61 (2.03)
T_8	26.25 (5.17)	15	3.70 (2.05)
T_9	13.46 (3.73)	9	5.22 (2.39)
T_{10}	13.29 (3.71)	7	13.24 (3.71)
SEm±	0.04	0.58	0.04
CD (5%)	0.11	1.7	0.11

*Square root transformation value

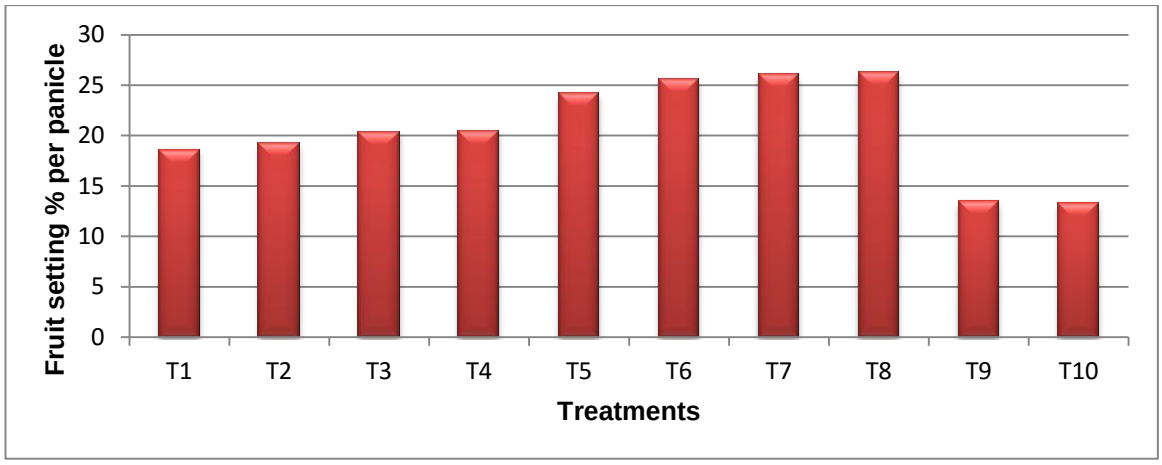


Fig. 4.6 Effect of NAA and micronutrients on fruit setting % per panicle

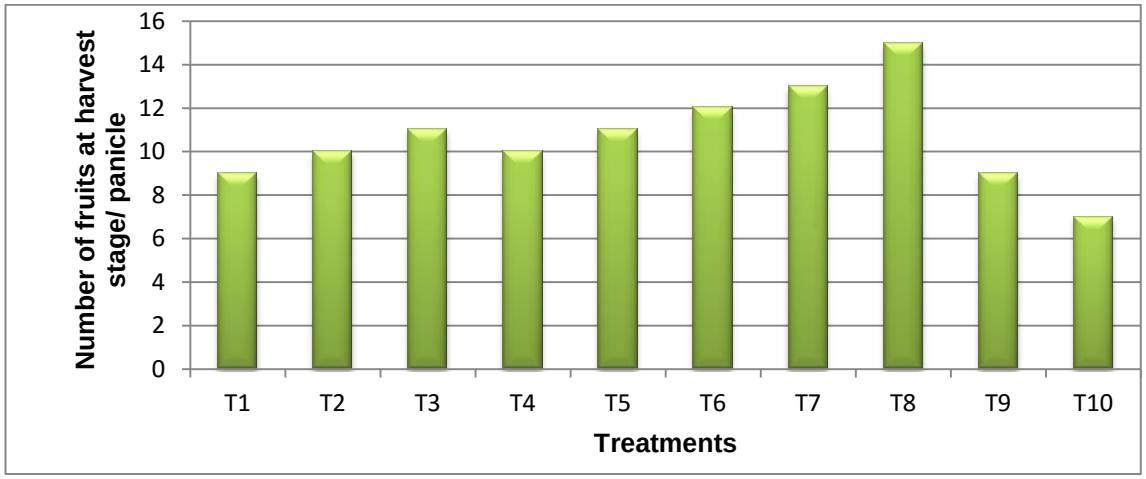


Fig. 4.7 Effect of NAA and micronutrients on number of fruits at harvest stage/panicle

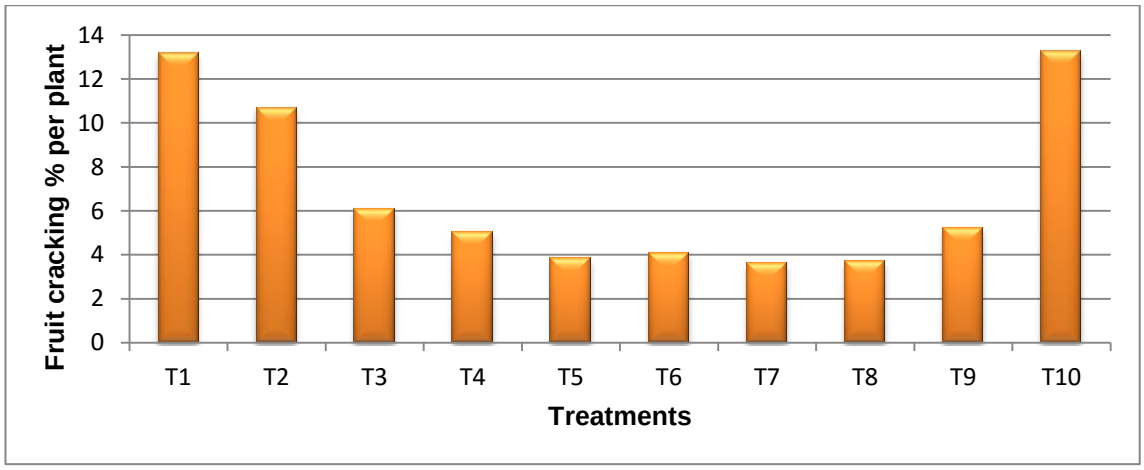


Fig. 4.8 Effect of NAA and micronutrients on fruit cracking % per plant

4.4 Fruit parameters

4.4.1 Fruit length (cm)

As shown in Table 4.4 and Fig 4.10 the effect of different treatments on fruit length was found to be non significant. However, the maximum fruit length was recorded in treatment T_8 (2.6 cm) and the minimum was found in treatment T_9 (2.57 cm).

4.4.2 Fruit diameter (cm)

The diameter of the fruit was found to be significant among the different treatments as presented in Table 4.4 and Fig 4.10. Maximum fruit diameter was seen in treatment T_7 (2.54 cm) which is at par with T_4 (2.53 cm) and T_9 (2.52 cm) and minimum was found in T_{10} (2.48 cm).

4.4.3 Fruit volume (cm^3)

The fruit volume was significantly affected by application of NAA and micronutrients and their combination as shown in Table 4.4 and Fig 4.11. Maximum fruit volume was recorded in treatment T_7 (18.4 cm^3) which is at par with T_4 (18.2 cm^3) and T_5 (18 cm^3) and minimum fruit volume was observed in T_{10} (15.2 cm^3).

4.4.4 Fruit weight (g)

The fresh weight of the fruit was found to be significant among different treatments due to the application of NAA and micronutrients and their combination as given in Table 4.4 and Fig 4.12. The highest fruit weight was observed in treatment T_7 (20.6 g) which is at par with T_5 (19.8 g) and T_4 (19.7 g) and the lowest was noticed in treatment T_{10} (17.8 g).

4.4.5 Peel weight (g)

The effect of NAA and micronutrients and their combination on peel weight of the fruit was found to be significant among the treatments as shown in Table 4.5 and Fig 4.13. Maximum peel weight of the fruit was noticed in treatment T_7 (3.77 g) and minimum peel weight of the fruit was observed in T_9 (3.29 g).

Table 4.4 Effect of NAA and micronutrients on yield per plant, fruit length, fruit diameter, fruit volume and fruit weight

Treatments	Yield/plant (kg)	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cm^3)	Fruit weight (g)
T_1	12	2.58	2.50	16.80	19.10
T_2	13	2.58	2.51	16.60	18.60
T_3	14	2.58	2.50	15.80	17.90
T_4	17	2.59	2.53	18.20	19.70
T_5	16	2.59	2.51	18.00	19.80
T_6	15	2.59	2.50	16.40	18.30
T_7	22	2.59	2.54	18.40	20.60
T_8	24	2.60	2.51	17.60	19.60
T_9	13	2.57	2.52	16.80	19.00
T_{10}	10	2.58	2.48	15.20	17.80
SEm±	0.52	0.01	0.01	0.21	0.31
CD (5%)	1.52	NS	0.02	0.60	0.91

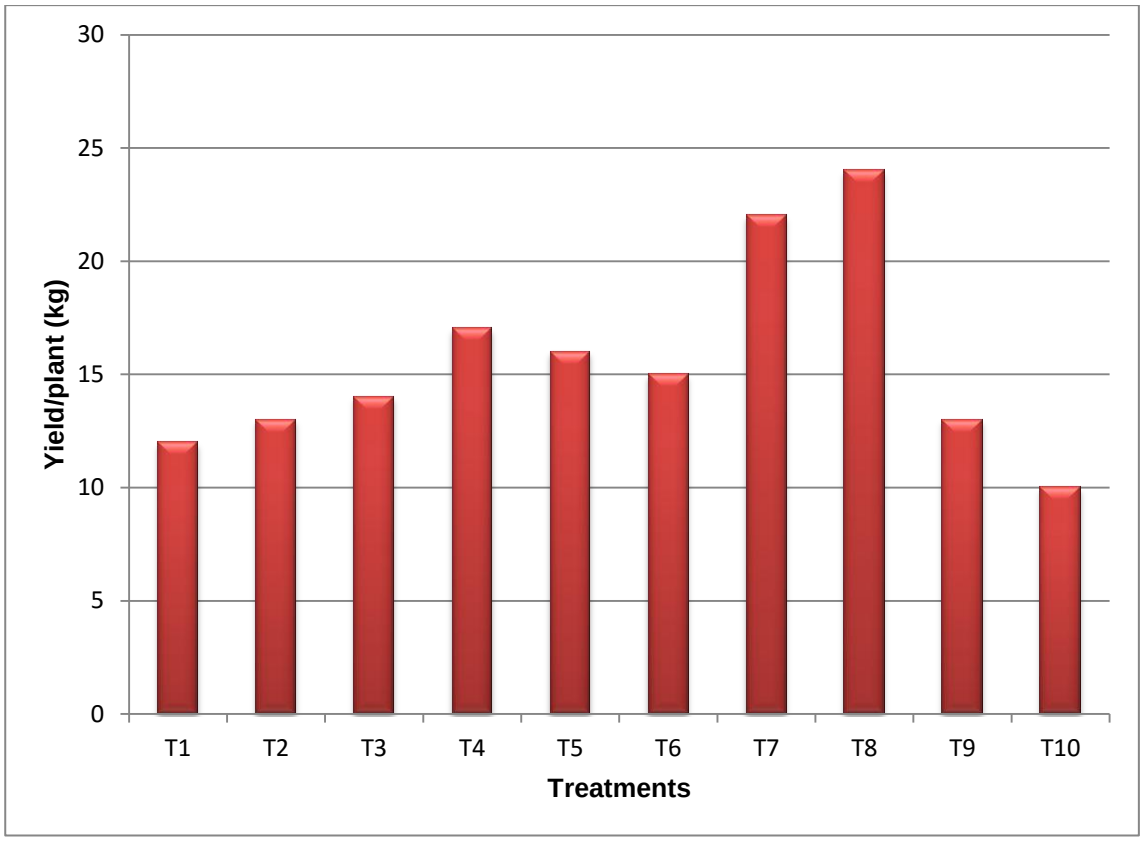


Fig. 4.9 Effect of NAA and micronutrients on yield/plant

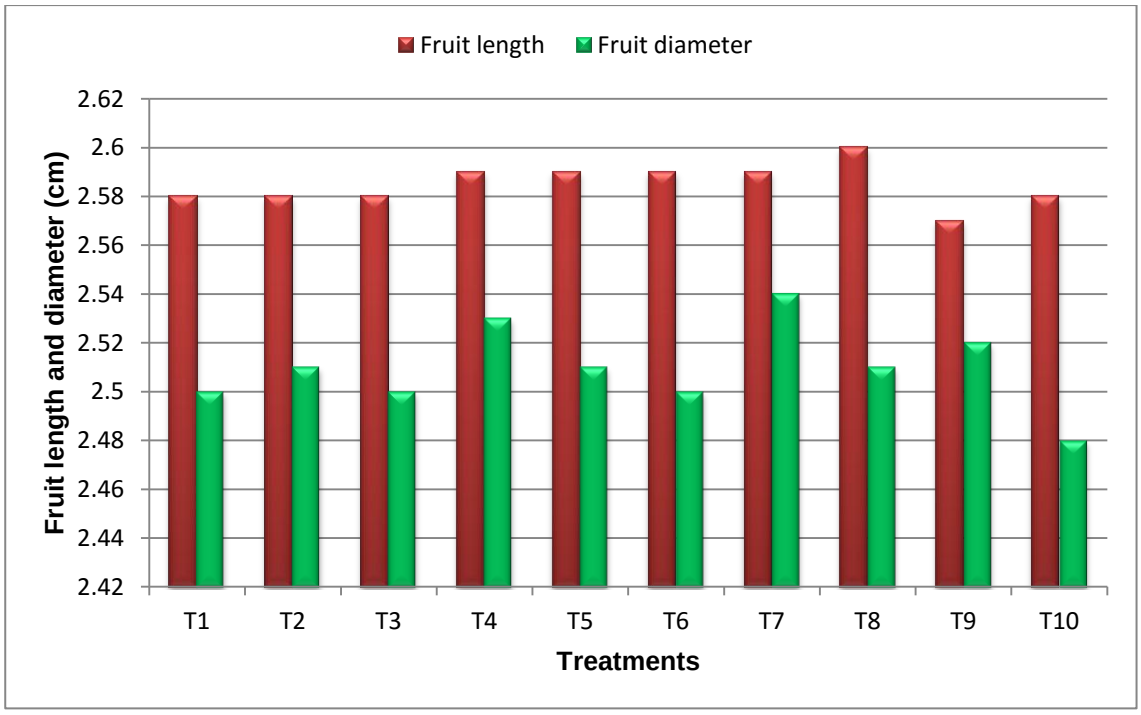


Fig. 4.10 Effect of NAA and micronutrients on fruit length and diameter

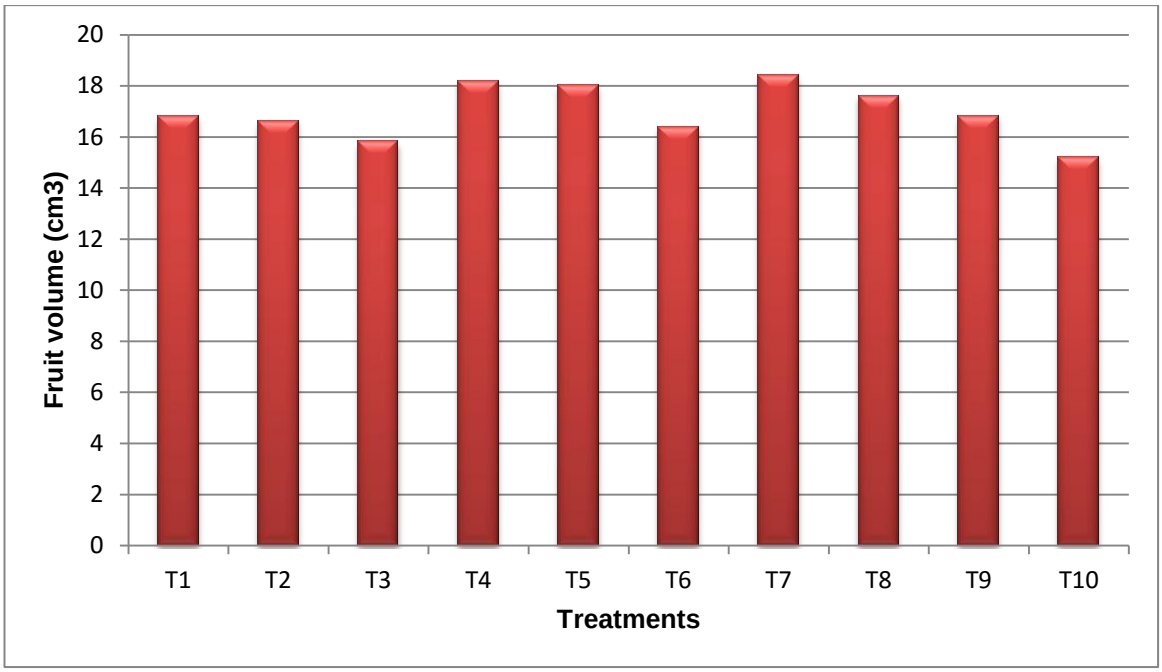


Fig. 4.11 Effect of NAA and micronutrients on fruit volume

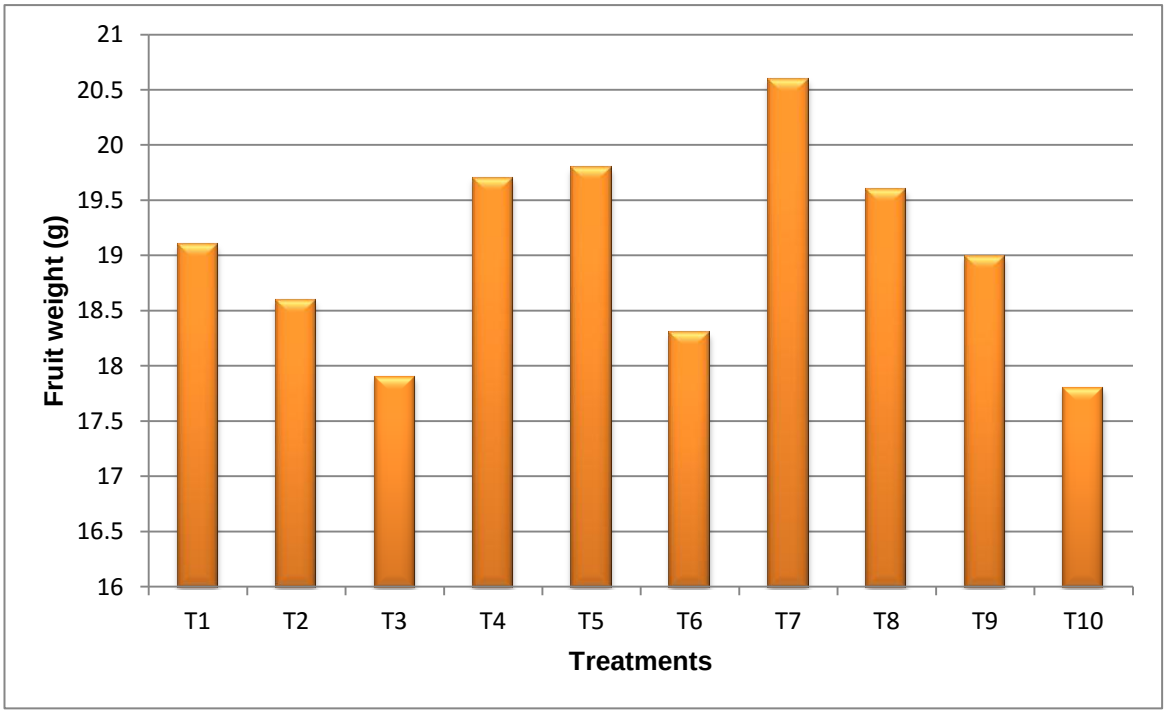


Fig. 4.12 Effect of NAA and micronutrients on fruit weight

4.4.6 Aril weight (g)

Effect of different treatments on aril weight of the fruit was found to be significant as given in Table 4.5 and Fig 4.13. The treatment T_7 (13.24 g) exhibited the highest aril weight of the fruit and the lowest aril weight of the fruit was recorded in T_{10} (10.13 g).

4.4.7 Juice content (ml)

Juice content of the fruit was found to be significantly influence by the application of NAA and micronutrients and their combination among the different treatments (Table 4.5 and Fig 4.14). The juice content per fruit was found highest in treatment T_7 (9.2 ml) and the lowest juice content per fruit was observed in treatment T_{10} (6.3 ml).

4.4.8 Seed weight (g)

In Table 4.5 and Fig 4.15, the data depicted that seed weight of the fruit was significantly influence due to the different treatments. Minimum seed weight was recorded in treatment T_7 (2.8 g) which is statistically at par with T_9 (2.82 g) and T_8 (2.9 g) and maximum was noticed in treatment T_2 (3.74g).

4.4.9 Seed length (cm)

The effect of different treatments on seed length of the fruit was found to be significant as shown in Table 4.5 and Fig 4.16. Least seed length was found in treatment T_7 (2.25 cm) which is at par with T_9 (2.28 cm) and highest seed length was observed in treatment T_{10} (2.46 cm).

4.4.10 Seed diameter (cm)

Seed diameter of the fruit was observed to be significant among the different treatments as given in Table 4.5 and Fig 4.16. Minimum seed diameter was recorded in treatment T_7 (1.31 cm) which is at par with T_9 (1.36 cm) and maximum was found in treatment T_2 (2.37 cm).

Table 4.5 Effect of NAA and micronutrients on peel weight, aril weight, juice content, seed weight, seed length and seed diameter

Treatments	Peel weight (g)	Aril weight (g)	Juice content (ml)	Seed weight (g)	Seed length (cm)	Seed diameter (cm)
T_1	3.66	12.36	7.40	2.99	2.43	2.34
T_2	3.54	10.75	7.20	3.74	2.45	2.37
T_3	3.54	10.54	6.60	2.96	2.44	2.34
T_4	3.58	12.47	8.60	3.36	2.44	2.35
T_5	3.38	12.68	8.60	3.36	2.33	1.41
T_6	3.39	10.55	6.80	3.59	2.45	2.36
T_7	3.77	13.24	9.20	2.80	2.25	1.31
T_8	3.73	12.47	8.20	2.90	2.38	1.46
T_9	3.29	11.13	7.30	2.82	2.28	1.36
T_{10}	3.69	10.13	6.30	3.61	2.46	2.35
SEm±	0.01	0.02	0.08	0.05	0.01	0.02
CD (5%)	0.03	0.05	0.24	0.15	0.03	0.06

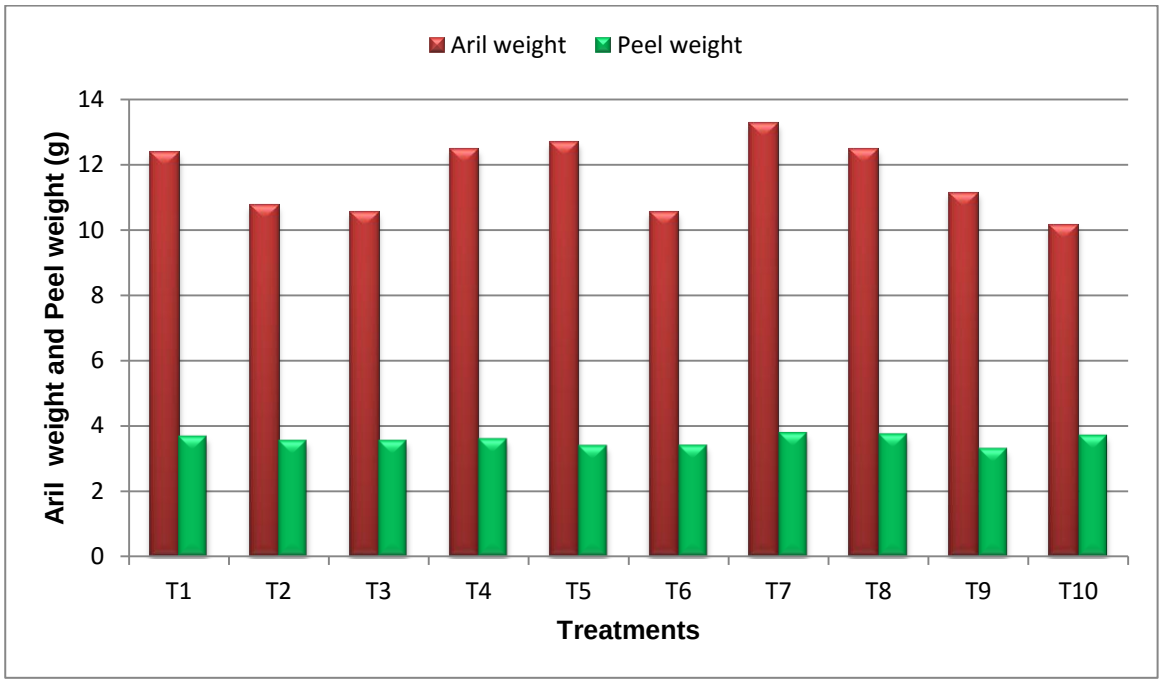


Fig. 4.13 Effect of NAA and micronutrients on aril and peel weight

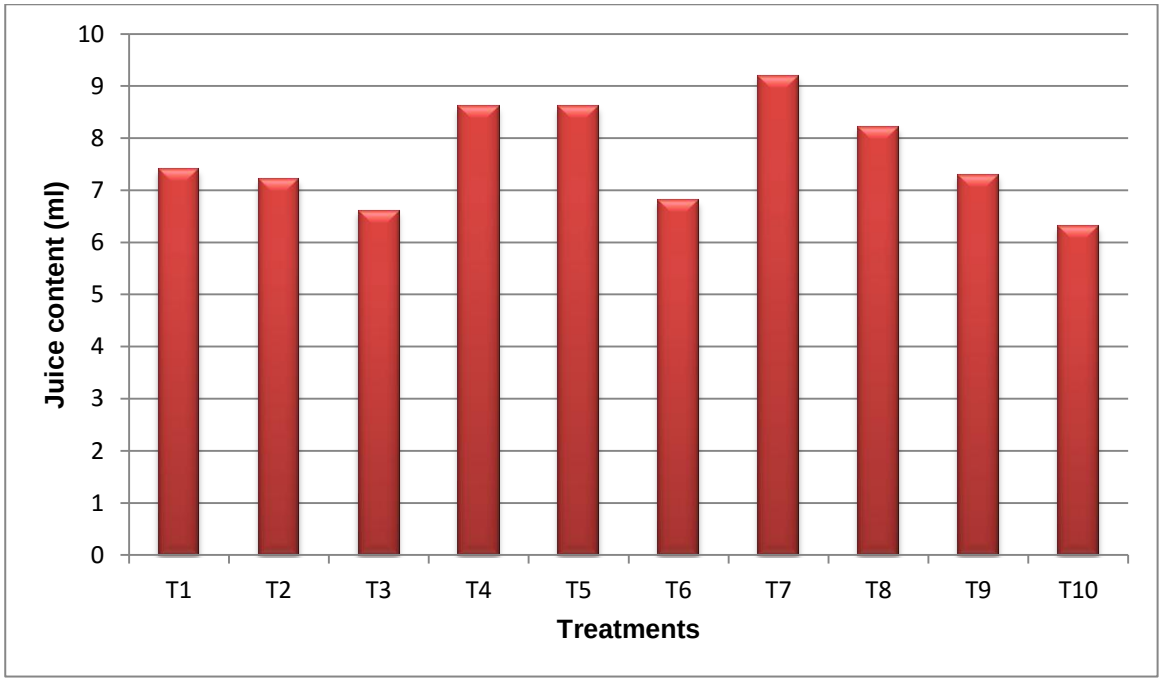


Fig. 4.14 Effect of NAA and micronutrients on juice content

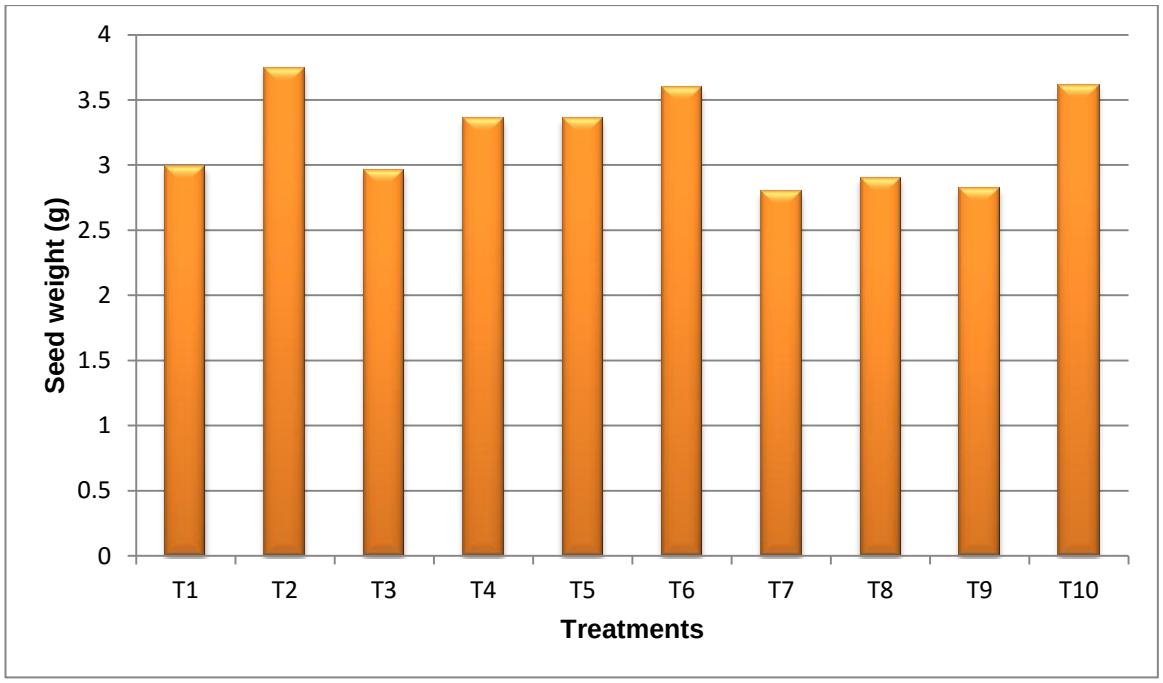


Fig. 4.15 Effect of NAA and micronutrients on seed weight

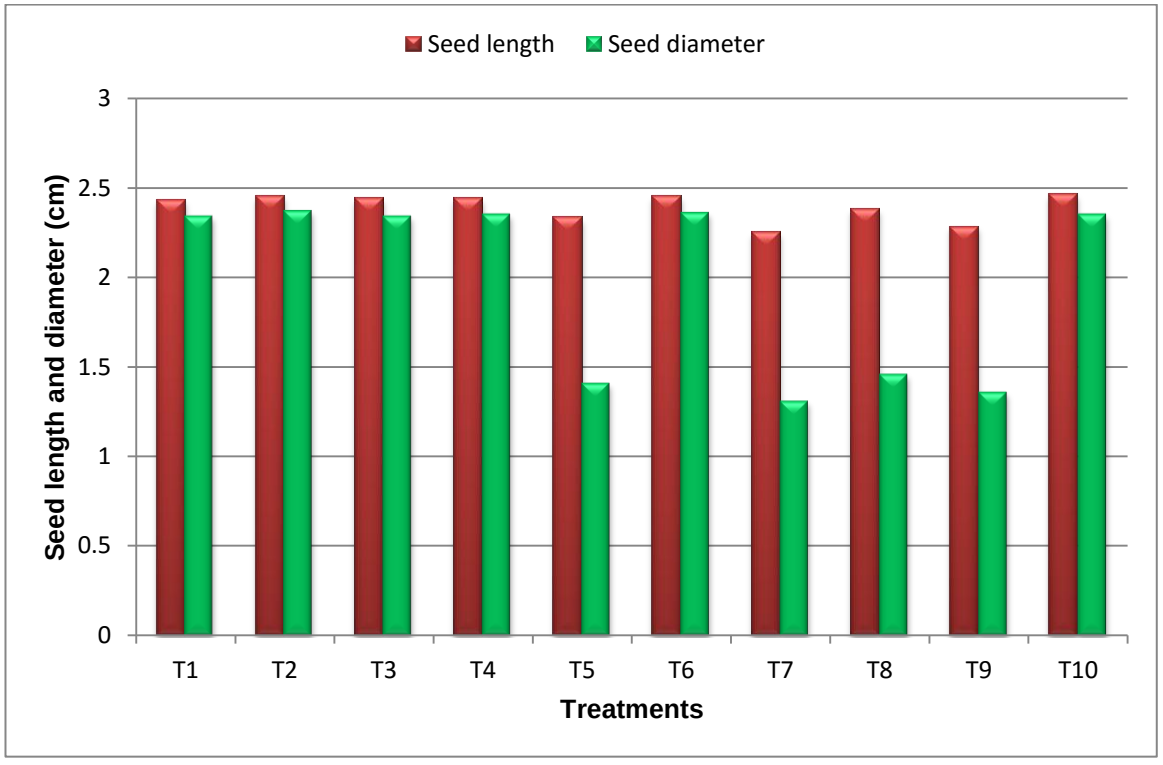


Fig. 4.16 Effect of NAA and micronutrients on seed length and diameter

4.5 Quality parameters

4.5.1 Total Soluble Solids (°Brix)

Data on the effect of NAA and micronutrients and their combination on TSS of the fruit are given in Table 4.6 and Fig. 4.17. The data shown in the table evident that TSS of the fruit was significantly influence by different treatments. The highest TSS was recorded in treatment T_8 (18.75 ºBrix) which is at par with T_7 (18.5 ºBrix) and lowest was observed in treatment T_{10} (15.55 ºBrix).

4.5.2 Titratable acidity (%)

The effect on titratable acidity content of the fruit was significant due the influence of NAA and micronutrients and their combination as shown in Table 4.6 and Fig. 4.18. Minimum acidity was found in treatment T_8 (0.24%) which is at par with T_7 (0.28%) and T_6 (0.29%) and maximum was observed in treatment T_{10} (0.4%).

4.5.3 Ascorbic acid (mg/100g)

The effect of different treatments on ascorbic acid content of the fruit was found to be significant as shown in Table 4.6 and Fig. 4.19. The highest ascorbic acid content of the fruit was noticed in treatment T_8 (25.7 mg/100 g) which is at par with T_7 (25.3 mg/100 g) and T_4 (25.17 mg/100 g) and the lowest ascorbic acid content of the fruit was recorded in treatment T_{10} (22.12 mg/100 g).

Table 4.6 Effect of NAA and micronutrients on TSS, titratable acidity, ascorbic acid

Treatments	Total soluble solids (ºBrix)	Titratable acidity (%)	Ascorbic acid (mg/100g)
T_1	16.00	0.39	22.90
T_2	16.40	0.37	23.55
T_3	16.50	0.35	23.27
T_4	17.00	0.33	25.17
T_5	18.00	0.31	24.50
T_6	18.25	0.29	24.05
T_7	18.50	0.28	25.30
T_8	18.75	0.24	25.70
T_9	17.55	0.32	25.00
T_{10}	15.55	0.40	22.12
SEm±	0.15	0.02	0.21
CD (5%)	0.45	0.05	0.62

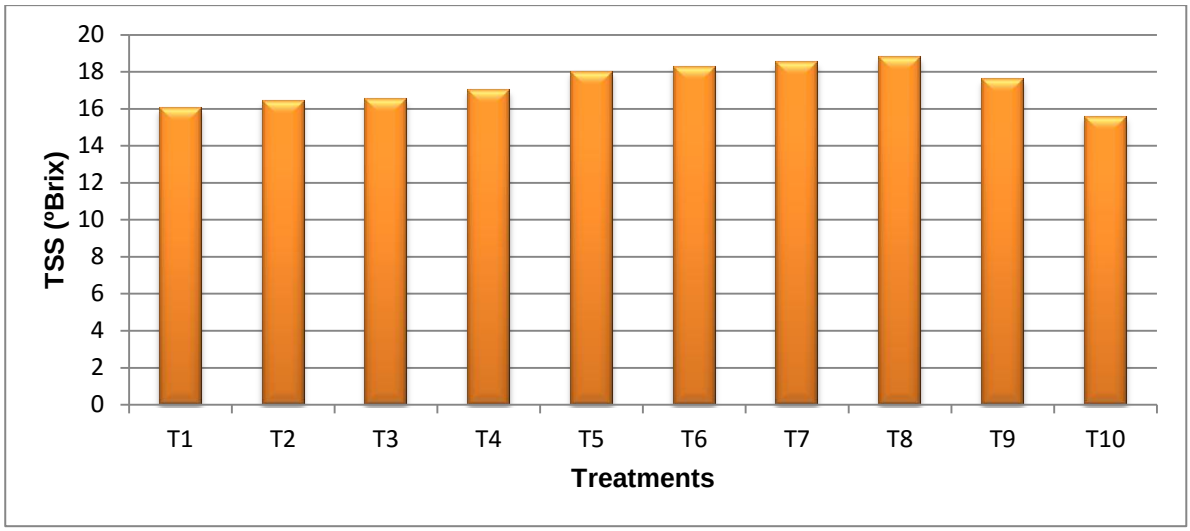


Fig. 4.17 Effect of NAA and micronutrients on Total Soluble Solids

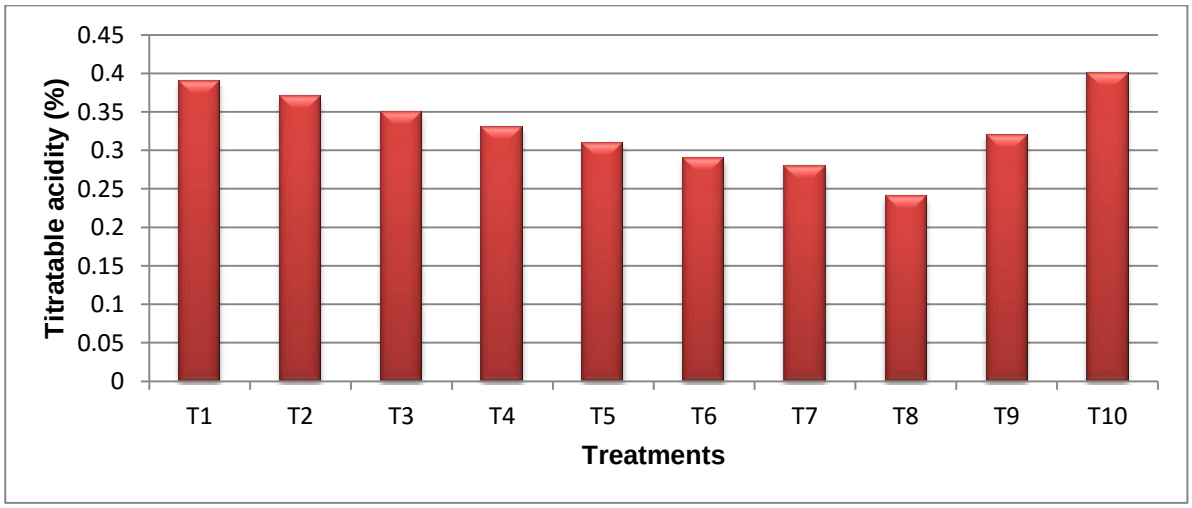


Fig. 4.18 Effect of NAA and micronutrients on titratable acidity

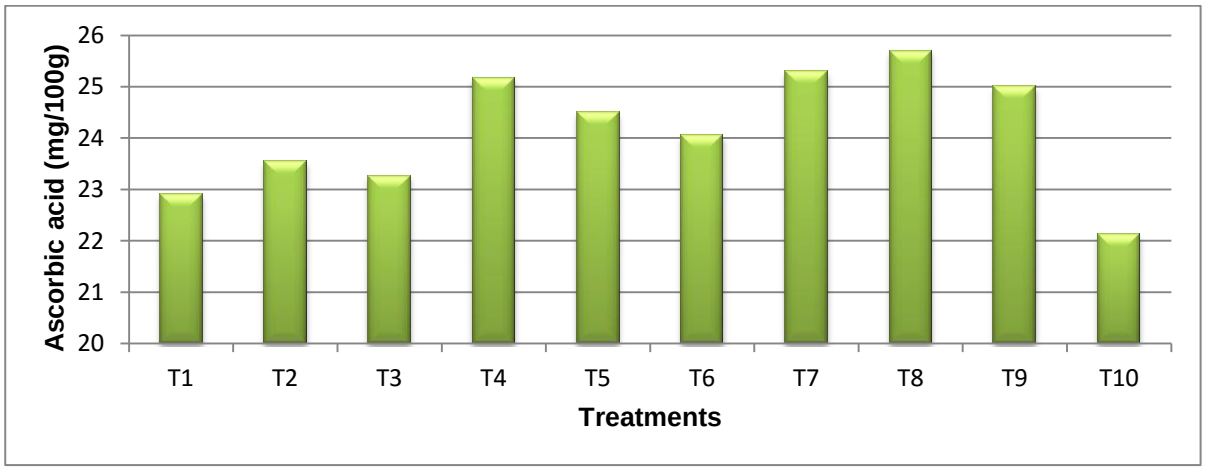


Fig. 4.19 Effect of NAA and micronutrients on ascorbic acid content

4.5.4 Total sugar (%)

Different treatments were found to have a significant effect on total sugar content of the fruit as given in Table 4.7 and Fig. 4.20. The treatment T_8 exhibited the maximum total sugar (15.7%) content of the fruit which is statistically at par with T_7 (15.25%) and the lowest total sugar content of the fruit was observed in treatment T_{10} (12.2%).

4.5.5 Reducing sugar (%)

The data presented in Table 4.7 and Fig. 4.20 depicted that the reducing sugar content of the fruit varied significantly due to the effect of the different treatments. Maximum reducing sugar content of the fruit was found in treatment T_8 (10.05%) which is at par with T_7 (9.57%) while minimum content was obtained from the treatment T_{10} (7.42%).

4.5.6 Non reducing sugar (%)

The data given in Table 4.7 and Fig. 4.20 revealed that the non reducing sugar content of the fruit was significantly influence in response to the application of NAA and micronutrients and their combination. The maximum non reducing sugar content of the fruit was recorded in treatment T_4 (6.02%) which is at par with T_9 (5.72%) and the lowest was observed in treatment T_3 (4.10%).

4.5.7 Date of fruit maturity for each treatment

Different treatments were found to have a non significant effect on date of fruit maturity for each treatment (Table 4.7). However, early fruit maturity was observed in treatment T_7 (25^{th} May) taking 81.5 days from flowering to fruit maturity and delay fruit maturity was recorded in T_{10} (4^{th} June) with 78.75 days taken from flowering to fruit maturity.

4.5.8 Shelf-life under room temperature (Number of days)

The effect of different treatments on shelf life of the fruit was found to be non significant among the treatments as shown in Table 4.7 and Fig. 4.21. However, longest shelf life was recorded in treatment T_6 (4.25 days) and T_3 (4.25 days) while shortest shelf life was observed in treatment T_9 (3 days).

Table 4.7 Effect of NAA and micronutrients on total sugar, reducing sugar, non-reducing sugar, date of fruit maturity for each treatment and shelf life of fruit

Treatments	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Date of fruit maturity for each treatment		Shelf life under room temperature (no. of days)
				Number of days taken from flowering to fruit maturity	Date of fruit maturity	
T_1	12.70	7.59	4.86	79.25	2nd June	3.50
T_2	12.45	7.71	4.50	82.50	1st June	3.50
T_3	12.42	8.10	4.11	80.00	31st May	4.25
T_4	14.65	8.31	6.02	75.50	30th May	3.50
T_5	13.90	8.79	4.86	76.25	29th May	3.75
T_6	14.00	9.03	4.72	80.50	26th May	4.25
T_7	15.25	9.57	5.39	81.50	25th May	3.25
T_8	15.70	10.05	5.37	84.00	27th May	3.50
T_9	14.42	8.40	5.72	75.00	3rd June	3.00
T_{10}	12.20	7.42	4.54	78.75	4th June	3.50
SEm±	0.21	0.22	0.23	3.39		0.28
CD (5%)	0.62	0.64	0.69	NS		NS

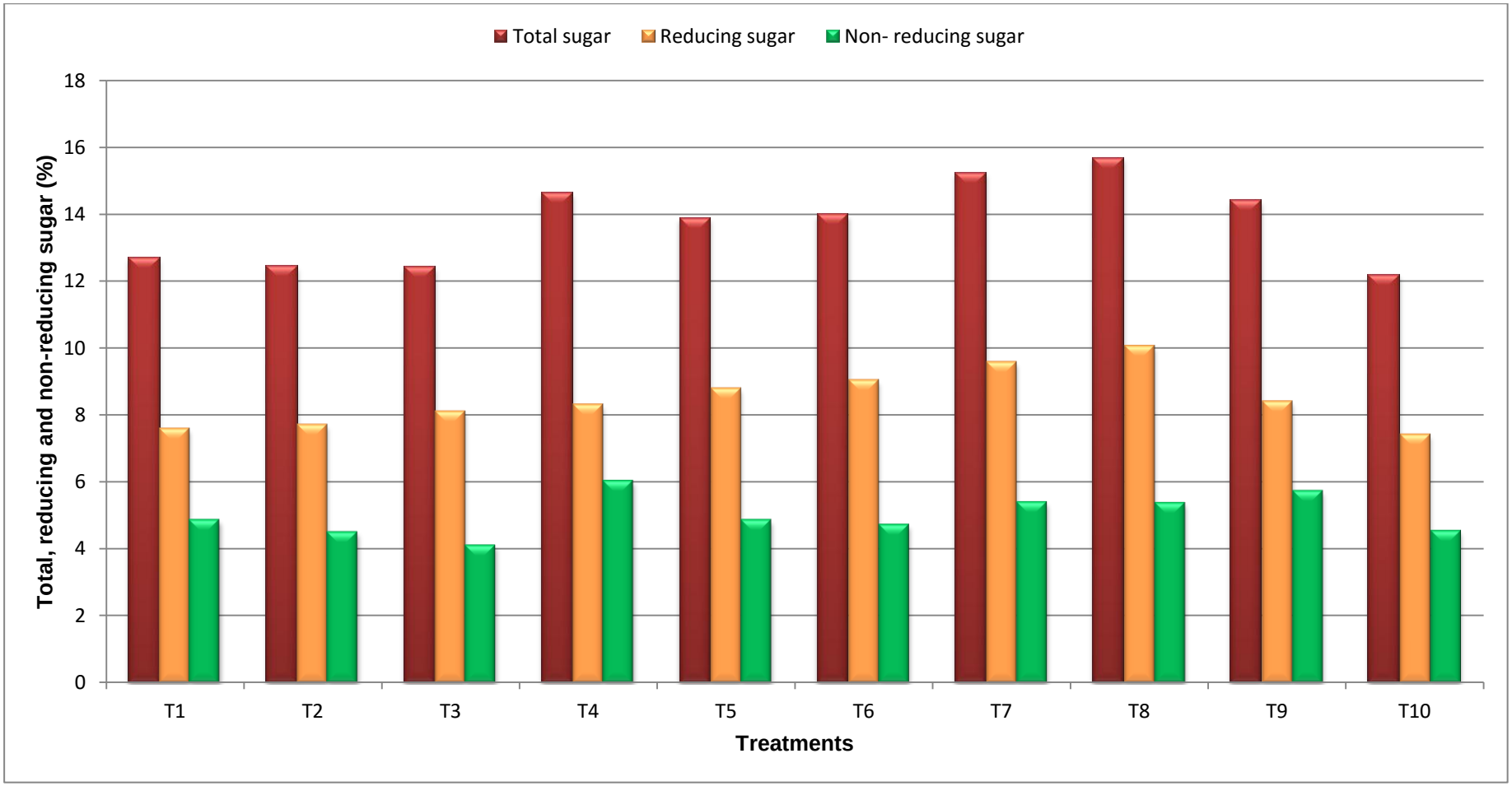


Fig. 4.20 Effect of NAA and micronutrients on total sugar, reducing sugar and non- reducing sugar content

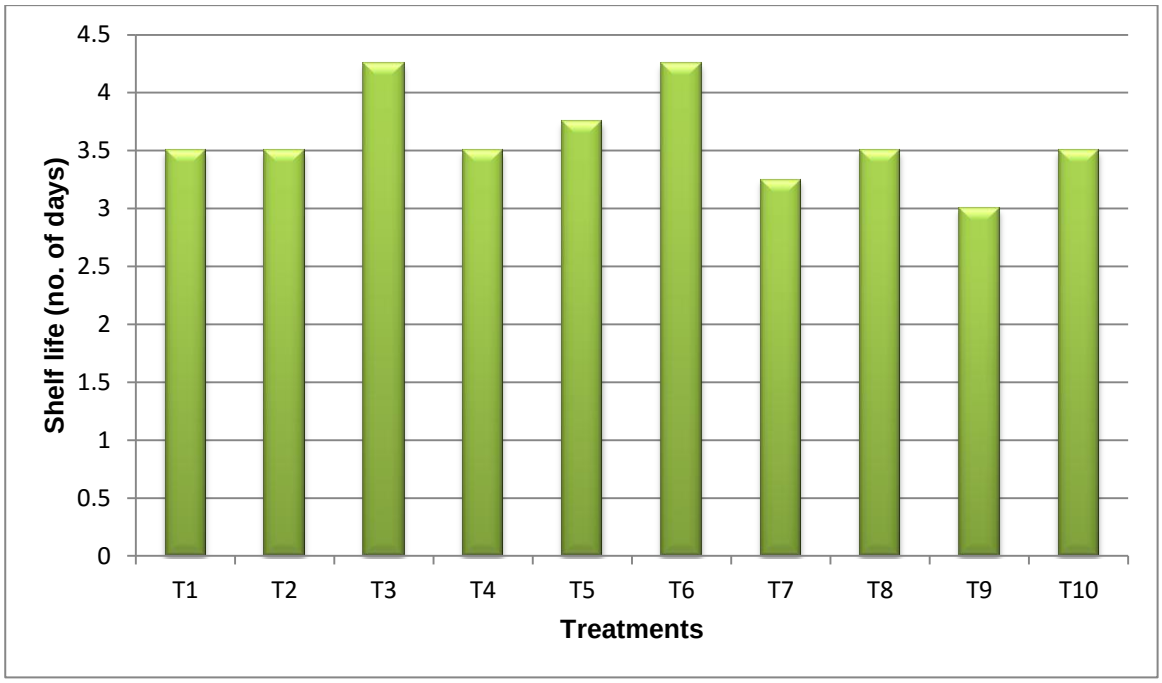


Fig. 4.21 Effect of NAA and micronutrients on shelf life of fruits

4.6 Soil parameters (Before and after experiment)

4.6.1 pH

Before experiment the pH of the soil was 5.1 and after experiment the pH of the soil is increase to 5.5.

4.6.2 Available Nitrogen (kg/ha)

The available nitrogen present in the soil before conducting the experiment was 275.58 kg/ha and after conducting the experiment the available nitrogen present in the soil is 294.14 kg/ha.

4.6.3 Available Phosphorous (kg/ha)

Before experiment the available phosphorous present in the soil was 25.17 kg/ha and after experiment the available phosphorous present in soil is 25.68 kg/ha.

4.6.4 Available Potassium (kg/ha)

The available potassium present in the soil before conducting the experiment was 268 kg/ha and after conducting the experiment the available potassium present in the soil is 280 kg/ha.

Table 4.8 Nutrient status of Soil

	pH	**Available N (Kg/ha)**	**Available P (Kg/ha)**	**Available K (Kg/ha)**
Before Experiment	5.1	275.58	25.17	268
After Experiment	5.5	294.14	25.68	280

Fig. 4.22 Fruits of litchi cv. Muzaffarpur

Fig. 4.23 Laboratory analysis for various qualitative parameters

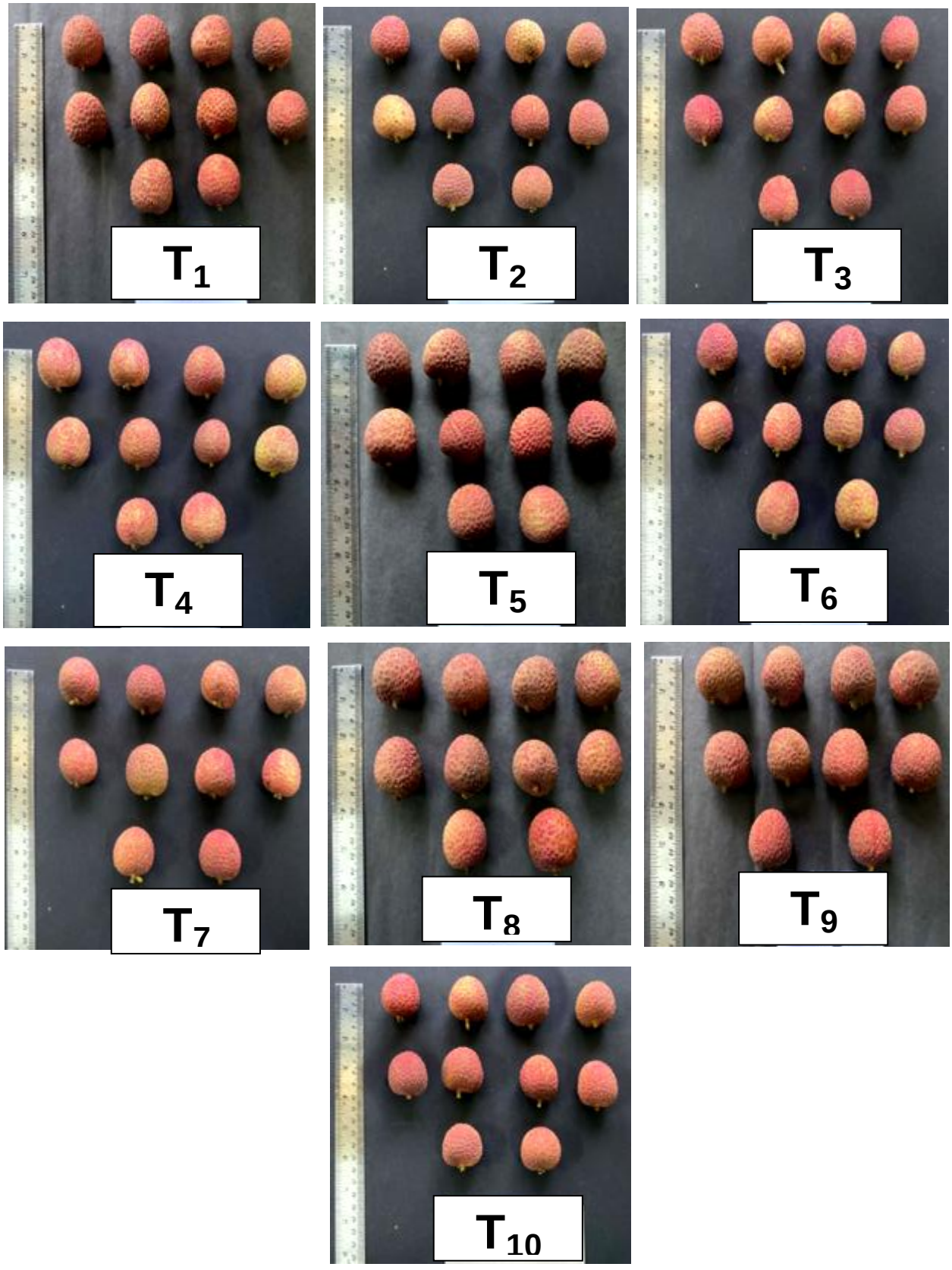


Fig. 4.24 Fruits of litchi cv. Muzaffarpur under different treatments

Chapter- 5
Discussion

Litchi is one of the most important sub-tropical fruit crops native to southern china. In India the production of litchi is concentrated mainly in the states of Bihar, West Bengal, Uttar Pradesh and Jharkhand and to small pockets in north eastern region of India. It comes to the market in the month of May-June when the market is full of other fresh fruits. Even though the availability of different types of fruit in the market is increase, the demand for fresh litchi is always very high due to its unique taste, flavour and colour. However, the growers face great economical loses due to poor fruit set, heavy fruit drop, fruit cracking and inferior fruit quality. Accordingly, to produce higher yield with good quality fruits it is necessary to maintain hormonal and micronutrients requirement of the plant in balance even though these elements are required in small quantities which enhance growth, flowering and fruit setting, yield and quality of the fruit. Therefore, the effect of NAA and micronutrients on flowering, fruit setting, yield and quality of litchi was evaluated in the present investigation. The findings of the experiment are briefly discussed in this chapter under the following headings.

5.1 Plant Growth Parameters

The experimental results showed that the plant growth parameters like plant height, canopy height, canopy volume and canopy spread (N-S and E-W directions) were significantly influence by the effect of treatments, however stem girth was non-significantly influenced by the effect of treatments. Maximum increase in plant height (36.25 cm), highest increase in canopy height (34.95 cm) and maximum increase in volume of the canopy (68.7 m^3) were observed in treatment T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate). Maximum increase in canopy spread in North-South direction (32.5 cm) was found in treatment T_4 (NAA @ 25 ppm) and highest increase in canopy spread in East- West direction (29.75 cm) was noticed in treatment T_3 (NAA @ 20 ppm). Maximum increase in stem girth (1.5 cm) was recorded in treatment T_5 (NAA @ 10 ppm + 0.5% Borax + 0.5% Zinc sulphate).

In this experiment, it was recorded that NAA when applied in combination with micronutrients were more effective in enhancing the vegetative growth of the plants rather than the application of NAA and micronutrients alone. The role of micronutrients in promoting plant growth may be attributed to zinc being an essential element for chlorophyll formation, the compound by which the plants absorb

sunlight energy to convert atmospheric carbon dioxide to carbohydrates through photosynthesis. Carbohydrates thus produce provide energy for plant growth and development. Enhancement in vegetative growth by spraying boron may be due to the enforcement of photosynthetic and other metabolic activities which lead to increase in various plant metabolites responsible for cell division and cell elongation, photosynthetic activity, respiration as well as growth of plant. NAA also stimulates cell division, cell enlargement and cell elongation in the apical region of the shoot which stimulates the growth and development of plants. Cell elongation occurs due to increasing osmotic pressure and permeability of cytoplasm to water. Increase in vegetative growth with foliar application of NAA had been reported by Sharma and Tiwari, (2015) in guava. The similar findings had also been recorded by Meena *et al.,* 2014 in aonla and Kumar *et al.,* 2015 in guava in which the combine spray of Borax and Zinc sulphate increases the vegetative growth of plants.

5.2 Flower and Fruit Setting Parameters

From the present study, it is revealed that the application of NAA and micronutrients influenced time of flowering, number of male, functionally female and functionally male flowers per panicle, fruit setting % per panicle, number of fruits at harvest stage per panicle and fruit cracking % per plant. First dehiscence of flowers (1st March) i.e. date of flowering of 50% of the plants of each treatment and minimum fruit cracking percentage per plant (3.61%) were observed in treatment T_7 (NAA @ 20 ppm + 0.5% Borax + 0.5% Zinc sulphate). Maximum fruit setting percentage per panicle (26.25%), maximum number of female flower per panicle (75) and largest number of fruit at harvest stage per panicle (15) were recorded in treatment T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate). Highest number of male flower (72) and functionally male flower (60) per panicle was seen in treatment T_{10} (control).

In litchi, the number of male flowers which appear during the first phase of flowering is generally higher than the number of functionally male flower which appear during the last phase of flowering (Jha, 2020). Application of NAA increased the number of female flowers and decreased the number of male flowers (Choudhury and Singh, 1970). NAA increased the number of female flowers may be due to increase in the mobilization of auxin substances in plants and also in reduction of sugar thereby bringing a change in membrane permeability. Application of NAA consistently decreased inflorescence and fruitlet abscission significantly as abscission of inflorescence and fruitlet is largely associated with the balance between auxin and ethylene that controls the cell separation processes (Khan *et al.,* 2014). Also

application of NAA can be attributed making up the deficiency of endogenous auxin preventing the formation of abscission layar. Increase in fruit setting and fruit retention percentage may be due to the ability of auxin in strengthening the cells in the abscission zone which is localised at the peduncle (Stewart and Hield, 1950). Similar results were also observed by Choudhari *et al.* (1982) in sweet orange and Kachave and Bhosale (2007) in Kagzi lime. Sharma and Tiwari (2015) revealed that foliar application of NAA improve the fruit set and fruit retention in guava.

In the present investigation, it was observed that NAA when applied in combination with 0.5% borax and 0.5% zinc sulphate gave superior effect in fruit setting and fruit retention. This may be due to the indirect action of boron and zinc in auxin synthesis that delayed the formation of abscission layer during early stages of fruit development. This finding is in agreement with Rathod *et al.* (2019) who reported that foliar application of NAA + 0.5% borax significantly increase fruit retention in Aonla. Similar findings were also concurred by Saraswat *et al.* (2006) in litchi where the application of NAA @ 20 ppm + 0.6% zinc sulphate increased fruit setting and fruit retention when compare to control.

Reduction in fruit cracking percentage with the application of NAA, borax and zinc sulphate may be due to the ability of zinc that helps in synthesis of tryptophan and regulate auxin in the plants which might have increased the osmotic pressure of the cell sap which will induce water uptake and reduce fruit cracking percentage of fruits. This finding is in conformity with Saraswat *et al.* (2006) who concluded that the application of NAA + zinc sulphate reduced fruit cracking in litchi. Srivastava and Singh (1969) reported that application of NAA @ 20mg/Litre reduced the percentage of fruit cracking in litchi. Boron is responsible for synthesizing pectin substances in cells, increasing the elasticity of the cell membranes, prevents the breakdown of vegetative tissues and enhanced translocation of sugars and synthesis of cell wall material. Kumar *et al.* (2001) reported that application of 0.4% borax exhibited the least amount of fruit cracking in Shahi cultivar of litchi. Similarly, Banyal and Rangra (2011) revealed that foliar spray of borax @ 0.4% reduced the fruit cracking percentage in Dehradun cultivar of litchi.

5.3 Yield Parameter

Imposition of the treatments was found to influence yield significantly as compared to control. Maximum yield per plant (24 kg) was recorded in treatment T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate). In the present investigation, it was observed that NAA when applied in combination with 0.5% borax and 0.5% zinc

sulphate gave superior effect in increasing fruit yield/plant. The increase in yield/plant with NAA and micronutrients may be due to the fact that zinc is required for the synthesis of tryptophan, a precursor of auxin, thus helps in reducing fruit drop and boron induces translocation of photosynthates from source to sink, promoting the physical attributes like fruit size and weight (Chaudhary *et al.*, 2018). Kumar *et al.* (2004) revealed that spray of borax and zinc sulphate gave maximum yield per plant as compared to control. Studies in mango revealed that application of NAA @ 50 ppm and micronutrients (0.5%) significantly increase yield per plant as compare to control (Gawande *et al.,* 2012). Sahay *et al.* (2018) also concluded that the application of NAA @ 20 ppm significantly increase yield/plant in Purbi cultivar of litchi.

5.4 Fruit parameters

Most of the fruit parameters of litchi were significantly influenced by the treatments. However, fruit length was found to be non-significantly influence by the treatments. Maximum fruit diameter (2.54 cm), fruit volume (18.4 cm^3), fruit weight (20.6 g), peel weight (3.77 g), aril weight (13.24 g) and juice content (9.2 ml) were recorded in treatment T_7 (NAA @ 20 ppm + 0.5% borax + 0.5% zinc sulphate). Minimum seed weight (2.8 g), seed length (2.25 cm) and seed diameter (1.31 cm) were observed in treatment T_7 (NAA @ 20 ppm + 0.5% borax + 0.5% zinc sulphate).

The improvement in overall physical characters of the fruit may be due to the contribution of NAA, borax and zinc sulphate in fruit development which has indirect role in hastening the process of cell division and cell elongation due to which size and weight of fruits would have improved (Sharma and Tiwari, 2015). Also boron being an essential trace element for plants, it is involved in many enzymatic reactions and is necessary for good growth and development. These findings are in agreement with the results of Yadav (2002) in guava and Sharma *et al.* (2005) concluded that the application of NAA and zinc sulphate significantly increase fruit weight in litchi. Rathod *et al.* (2019) also revealed that 0.5% borax spray increased the fruit weight, fruit diameter and fruit volume in Aonla.

5.5 Quality parameters

In the present study it was observed that quality parameters like TSS, total sugar, reducing sugar, non reducing sugar, titratable acidity and ascorbic acid were significantly influenced by the application of NAA and micronutrients. Highest value of TSS (18.75ºBrix), total sugar (15.7%), reducing sugar (10.05%) and ascorbic acid (25.7%) were recorded in treatment T_8 (NAA @ 25 ppm + 0.5% borax + 0.5% zinc

sulphate) in comparison to other treatments but was found to be at par with T_7 (NAA @ 20 ppm + 0.5% borax + 0.5% zinc sulphate). Maximum value of non reducing sugar (6.02%) was observed in treatment T_4 (NAA @ 25 ppm) which was at par with T_9 (0.5% borax + 0.5% zinc sulphate).

The increase in total soluble solid, total sugar, reducing sugar and ascorbic acid as a result of NAA and micronutrients spray may be due to the fact that application of auxin, boron and zinc probably improved the physiology of leaves and thereby causing quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to developing fruits. The results are in agreement with the findings of Brahmachari and Rani (2001) and Singh and Kaur (2016) in which application of boron and zinc significantly increased TSS, total sugar, reducing sugar and ascorbic acid in litchi. Increase in TSS, total sugar with the application of NAA was reported by Hifny *et al.,* 2017 in Washington navel orange. The increase in ascorbic acid may be due to catalytic influence of growth regulators on biosynthesis of ascorbic acid from sugars or inhibition of oxidative enzymes or both (Brahmachari *et al.,*1997).

Titratable acidity was found to have a decreasing trend in response to the treatments. Minimum value of titratable acidity (0.24%) was recorded in T_8 (NAA @ 25 ppm + 0.5% borax + 0.5% zinc sulphate) having a par value with T_7 (NAA @ 20 ppm + 0.5% borax + 0.5% zinc sulphate). This result is in accordance with the findings recorded by Barar *et al.* (2012) in guava in which foliar application of NAA significantly reduced titratable acidity of the fruit. The reason for reduction in titratable acidity may be due to the conversion of organic acids to sugars (Taun and Ruey, 2013) and increase in total sugar (Singh and Kaur, 2016).

In the present study, it was observed that date of fruit maturity for each treatment and shelf life of the fruits under room temperature were not significantly influenced by the treatments. However, early fruit maturity (25^{th} May) among the different treatments was recorded in treatment T_7 (NAA @ 20 ppm + 0.5% borax + 0.5% zinc sulphate), and longest shelf life (4.25 days) was noticed in treatment T_3 (NAA @ 20 ppm) and T_6 (NAA @ 15 ppm + 0.5% borax + 0.5% zinc sulphate). The reason may be attributed to the action of auxin in retarding the senescence that could be initiated by ethylene and abscissic acid (Mandal *et al.,* 2012) and micronutrients which increase the amount of photosynthetic activity during its development and optimum levels of assimilates cell wall integrity. This result is in conformity with the findings reported by Thirupathaiah *et al.* (2017) in sapota and Singh (2008) in mango.

From the results of all the quality parameters we can conclude that among all the treatments, T_8 (NAA @ 25 ppm + 0.5% borax + 0.5% zinc sulphate) and T_7 (NAA @ 20 ppm + 0.5% borax + 0.5% zinc sulphate) showed maximum improvement in the quality parameters of litchi cv. Muzaffarpur.

5.6 Soil parameters

In the present experiment, it was observed that application of chemical fertilizers (NPK) increased the pH (5.5), available nitrogen (294.14 kg/ha), available phosphorous (25.68 kg/ha) and available potassium (280 kg/ha) of the soil. The reason may be attributed to the action of chemical fertilizers which can alleviate soil acidification to some extent and long term inputs of chemical fertilizers as recommended dose of NPK maintained available nitrogen, phosphorous and potassium at higher level which in turn improves soil fertility and promotes plant growth and development. This result is in accordance with the findings recorded by Laxminarayana (2006) and Kundu *et al.* (2016).

Chapter- 6
Summary and Conclusion

The current investigation entitled “Effect of NAA and Micronutrients on Flowering, Fruit Setting, Yield and Quality of Litchi (*Litchi chinensis* Sonn.) cv. Muzaffarpur was performed in the year 2020-2021 at Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. The eventual outcomes of the research are summarized below.

Foliar application of NAA and micronutrients (Borax @ 0.5% and Zinc sulphate @ 0.5%) were found to influence most of the plant growth parameters significantly. However stem girth was statistically non-significant. The maximum increase in plant height (36.25 cm), canopy height (34.95 cm) and volume of the canopy (68.7 m^3) were observed in treatment T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate). The highest increase in canopy spread in N-S direction (29.75 cm) and E- W direction (32.50 cm) were found in treatment T_3 (NAA @ 20 ppm) and T_4 (NAA @ 25 ppm) respectively. Maximum increase in stem girth (1.5 cm) was recorded in treatment T_5 (NAA @ 10 ppm + 0.5% Borax + 0.5% Zinc sulphate).

Flower and fruit setting parameters were also significantly influenced by different treatments. Early emergence of flower (1st March) and minimum fruit cracking percentage per plant (3.61%) were observed in treatment T_7 (NAA @ 20 ppm + 0.5% Borax + 0.5% Zinc sulphate). Maximum number of male flower (72) and functionally male flower (60) per panicle was seen in treatment T_{10} (control) whereas maximum fruit setting percentage per panicle (26.25%), highest number of female flower per panicle (75) and largest number of fruit at harvest stage per panicle (15) were recorded in treatment T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate).

Foliar spraying of NAA and micronutrients was found to influence yield of the plant significantly as compared to control. Maximum yield per plant (24 kg) was obtained in treatment T_8 (NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate).

Majority of the fruit parameters were also significantly influenced by the different treatments. However, fruit length was found to be non-significantly influence by the treatments. The maximum fruit diameter (2.54 cm), fruit volume (18.4 cm^3), fruit weight (20.6 g), peel weight (3.77 g), aril weight (13.24 g), juice content (9.2 ml), minimum seed weight (2.8 g), minimum seed length (2.25 cm) and minimum seed

diameter (1.31 cm) were recorded in treatment T_7 (NAA @ 20 ppm + 0.5% borax + 0.5% zinc sulphate).

The influence of NAA and micronutrients application on the quality parameters of fruit was notably significant. Highest TSS (18.75ºBrix), total sugar (15.7%), reducing sugar (10.05%), ascorbic acid (25.7%) and minimum titratable acidity (0.24%) were recorded in treatment T_8 (NAA @ 25 ppm + 0.5% borax + 0.5% zinc sulphate) whereas maximum non reducing sugar (6.02%) was obtained in treatment T_4 (NAA @ 25 ppm). However, shelf life of the fruits under room temperature and date of fruit maturity were found to be non significant under the effect of different treatments.

6.1 Conclusion

As per the experimental result of the present work of investigation, it can be concluded that NAA and micronutrients when applied as foliar spray at the right concentration can be efficiently utilized for regulating the physiological processes in Litchi. The following conclusions can be drawn from the experiment.

- Application of recommended dose of fertilizers 1200:500:600 g NPK/plant/year along with the foliar spray of NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate (T_8) significantly improved in term of yield and quality parameters of litchi which is at par with application of NAA @ 20 ppm + 0.5% Borax + 0.5% Zinc sulphate (T_7) by applying micronutrients and NAA after emergence of new flushes during November followed by second application at one month interval during December and third application after fruit setting during April to increase the flowering (number of female flowers), fruit setting, yield and quality parameters in litchi under foot hill condition of Arunachal Pradesh.
- However, among the different treatments optimum yield and superior fruit quality could be achieved by application of NAA @ 25 ppm + 0.5% Borax + 0.5% Zinc sulphate (T_8) which may also be recommended to increase the fruit yield per plant which ultimately will increase the productivity and quality (minimize fruit cracking) of the crop resulting more income to litchi growers.

6.2 Future trend of research

Litchi cv. Muzaffarpur is one of the important litchi cultivar in North East India and it has a very vast scope for improvement in productivity mainly because of it good performance in North East India. The endeavour has made so far in the present studies are joint to pore the ways for the improvement of litchi cv. Muzaffarpur

productivity by improving fruit setting after application of micronutrients and plant growth regulators. The study also indicated the necessity for more research in the following

- To continue the present investigation for 4-5 years with multiplication trial for confirming as observed in the present findings.
- Elaborate and repetition of the present study should be used on the nutrient status of the plant along with micro and macro nutrient status of the fruit.
- Finally, elaborate study with higher concentration of the different PGRs and other micronutrients along with biofertilizers combination on the yield and quality parameters of the litchi fruit.

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Appendix- I

Meteorological data during the experiment (2020-2021)

Months	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Number of rainy days	Evaporation (mm)
	Max.	Min.	Forenoon	Afternoon			
July	28.3	---	94.5	93.0	1414.73	19	3.75
August	28.5	---	92.7	91.3	581.83	11	4.2
September	28.67	---	86.17	85.57	991.31	18	3.13
October	30.34	---	77.84	76.77	183.48	10	2.10
November	27.20	---	78.37	69.50	48.00	5	1.92
December	25.71	---	83.61	66.58	15.38	3	2.35
January	24.23	---	83.77	68.06	26.8	4	1.82
February	24.00	---	77.31	67.58	-	-	1.77
March	27.04	---	85.19	84.67	36.71	8	2.81
April	26.67	---	83.21	85.82	133.74	10	5.14
May	24.90	---	84.48	85.41	281.53	17	3.26
June	27.60	---	91.50	88.88	668.50	18	1.8

Source: Meteorological observatory, Department of NRM, CHF, CAU, Pasighat.